Copyright © 2004, Paper 8-017; 3,366 words, 3 Figures, 0 Animations, 4 Tables.
http://EarthInteractions.org

Land Use—Iron Pollution in Mangrove Habitat of Karachi, Indus Delta

S. M. Saifullah*

Mangrove Ecosystem Laboratory, Botany Department, University of Karachi, Karachi, Pakistan

Sarwat Ismail

Pakistan Council of Scientific and Industrial Research Laboratories, Karachi, Pakistan

S. H. Khan and M. Saleem

National Institute of Oceanography, Clifton, Karachi, Pakistan

Received 11 December 2003; accepted 23 February 2004

ABSTRACT: The coastal area of Karachi, Pakistan, which lies at the northwestern part of the Indus delta, is heavily polluted particularly in the mangrove habitat. The present study traces the pathway of trace metal iron from the source to the different mangrove parts via seawater and sediment. The concentration in the sediment was as high as 34 436 ppm and as low as 0.01 ppm in seawater, while vegetative mangrove parts like pneumatophores, bark, twigs, and leaves possessed generally less than 1000 ppm. The concentration factor (CF) of mangroves was very low, indicating minimum bioavailability of iron from the sediment. The concentration of the metal decreases progressively through different sections of the mangrove habitat in the following sequence: from sediment to pneumatophores to bark to leaves to twigs to seawater.

KEYWORDS: Indus delta; Mangroves; Iron pollution

---

* Corresponding author address: S. M. Saifullah, Mangrove Ecosystem Laboratory, Botany Department, University of Karachi, Karachi, Pakistan.

E-mail address: smsaifullah2001@yahoo.com

Unauthenticated | Downloaded 07/31/21 12:24 AM UTC

1. Introduction

The Indus River is one of the largest in the world in terms of the drainage area, river discharge, and sediment load. It drains the arid and semiarid western Himalayas and traverses across the broad Indus plain for nearly 1000 km before entering the North Arabian Sea (Milliman et al. 1984). The total drainage area is 970 000 km^2. The highest water discharge occurs in the southwest monsoon season, amounting to 80% of the total discharge. The deltaic plain is in the shape of a broad fan, covering an area of 20 500 km^2 between the shoreline and the alluvial valley (Fig. 1). The lower deltaic plain is characterized by tidal creeks and small overbank splays that are lined with stunted mangroves of *Avicennia marina* (Wells and Coleman 1984; Spalding et al. 1997). The mangrove cover some decades ago was as large as 250 000 ha (Mirza et al. 1983), but has now been decreased drastically due to hypersalinity, which is in itself a result of the updamming of rivers with barrages, dams, impoundments, and dykes in response to the increasing demand of river water for agriculture and industrial development. The present situation is that hardly any river water reaches the shores of the delta, except during occasional flood periods.

