Bull Environ Contam Toxicol (2010) 85:397–401
DOI 10.1007/s00128-010-0097-7

Petroleum Hydrocarbon Concentrations in Marine Sediments Along Chennai Coast, Bay of Bengal, India

R. Venkatachalapathy · S. Veerasingam · T. Ramkumar

Received: 5 March 2010 / Accepted: 30 July 2010 / Published online: 11 August 2010

Abstract The spatial and temporal distribution of petroleum hydrocarbons (PHC) in marine sediments along the Chennai coast, Bay of Bengal was quantified by Ultra-Violet Fluorescence (UVF) Spectroscopy. The concentration of PHC in surface sediments varied from 1.88 to 39.76 ppm. The highest values obtained in the northern part of the study area, where shipping activities and land-based waste waters disposed into sea through the rivers like Kuvam and Adayar. The Adayar (7.26–16.83 ppm) and Kuvam (5.5–39.72 ppm) cores reveal a clear horizon of increase in PHC above 50 and 35 cm respectively. PHC values showed a decreasing pattern with depth in all sediment cores suggesting the excess anthropogenic loading occurring in the recent past. The present study revealed that the PHC values of Chennai coastal sediments are lower than the values reported from selected costal areas including the sediment of the Mumbai coast (7.6–42.8 ppm), Arabian Sea. The results will be useful for pollution monitoring program along the coastal region and also to check the level of petroleum hydrocarbons in marine sediments.

Keywords Petroleum hydrocarbons · Marine sediments · Pollution · Chennai coast

R. Venkatachalapathy (✉)
Centre of Advanced study in Marine Biology,
Faculty of Marine science, Annamalai University,
Parangipettai, Tamilnadu 608 502, India
e-mail: venkatr5@rediffmail.com

S. Veerasingam
Department of Physics, Annamalai University,
Annamalainagar, Tamilnadu 608 002, India

T. Ramkumar
Department of Earth Sciences, Annamalai University,
Annamalainagar, Tamilnadu 608 002, India

Petroleum consists of crude oils and a wide variety of refined oil products that the elemental composition varies over a narrow range 82%–87% carbon, 12%–15% hydrogen, the balance being oxygen, nitrogen and sulfur. Pollution of the sea by petroleum hydrocarbons occurs mainly through marine operations, land based discharges, and atmospheric and natural inputs (GESAMP 1993). The total input of petroleum into the oceans through human activities and sources such as atmospheric fallout, natural seepage, etc. is estimated at, 2.37×10^6 t year^{-1} (Kennish 1997). Out of these, about 65.2% is discharged through municipal and industrial wastes, urban and river runoffs, oceanic dumping and atmospheric fallout; 26.2% derived from discharge during transportation, dry docking, tanker accidents, and de-blasting. The remaining 8.5% comes from fixed installations like coastal refineries, offshore production facilities, and marine terminals (GESAMP 1993). When petroleum hydrocarbon is released directly to water through spills or leaks, certain petroleum hydrocarbon fractions will float in water and form thin surface films. Other heavier fractions will accumulate in the sediment at the bottom of the water, which may affect bottom-feeding fish and organisms. Some organisms found in the water (primarily bacteria and fungi) may break down some of the petroleum hydrocarbon fractions. Petroleum hydrocarbon released to the soil may move through the soil to the groundwater. Individual compounds may then separate from the original mixture, depending on the chemical properties of the compound. Some of these compounds will evaporate into the air and others will dissolve into the groundwater and move away from the release area (Sharma et al. 2000; Nour El-Din and Abdel-Moati 2001). The occurrence of enhanced levels of hydrocarbons especially in sediments can be a good indication of anthropogenic sources of pollution. Hydrocarbons can be bio-concentrated

in sea foods, especially in shellfishes, such as mussels, oysters and cockles to levels in excess of public health standards, thus presenting a health hazard to those eating them (Magliette et al. 1995; Szefer et al. 1997).

Tamilnadu is the southern most state on the east coast of India with a coastline of ~1,000 km. Chennai, the capital of Tamilnadu is located on the northern end of the Tamilnadu coast. The study area covers part of the Chennai coast, starting from Ennore to Kovalam. Ennore is on the northeast coast of Chennai, while Kovalam is on the southeast coast of Chennai. The Kuvam and Adyar are the two rivers that run across the city. The Chennai city is served by two major ports, Chennai port, one of the largest artificial ports, and Ennore port. The Chennai port is the largest in Bay of Bengal and India's second busiest container hub. A smaller harbour at Rayapuram is used for harbouring local fishing boats and trawlers. Coastal pollution in Tamilnadu has seriously affected the exploitable living resources, recreational and commercial uses of coastal areas and the overall integrity of the marine and coastal ecosystems. Hence protection of the coastal and marine regions from continuing pollution becomes the most essential work in coastal resources management. Effective planning for controlling and combating coastal pollution requires knowledge about the magnitude of the pollution, the entry, transport and the state of pollutants in the marine environment and their effects on marine ecosystems. The aim of this study was to determine the spatial and temporal distribution of petroleum hydrocarbons in marine sediments along the Chennai coast.