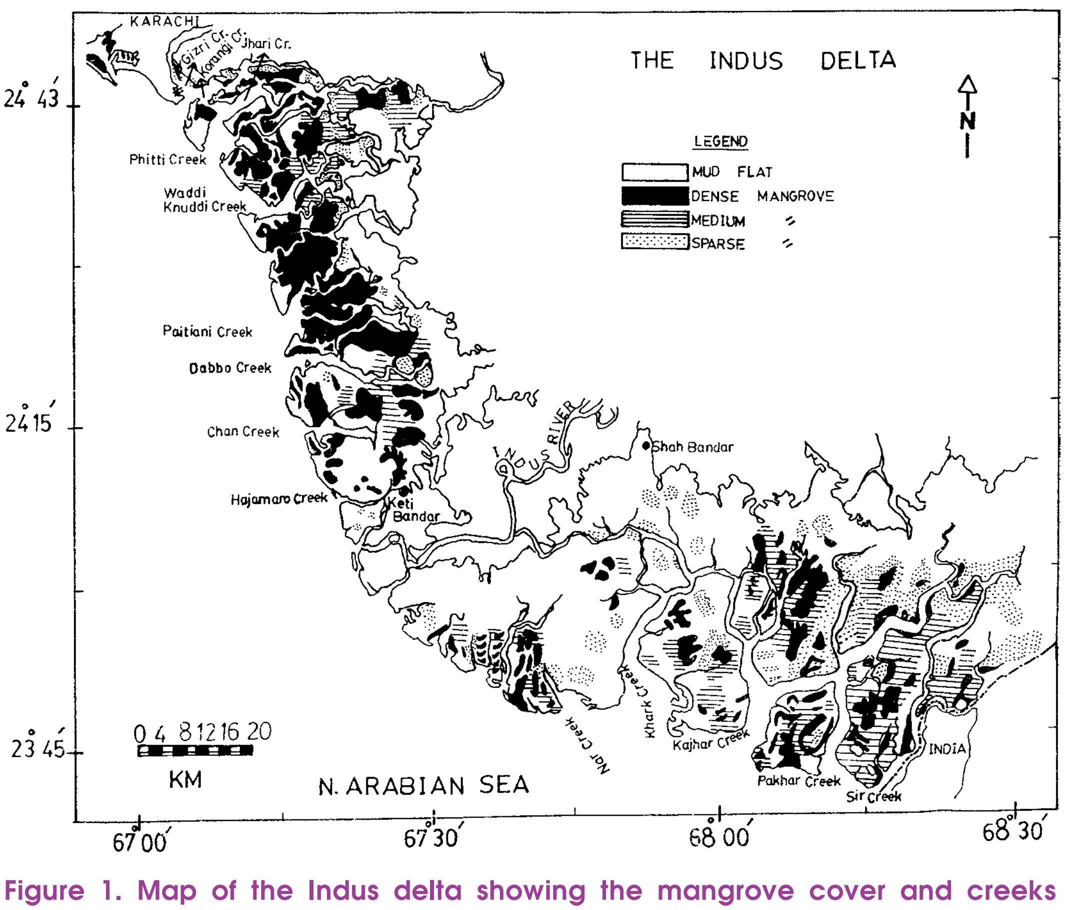

Figure 1. Map of the Indus delta showing the mangrove cover and creeks (Saifullah 1997).

Unauthenticated | Downloaded 07/31/21 12:24 AM UTC

The present study deals with the study of heavy metal pollution in the mangrove habitat of Karachi, Pakistan, which forms the northwestern limit of the 250-km-long coastline of the delta. This site is unique in coastal Pakistan in the sense that in addition to the problem of hypersalinity, it is also faced with intense and severe domestic and industrial pollution. It is the largest city of Pakistan, housing 60% of the country's industries and a population of over 12 million. It is also a financial center, serving as a location of a large proportion of primary export industries, which produce large amounts of industrial waste. The port of Karachi handles a majority of the country's seaborne trade, and the city accounts for half of the government's revenues and contributes 20% of its gross domestic product (GDP).

The coastline of Karachi is increasingly highly polluted with a variety of hazardous substances of an industrial, municipal, and agricultural origin, yet there are not any proper monitoring or treatment facilities to mitigate their harmful effects. The levels of pollutants have already crossed the limits of natural oceanic concentrations (Bruland 1983), and in view of the colossal pollution problem threatening the coastal life, it is surprising that very few studies have been carried out to assess heavy metal pollution in the coastal area of Karachi, with studies of iron (Fe) being even more scarce (Beg et al. 1984; Khan and Saleem 1988; Tariq et al. 1993; Siddiqui and Qasim 1994; Rizvi 1997; Saifullah et al. 2002). Moreover, there is a dearth of information on Fe pollution in mangrove habitats of the world. The present study describes distribution of Fe in the mangrove habitat of Karachi. It is generated from various industries within the city, but the major source is a steel mill. The suspended load in effluents may be as high as 250–300 ppm, consisting mostly of iron oxide dust (Khan 1995).

2. Area of study and material and methods

The coastal area of Karachi is occupied by dense mangrove vegetation, which is spread over several small islets isolated by small and large creeks that are flushed twice daily with moderate diurnal tides. Only one species *Avicennia marina* (Forssk.) Vierh. thrives in the area that is highly polluted from the entire city, mainly through the Lyari and Malir Rivers. The former river collects industrial and municipal waste from the Sindh Industrial Trading Estate (SITE), which it then discharges into the sea through Karachi Harbour, affecting especially the mangroves of Sandspit and backwater. The effluents from the Landhi Industrial Trading Estate (LITE) are collected by the Malir River and are dumped in the Korangi Creek area where a majority of the mangroves of the city are located (Fig. 2). The coastline of Karachi receives land-based pollution at the rate of 3750 tons day^{-1}, which includes a 12% share of domestic waste and a remaining 84% of industrial waste (Beg 1993).

Two hundred and twenty samples of water, sediment, and different parts of mangrove plants, like leaves, twigs, flowers, bark, and pneumatophores, were collected from various study sites like Sandspit, between Baba and Shams Islands, Shamspir, Lut Basti, Rehri, Port Qasim, and Bakran, Chara, and Phitti Creeks (Fig. 2) from December 1997 to December 1998, and also in July 1999. A few samples were also taken from the mangrove lagoon Miani Hor located 100 km west of the study site, which is free from any kind of industrial pollution. The methods of

Unauthenticated | Downloaded 07/31/21 12:24 AM UTC

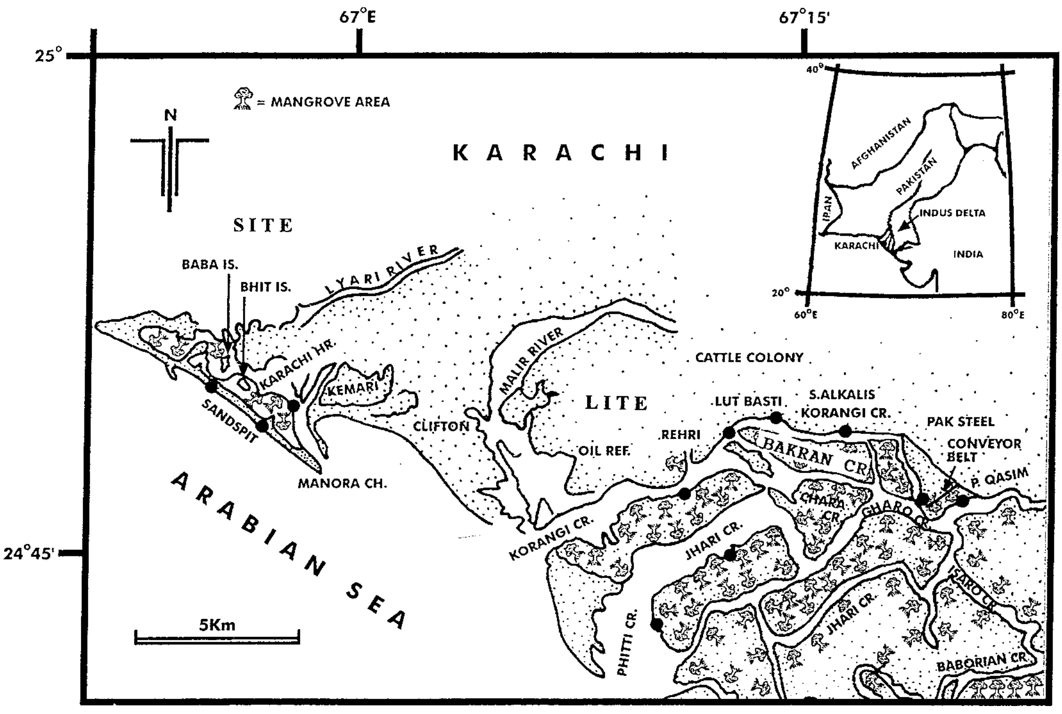

Figure 2. Map showing the study area with sampling sites at Karachi (Saifullah et al. 2002).

collection, treatment, and analysis of the different types of samples have already been described in detail (Saifullah et al. 2002).