Materials and Methods

Twenty-one surface sediment samples (Fig. 1) were collected from Ennore to Neelangarai at 10, 15 and 20 m water depths in July 2008 during a Cruise onboard the Research Vessel "Sagar Paschimi" using a Van Veen grab sampler. Differential Global Positioning system (DGPS-Trimble) was used to determine the geographic coordinates of the sampling points. The water depth at each sampling point was determined using Multi-beam Eco-sounder. Samples were taken from the central part of the grab sampler by plastic spoon to avoid any metallic contamination from the metallic sampler. Four sediment cores (C1-72 cm, T1-77 cm, A1- 84 cm and K1-106 cm) were obtained by a gravity core sampler during October 2009 cruise of the R/V "*Sagar Paschimi*" at 60 m water depth from Kuvam, Adayar, Thiruvanmiyur and Kovalam respectively. The collected sediment cores were sectioned into 5 cm slices. Representative samples from each successful grab and core were stored in labeled self seal plastic bags and were frozen at −4°C immediately onboard until further analysis.

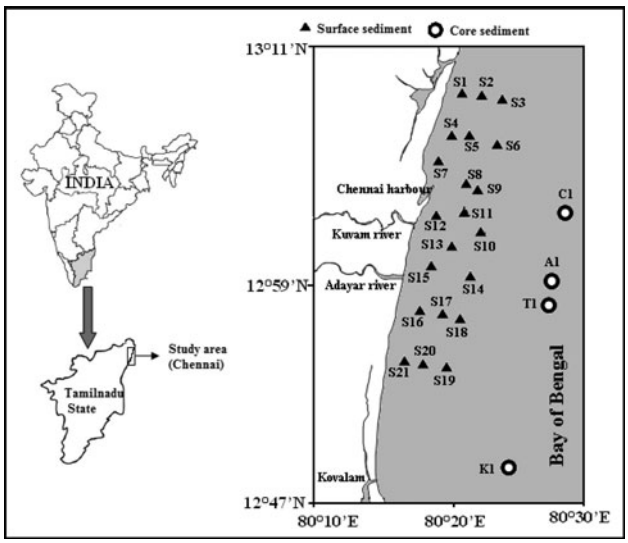

Fig. 1 The study area map

The collected sediment was thawed, saponified using a KOH methyl alcohol mixture followed by extraction with n-hexane. The concentrated extract, after drying, was separated into alkane and aromatic fractions on an alumina column and the intensity of fluorescence of the aromatic fraction was measured (IOC-UNESCO 1982). Petroleum hydrocarbon concentrations in sediment samples were determined using UV-Fluorescence (UVF) Spectroscopy (Varian make Cary Eclipse). The fluorescence of the samples was measured at an emission wavelength of 364 nm (excitation wavelength 310 nm). All blanks, standards and samples were measured in a Teflon–capped 1 cm silica fluorescence cell under identical instrumental settings and conditions. Duplicates, spikes and blanks were treated identically using Chrysene as a standard reference to test precision, accuracy and solvent purity in the analytical procedure and the data were expressed in terms of Chrysene equivalents. Percentage recovery for spiked samples ranged from 96%–99%, whereas precision agreed within 5%. Blank values were almost negligible. All experiments were conducted in 5 replicates and the average of the values was reported.

Results and Discussion

The spatial distribution of petroleum hydrocarbon concentration in marine sediment along the Chennai coast varies in a wide range of 1.88–39.76 ppm. The high concentrations of petroleum hydrocarbon (10.03–39.79 ppm) were recorded near the Chennai harbour area sediments.