3. Results and discussion

Water temperature in the area varied between 18°C in January and 35°C in May. Salinity values generally fluctuated between 35 and 40 psu (Saifullah et al. 2002), but may be as high as 47 psu. These high values are attributed to a decrease in Indus River discharge as a result of upstream diversion of its water for agricultural and industrial purposes (Saifullah 1997).

Concentration of Fe in seawater ranged between 0.01 and 0.24 ppm with an average value of 0.08 ppm (Table 1). Tariq et al. (Tariq et al. 1993) reported very

Table 1. Average concentration (ppm) of Fe in water in different mangrove habitats of Karachi, where *N* is the number of samples. SE is the standard error.

Locality	Avg concentration (ppm)	± SE	*N*	Range
Sandspit	0.09	0.025	7	0.020–0.176
Port Qasim	0.099	0.039	5	0.016–0.211
Rehri	0.06	0.03	3	0.012–0.118
Chara Creek	0.094	0.042	3	0.010–0.152
Karachi Harbour	0.042	0.114	10	0.019–0.059
Lat Basti	0.115	0.031	7	0.012–0.247

Unauthenticated | Downloaded 07/31/21 12:24 AM UTC

low values of Fe from the offshore waters of Pakistan, which may be due to the distance from the source. The present study site, on the other hand, lies in close proximity to a steel mill, which is the major source of pollution in the area. Rizvi et al. (Rizvi et al. 1986) recorded similarly high values from Bakran Creek in the same area, that is, 0.042–0.17 ppm, whereas Goldberg (Goldberg 1965) gives a figure of 0.01 ppm for the world oceanic waters, which are free from land-based pollution.

Iron enters into the sea in large quantities through four major sources: industrial effluents, municipal waste, corrosion of underwater structure, and atmospheric fallout. One would, therefore, expect a relatively higher concentration of this element in the water, but, in fact, this is not so. A larger proportion forms oxides and hydroxides in the suspended matter and is also precipitated as iron sulfide in the sediments as pyrite (Lacerda et al. 1991; Sadiq 1992).

The concentration of Fe in the sediments (Table 2) is extremely higher than that in seawater, ranging between 6369 and 34 436 ppm with an average value of 22 773 ppm, which is about 300 000 times more than that in the water. It is striking that although there is great variation in the values of Fe in seawater, its concentration in marine sediments does not vary that much the whole world over. Thus, Patel et al. (Patel et al. 1985), Paez-Osuma et al. (Paez-Osuma et al. 1986), Castagna et al. (Castagna et al. 1987), Bryan and Longston (Bryan and Longston 1992), Tariq et al. (Tariq et al. 1993), and Prudente et al. (Prudente et al. 1994) reported more or less similar values from Bombay, Mexico Bay, Sicily, Italy, the U.K.'s estuaries, Pakistan, and Manila Bay, respectively. The values of the sediments were 20 times higher than that recorded in Miani Hor (1248 ppm), which is a pollution-free mangrove site that is located far away in Balochistan.

A comparison between surficial and root-level sediments (25-cm depth) reveals a mixed trend with both types superseding each other in different localities and on different occasions (Fig. 3). This may be related to the twice-daily tidal submergence and exposure of the surface sediments. At low tide they are exposed and Fe is oxidized to form precipitate, whereas at high tide iron sulfide goes into solution as a result of anoxic conditions during submergence. It is noteworthy, however, that surficial sediments showed larger variation in values range as compared to root-level sediments. This may be most probably due to the fact that the former type is easily perturbed and influenced by the tidal and other types of

Table 2. Average concentration (ppm) of Fe in sediments of mangrove habitats of Karachi, where *N* is the number of samples. SE is the standard error.