These elevated levels of petroleum hydrocarbons are attributed to marine based sources, in particular those due to shipping activities. Moreover, it is also due to the recent

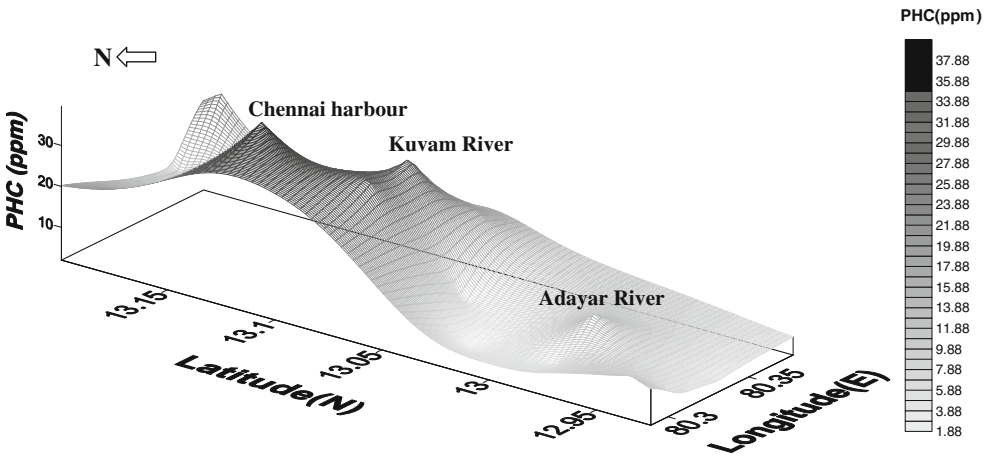

Fig. 2 Petroleum hydrocarbon concentration profile for Chennai surface sediments

development of major industries in the coastal areas. The lowest petroleum hydrocarbon concentration found at S15 sediment sample located near Marina beach. The observed low level of petroleum hydrocarbon from this area is considered the background level for the present study. The spatial distribution of petroleum hydrocarbon concentration profile for Chennai coastal sediments is shown in Fig. 2, which shows Chennai harbour, Kuvam River and Adayar river areas have high petroleum hydrocarbon concentrations (39.76, 33.62 and 14.84 ppm).

The textural distribution of the surface sediment reveals the predominance of sand along the Chennai coast. The differences in the textural parameters indicate that they are mainly depending on the dynamic process. The higher mud content is due to the fluvial discharge and better mixing of saline and freshwater that facilitated flocculation and faster settling of suspended particles (Nair et al. 1993). The sampling locations such as S7, S11 and S12 have more mud percentages, which are due to the river water (Kuvam) input with finer particles that settled at the bottom when wave, tide, current and wind speeds are less (Thomson-Becker and Luoma 1986). The lack of substantial river input and the elongated shape of the creek are also responsible for high mud content (Ergin and Yörük 1990). The coarse nature of sediments at Adayar river end of the estuary is due to the fluvial input. The higher sand contents indicating a relatively higher energy regime that prevents sedimentation of fine grained particles. Sediments containing fine particles tend to be good accumulations of organic pollutants presumably because of their greater effective surface area.

The vertical distribution of petroleum hydrocarbons has shown in Fig. 3. The ranges of petroleum hydrocarbons for Kuvam (C1), Thiruvanmiyur (T1), Adayar (A1) and Kovalam (K1) are 5.5–39.72, 6.3–10.4, 7.26–16.83 and 4.1–8.1 ppm respectively.

Petroleum hydrocarbon pollution in marine environment undergoes significant changes as a result of environmental degradation, weathering processes and diagenesis. Over the