Locality	Avg concentration (ppm)	± SE	*N*	Range
Sandspit	25 624	1778	19	6369–32 440
Baba/Shams Islands	28 120	—	1	—
Port Qasim	27 489	2481	3	22 678–31 148
Lat Basti	23 310	4105	3	17 657–31 545
Miani Hor	1248	—	1	—
Chara Creek	30 067	2515	4	22 640–33 120
Rehri	34 436	2249	2	29 982–34 436
Phitti Creek	16 480	9333	2	7240–25 720
Bakran Creek	23 900	866	2	23 040–24 760
Shamspir	17 060	381	2	13 280–20 840

Unauthenticated | Downloaded 07/31/21 12:24 AM UTC

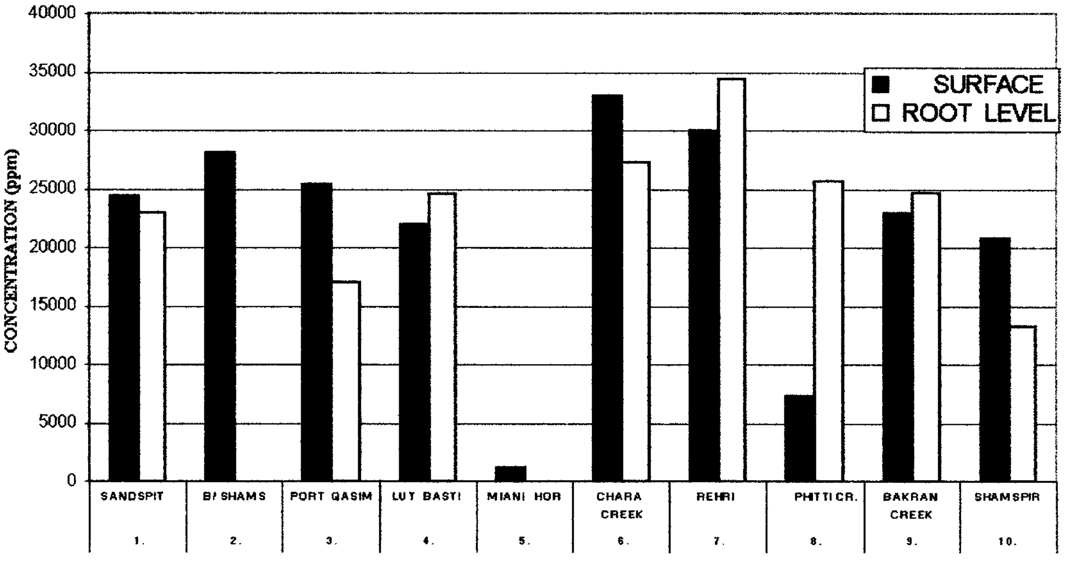

Figure 3. Average concentrations of iron in surficial and root-level sediments.

water movement and the irregular influx of effluents from the nearby sources, whereas the latter is not.

Among the different mangrove parts, pneumatophores and bark possessed the highest concentration of Fe (Table 3), but values of pneumatophores tended to be higher than those of bark as is evident from the range in values. On the other hand, leaves, twigs, and flowers possessed less than one-third of the concentration in pneumatophores and bark (Table 3). The reason for the discrepancy in Fe values in the parts of the mangrove tree is to be found in the nature of the different tissues. Pneumatophores and bark are relatively permanent tissues and, therefore, they accumulate iron for longer periods of time, whereas the other three parts are temporary ones that are shed in shorter periods of time such as weeks and months. Moreover, tannins are present in significant concentrations in both pneumatophores and bark, which are known to bind to trace metals (Zheng et al. 1997). Jayasekera (Jayasekera 1988) experimentally showed that roots of *Rhizophora mangle* accumulate more Fe than shoots or leaves.

Studies of Fe concentration in leaves are available in literature, but are difficult to find for other parts of the plant. The values of Fe in leaves in the present study

Table 3. Overall average concentration of Fe (ppm) in seawater, sediments, and different parts of the mangrove. SE is the standard error.

Components	Sediments	Pneumatophores	Bark	Leaves	Flowers	Twigs	Water
No. of samples	40	14	27	72	7	25	35
Range	6369.2–34 436.0	218–7494	528.5–1886.0	60.2–825.0	122.4–492.0	58.2–454.4	0.010–0.24
Mean ± SE	22 773.6 ± 1497.5	1047 ± 168.8	985.7 ± 113.7	309.8 ± 29.3	194.1 ± 30.5	180.1 ± 10.4	0.083 ± 0.004

Unauthenticated | Downloaded 07/31/21 12:24 AM UTC

Table 4. Concentration factors for different parts of the mangrove tree.

Mangrove parts	Avg concentration (ppm)	CF*
Pneumatophores	1047	0.045
Bark	985.75	0.043
Leaves	302.44	0.013
Flower	194.17	0.008
Twigs	180.17	0.008

* CF = Avg concentration of mangrove part/avg concentration in sediments (22 773 ppm).

(Table 3) are more or less similar to those found in Malaysia (Peterson et al. 1979), India (Bhosale 1979), and Brazil (Lacerda et al. 1986). It is also noteworthy that the uptake of the element by the mangrove from sediment was very low—even lower than that of other trace metals (Lacerda 1997; Patel et al. 1985; Rao et al. 1991). This is evident from the concentration factors (CFs) of different parts of the mangrove plant listed in Table 4.

This means that Fe is bioavailable to the plants in very small concentrations, which may be due to a number of reasons. First, Fe is present as insoluble oxides, hydroxides, and sulfides in the sediment in large amounts (Sadiq 1992). Even soluble Fe is precipitated as oxides, which form plaque on the root surface (Lacerda 1997), acting as a barrier to the uptake. Iron ions also become immobile in the cell wall, and organic exudates of roots are known to bind the element. Finally, the organic matter present in the sediment also binds iron and renders it inactive. In short, huge amounts of Fe are available in sediment, but the mangroves absorb only a small fraction thereof.

Mangroves habitat serves as a sink of iron like other heavy metals (Badruddin et al. 1996; Dubinski et al. 1986). The sediments are the major trap of metals, followed by the mangrove plant. The order of accumulation in different sections of the habitat is as follows: from sediment to pneumatophores to bark to leave to flowers to twigs (Table 3). According to Williams et al. (Williams et al. 1996), detrital silicates and sulfides are the principal carriers of iron and other heavy metals and, therefore, make sediment a long-term contaminant sink. In the present study, sediment accumulates as much as 97% of the total Fe in the habitat. Silva et al. (Silva et al. 1990) have also reported similar values for other heavy metals.

Acknowledgments. The present study was supported by a research grant from the Office of Naval Research in the United States, for which we are thankful to Dr. Bernard Zahuranec. The assistance provided by Mr. Shahid Nasim, Mr. Qasim Memon, and Mr. Javed Aftab in the procurement and analysis of samples is duly acknowledged herewith, and also that of Taha Hameedi in processing and composing the manuscript.

References

Badruddin, A., K. T. Damodaran, and K. Sajan, 1996: Texture and geochemistry of the sediments of a tropical mangrove ecosystem, southwest coast of India. *Environ. Geol.,* **27,** 164–169.

Beg, M. A. A., 1993: Status of some environmental problems of Karachi. *Wildl. Environ.,* **2,** 14–17.

Unauthenticated | Downloaded 07/31/21 12:24 AM UTC

——, S. N. Mahmood, N. Sitwat, and A. H. K. Yousufzai, 1984: Land based pollution and the marine environment of Karachi. *Pak. J. Sci. Ind. Res.,* **27,** 199–205.