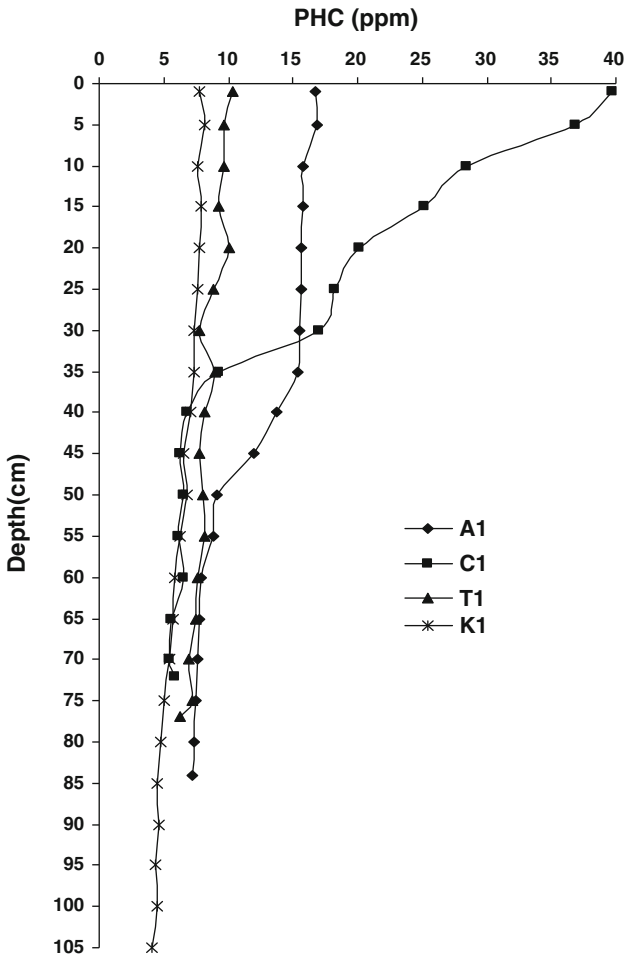

Fig. 3 The temporal variation of petroleum hydrocarbons in Chennai core sediments

Table 1 Comparison of PHC (ppm) in sediment of Chennai coast with those of selected marine areas

Location	PHC	Reference
Abu Dhabi, UAE	6.14–62.7	Abd et al. (2008)
Arabian Gulf	5.4–92.0	Al-Lihaibi and Ghazi (1997)
Arabian Sea along the Indian coast	0.6–5.8	Sengupta et al.(1993)
Bassein-Mumbai coast, India	7.0–38.2	Chouksey et al. (2004)
Bizerte lagoon, Tunisia	0.05–19.5	Mzoughi et al. (2005)
Changjiang estuary, China	2.2–11.82	Bouloubassi et al. (2001)
Fraser River Basin, Canada	1.6–20.6	Yunker and Macdonald Robie (2003)
Gulf of Fos, France	7.8–180	Mille et al. (2007)
Jiaozhou Bay, China	0.54–8.12	Wang et al. (2006)
Shetland Island, UK	7–8,816	Kingston et al. (1995)
Straits of Johor, Malaysia	0.7–36.7	Abdullah et al.(1996)
Tamilnadu coast, India	1.48–4.23	Veerasingam et al. (2010)
Thane Creek, Mumbai coast, India	7.6–42.8	Chouksey et al. (2004)
Chennai coast, India	1.8–39.72	Present study

last few decades, the study of sediment cores showed to be an excellent tool for establishing the effects of anthropogenic and natural processes on depositional environments. The C1 and A1 cores reveal a clear horizon of increase in PHC above 35 and 50 cm respectively. The boundary separating the high and low PHC zone is often an abrupt one. The enrichment of petroleum hydrocarbons in the upper part of these sediment cores reflecting the increase of contamination in the study area, due to more sewage water discharge from Kuvam and Adayar Rivers. The sedimentation rate of the Kuvam and Adayar estuaries are 7.88 and 5.28 mm year^{-1} respectively (Ramesh et al. 2002). The high rates of sedimentation in the coastal region reflect the influence of both the chemical processes such as sorption (adsorption), flocculation, and precipitation. The estuarine region is filled with freshly deposited sediments, a large part of it being of recent origin. Intense human activities such as discharge of sewage, road and building constructions, in addition to bank erosion have resulted in an accelerated rate of sedimentation (Ramesh et al. 2002). The PHC values for T1 and K1 cores are low and were almost constant from the top to bottom. PHC values show a decreasing pattern with depth in all core sediments suggesting the excess anthropogenic loading that occurred in the recent past. The overall petroleum hydrocarbon concentrations in Chennai coastal sediments are compared with those reported for selected coastal areas including the sediment of the Mumbai coast (Table 1).

From this study, the spatial and temporal variation of petroleum hydrocarbon concentration along the Chennai coast has been investigated. The northern part of the study area is highly contaminated than the southern part due to shipping activities and land-based waste water discharges. The study revealed that the PHC values of Chennai coastal sediments are lower than the values reported from selected costal areas including the sediment of the Mumbai coast. The results signify that industrial growth has affected the aquatic environments and regular monitoring will help to adopt stringent pollution control measures for better management of the aquatic region.

Acknowledgments We thank Prof. T. Balasubramanian, Dean, Faculty of Marine Science, and Prof. AN. Kannappan, Dean, Faculty of science, Annamalai University, for providing all the facilities. We are grateful to the Ministry of Earth Sciences, Government of India, New Delhi, for financial support under the project MoES/11-MRDF/1/13/P/07. We are also thankful to the crew members in R\V Sagar Paschimi for their help during the cruise.