Bhosale, L. J., 1979: Distribution of trace elements in leaves of mangroves. *Ind. J. Mar. Sci.,* **8,** 58–59.

Bruland, K. W., 1983: Trace elements in seawater. *Chemical Oceanography,* J. P. Riley and R. Chester, Eds., Vol. 8, Academic Press, 157–215.

Bryan, G. W., and W. J. Longston, 1992: Bioavailability, accumulation and effects of heavy metals in sediments with special reference to United Kingdom estuaries: A review. *Environ. Pollut.,* **76,** 89–131.

Castagna, A., F. Sinatra, A. Zanini, N. Sanctis, and R. Giardinelli, 1987: Surface sediments and heavy metals from the Sicily channel coast. *Mar. Pollut. Bull.,* **18,** 136–140.

Dubinski, B. J., R. L. Simpson, and R. E. Good, 1986: The retention of heavy metals in sewage sludge applied to a freshwater tidal wetland. *Estuaries,* **9,** 102–111.

Goldberg, E. D., 1965: The oceans as chemical systems. *The Sea, Ideas Observations on Progress in the Study of Seas,* M. N. Hill et al., Eds., Wiley, 3–25.

Jayasekera, L. J., 1988: Growth characteristics and uptake of minerals of the two mangrove spp. *R. Mangle* L. and *R muconata* Lam. under different environmental conditions. Ph.D. thesis, University of Osnabruck, 215 pp.

Khan, R. B., 1995: Waste water situation in Karachi. IUCN Internship Rep., 19 pp.

Khan, S. H., and M. Saleem, 1988: A preliminary study of Pollution in Karachi Harbour. *Marine Science of the Arabian Sea,* M. F. Thompson and N. M. Tirmizi, Eds., A.I.B.S., 539–547.

Kremling, K., 1983: Determination of trace metals. *Method of Seawater Analysis,* K. Grasshof, M. Erhardt, and K. Kremling, Eds., Verlag Chemie, 189–214.

Lacerda, L. D., 1997: Trace metals in mangrove plants: Why such low concentrations? *Mangrove Ecosystem Studies in Latin America and Africa,* B. Kjerfive et al., Eds., UNESCO, 171–178.

——, C. E. Rezende, D. M. V. Jose, and M. C. F. Francisco, 1986: Metallic composition of mangrove leaves from the southeastern Brazillian coast. *Rev. Brasil. Biol.,* **46,** 385–399.

——, ——, G. T. Aragon, and A. R. Ovalle, 1991: Fe and chromium transport and accumulation in a mangrove ecosystem. *Water Air Soil Pollut.,* **57/58,** 513–520.

Milliman, J. D., G. S. Quraishi, and M. A. A. Beg, 1984: Sediment discharge from the Indus River to the ocean. Past, present and future. *Marine Geology and Oceanography of Arabian Sea and Coastal Pakistan,* B. U. Haq and J. D. Milliman, Eds., Van Nostrand Reinhold, 65–70.

Mirza, M. I., M. Z. Hasan, S. Akhtar, and J. Ali, 1983: Identification and area estimation of mangrove vegetation in Indus delta using Landsat data. *Mangroves of Pakistan, ESCAP Regional Workshop in Remote Sensing Applications for Vegetation Mapping,* Colombo, Srilanka, ESCAP, 89–92.

Paez-Osuma, F., A. V. Botello, and S. Villanueva, 1986: Heavy metals in Coatzacoalcas estuary and Ostion Lagoon, Mexico. *Mar. Pollut.,* **17,** 516–519.

Patel, B., V. S. Bangera, and M. C. Balani, 1985: Heavy metals in the Bombay harbour area. *Mar. Pollut. Bull.,* **16,** 22–28.

Peterson, P. J., M. A. S. Burton, M. Gregson, S. M. Nye, and E. K. Porter, 1979: Accumulation of tin by mangrove species in West Malaysia. *Sci. Total Environ.,* **11,** 213–221.

Prudente, M. S., H. Ichichasi, and R. Tatsukawa, 1994: Heavy metals concentration in sediments from Manila Bay, Philippines and in flowing rivers. *Environ. Pollut.,* **86,** 83–88.

Unauthenticated | Downloaded 07/31/21 12:24 AM UTC

Rao, Ch. K., S. Chinnarary, S. N. Inamar, and A. G. Untawala, 1991: Arsenic content in certain marine brown algae and mangroves from Goa coast. *Ind. J. Mar. Sci.,* **20,** 283–285.

Rizvi, S. H. N., 1997: Status of marine pollution in the context of coastal zone management in Pakistan. *Coastal Zone Management Imperative for Maritime Developing Nations,* B. U. Haq, S. M. Haq, and J. M. Stel, Eds., Kluwer Academic, 347–371.

——, M. Saleem, and J. Baquer, 1986: Effects of the effluents from Pakistan steel mills on the adjacent marine environment of creek areas Karachi coast. National Institute of Oceanography, Final Tech. Rep. NIO TR-15/86, 103 pp.

Sadiq, M., 1992: *Toxic Metal Chemistry in Marine Environments*. Mercel Dekker, 390 pp.

Saifullah, S. M., 1997: Management of the Indus Delta mangroves. *Coastal Zone Management Imperative for Maritime Developing Nations,* B. U. Haq, S. M. Haq, and J. M. Stel, Eds., Kluwer Academic, 347–371.

——, S. H. Khan, and S. Ismail, 2002: Distribution of nickel in a mangrove habitat of the Indus Delta. *Mar. Pollut. Bull.,* **44,** 571–576.

Siddiqui, P. J. A., and R. Qasim, 1994: Variation in chemical constituents of mangrove foliage *A. marina* (Forsk.) Vierh. (*Avicenniaceae*). *Pak. J. Sci. Ind. Res.,* **37,** 137–143.

Silva, C. A. R., L. D. Lacerda, C. E. Rezende, and A. R. C. Ovalle, 1990: Heavy metals reservoirs in a red mangrove forest. *Biotropica,* **22,** 339–345.

Spalding, M. D., F. Blasco, and C. D. Field, 1997: *World Mangrove Atlas*. The International Society for Mangrove Ecosystems, 178 pp.

Tariq, J., M. Jaffer, and M. Moazzam, 1993: Heavy metals concentrations in fish, shrimp, seaweed, sediment and water from the Arabian Sea, Pakistan. *Mar. Pollut. Bull.,* **26,** 644–647.

Wells, T. J., and J. M. Coleman, 1984: Deltaic morphology and sedimentology, with special reference to Indus River Delta. *Marine Geology and Oceanography of Arabian Sea and Coastal Pakistan,* B. U. Haq and J. D. Milliman, Eds., Van Nostrand Reinhold, 65–70.

Williams, T. M., J. G. Rees, K. K. Kairu, and A. C. Yobe, 1996: Assessment of contamination by metals and selected organic compounds in coastal sediments and waters of Mombasa, Kenya. Tech. Rep. W C-96 -37, 85 pp.

Zheng, S., D. Zheng, B. Liao, and Y. Li, 1997: Tideland pollution in Guangdong Province of China and mangrove afforestation. *For. Res.,* **10,** 639–646.

Earth Interactions is published jointly by the American Meteorological Society, the American Geophysical Union, and the Association of American Geographers. Permission to use figures, tables, and *brief* excerpts from this journal in scientific and educational works it hereby granted provided that the source is acknowledged. Any use of material in this journal that is determined to be “fair use” under Section 107 or that satisfies the conditions specified in Section 108 of the U.S. Copyright Law (17 USC, as revised by P.IL. 94-553) does not require the publishers’ permission. For permission for any other form of copying, contact one of the copublishing societies.

Unauthenticated | Downloaded 07/31/21 12:24 AM UTC