References

Abd EL, Gawad EA, Lotfy MM, Sadooni FN, Katheery BE (2008) Assessment of the Oil Pollution Extent in the Offshore Sediments, Abu Dhabi, UAE. Australian J Basic Appl Sci 2: 617–631

Abdullah AR, Woon WC, Bakar RA (1996) Distribution of Oil and Grease and Petroleum Hydrocarbons in the Straits of Johor, Peninsular Malaysia. Bull Environ Contam Toxicol 57:155–162

Al-Lihaibi SS, Ghazi SJ (1997) Hydrocarbon distributions in sediments of the open area of the Arabian Gulf following the 1991 Gulf War oil spill. Mar Poll Bull 34:941–948

Bouloubassi I, Fillaux J, Saliot A (2001) Hydrocarbons in surface sediments from the Changiang (Yangtze River) estuary, east China Sea. Mar Poll Bull 42:1335–1346

Chouksey MK, Kadam AN, Zingde MD (2004) Petroleum hydrocarbon residues in the marine environment of Bassein–Mumbai. Mar Poll Bull 49:637–647

Ergin M, Yörük R (1990) Distribution and texture of bottom sediments in semi- enclosed coastal inlet, the Izmit Bay from the eastern sea of Marmara (Turkey). Estuar Coast Shelf Sci 30: 647–654

GESAMP (1993) Impact of oil and related chemicals and wastes on the marine environment. Report and Studies, GESAMP 50: 180 pp

IOC-UNESCO (1982) The determination of petroleum hydrocarbons in sediments. Manuals and Guides No. 11: 38 pp

Kennish MJ (1997) Practical handbook of estuarine and marine pollution. CRC Press, London, p 524

Kingston PF, Dixon IMT, Hamilton S, Moore DC (1995) The impact of the Braer oil spill on the Macrobenthic infauna of the sediments off the Shet-Land Islands. Mar Poll Bull 30:445–459

Magliette RJ, Doherty FG, Mackinney D, Venkataramani L (1995) Need for environmental quality guidelines based on ambient freshwater quality criteria in natural waters-case study Zinc. Bull Environ Contam Toxicol 54:532–626

Mille G, Asia L, Guiliano M, Malleret L, Doumenq P (2007) Hydrocarbons in coastal sediments from the Mediterranean sea (Gulf of Fos area, France). Mar Poll Bull 54:566–575

Mzoughi N, Dachraoui M, Villeneuve JA (2005) Evaluation of aromatic hydrocarbons by spectrofluorometry in marine sediments and biological matrix: what reference should be considered? C R Chimie 8:97–102

Nair CK, Balchand AN, Chacko J (1993) Sediment characteristics in relation to changing hydrography of Cochin estuary. Indian J Mar Sci 22:33–36

Nour El-Din NM, Abdel-Moati MAR (2001) Accumulation of Trace Metals, Petroleum Hydrocarbons, and Polycyclic Aromatic Hydrocarbons in Marine Copepods from the Arabian Gulf. Bull Environ Contam Toxicol 66:110–117

Ramesh R, Purvaja R, Ramesh S, James RA (2002) Historical pollution trends in coastal environments of India. Environ monitor Assess 79:151–176

Sengupta R, Fondekar SP, Alagsamy R (1993) State of pollution in the northern Arabian Sea after the 1991 Gulf oil spill. Mar Poll Bull 27:85–91

Sharma VK, Hicks SD, Rivera W, Vazquez FG (2000) Hydrocarbon contamination in sediments of Nueces Bay, Texas. Bull Environ Contam Toxicol 65:253–260

Szefer P, Ikuta K, Kushiyama S, Frelek K, Geldon J (1997) Distribution of trace metals in the pacific oyster, crassostrea gigas and crabs from the East Coast of Kysha Island, Japan. Bull Environ Contam Toxicol 58:108–114

Thomson-Becker EA, Luoma SN (1986) Temporal fluctuations in grain size, organic materials and iron concentrations in intertidal surface sediment of San Francisco Bay. Hydrobiologia 129: 91–107

Veerasingam S, Raja P, Venkatachalapathy R, Mohan R, Sutharsan P (2010) Distribution of petroleum hydrocarbon concentrations in coastal sediments along Tamilnadu coast, India. Carpathian J Earth Environ Sci 5:5–8

Wang X-C, Sun S, Ma H-Q, Liu Y (2006) Sources and distribution of aliphatic and polyaromatic hydrocarbons in sediments of Jiaozhou Bay, Qingdao, China. Mar Poll Bull 52:129–138

Yunker MB, Macdonald Robie W (2003) Petroleum biomarker sources in suspended particulate matter and sediments from the Fraser River Basin and Strait of Georgia, Canada. Org Geochem 34:1525–1541