Ocean & Coastal Management 102 (2014) 161–168

Contents lists available at ScienceDirect

Ocean & Coastal Management

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

Review

Decline of mangroves – A threat of heavy metal poisoning in Asia

S. Sandilyan [a, b, *], K. Kathiresan [c]

[a] PG and Research Department of Wildlife Biology and Zoology, A. V. C. College, Mannampandal, 609 305 Mayiladuthurai, Tamilnadu, India
[b] Mass College of Arts and Science, Kumbakonam, Tamilnadu, India
[c] Centre of Advanced Study in Marine Biology, Faculty of Marine Sciences, Annamalai University, Parangipettai 608 502, Tamilnadu, India

A R T I C L E I N F O

Article history:
Received 7 February 2014
Received in revised form
8 September 2014
Accepted 23 September 2014
Available online

Keywords:
Asian countries
Coastal system
Mangroves
Heavy metals
Shore birds

A B S T R A C T

Mangroves are coastal habitats, contributing significantly to the well-being of coastal community, especially in Asia wherein over 70% of human population depends on the coastal resources for food and employment. In recent decades the uncontrolled run off materials from agriculture and industry are entering in to the mangrove system and polluting it alarmingly. The pollutants in particular, heavy metals (Hg, Cd, Ni, Pb, Cu, Cr, and Zn) enter into this system and maroon the mangrove substrate soil. Due to this property, there is a wide accumulation of heavy metals in mangrove flora and fauna. Obviously any small change in mangrove habitat has profound impacts on adjacent coastal systems including seagrass beds and coral reefs. This results in alteration of density and diversity of coastal life which is interlaced with coastal economy. Moreover, coastal people in Asian region are highly prone to heavy metal contamination due to diminishing of mangroves which will release the deposited heavy metals, which will reach man in several ways. It is the time to control further decline of mangroves and to encourage reforestation in coastal Asia for the well-being of the entire subcontinent.

1. Introduction

Mangrove forests are one of the vital coastal ecosystems, which exist only in tropical and subtropical countries. This unique forest is among the most productive systems on the earth (Sandilyan and Thiyagesan, 2010; Sandilyan and Kathiresan, 2012a). The mangroves provide more than 21 ecological services including the coastal protection against natural calamities such as cyclones and tsunamis, as well protection of the shore and inland natural resources (Ronnback, 1999; Kathiresan and Bingham, 2001; Sandilyan, 2007, 2009; Sandilyan and Thiyagesan, 2010; Farley et al., 2010; Sandilyan et al., 2010a, b; Sandilyan and Kathiresan, 2012a, b). Moreover, mangrove forests reduce the harmful effects of greenhouse gases and slow down global warming by mopping up a large amount of Carbon monoxide (CO) and carbon dioxide (CO_2) and acting as a natural carbon sink (Sandilyan and Kathiresan, 2012a). Furthermore, mangroves and their soil are known to sequester approximately 22.8 million metric tons of carbon each year (*i.e.* 11% of the total input of terrestrial carbon in to ocean) (Jennerjahn and Ittekot, 2002). Interestingly, mangroves are natural counter systems which step down the man-induced global warming (Sandilyan and Kathiresan, 2012a). Globally the mangrove wetland systems receive a number of pollutants and have become a massive pollution sink in recent decades (Peters et al., 1997; Tam and Wong, 1997). Ironically, heavy metals are one of the main anthropogenic toxic compounds reported high in mangroves, arising from numerous sources including agriculture runoff (MacFarlane et al., 2001; Caregnato et al., 2008). Several studies have proved that the mangrove flora and its substrate soil have an extraordinary ability to immobilize the heavy metals which entered into the system (Saenger et al., 1990; Tam and Wong, 1997; Peters et al., 1997; Vannucci, 2001; Huang and Wang, 2010). The heavy metals which enter into mangroves are adsorbed on ion exchange sites of fine silt or clay and marooned into the lattice structure of clay, or adsorbed within iron and manganese colloidal oxide compounds (Harbison, 1986). This soil property arrests the dispersion of the heavy metals to the coastal and adjoining terrestrial habitats and it prevents the deleterious impacts of heavy metals on coral reefs and seagrass beds. Likewise, changes in the shape of the cell wall of phytoplankton due to copper and mercury accumulation, which inhibit independent cell division of planktons, were reported (Kayser, 1976; Davies, 1978). Moreover heavy metals such as cadmium and lead are reportedly accumulating in mangrove shrimp, crab and fishes from Asian region (Jothi and Nair, 1999). However the impact of heavy metals on the density and diversity of mangrove fauna is not studied well/or the reported results are

* Corresponding author. Plot # 15, Abdul Kalam Street, PS. Ponninagar, Srinivasapuram, Mayiladuthurai 609001, Nagai District, Tamilnadu, India.
E-mail address: sssandilyan@gmail.com (S. Sandilyan).

http://dx.doi.org/10.1016/j.ocecoaman.2014.09.025
0964-5691/

abysmal. In general, there are many gaps in identifying the relationships between pollution and aquatic species populations such as insufficient data, insufficient use of existing data, lack of analytical tools, few direct examples of pollution effects, and institutional constraints (Griswold, 1997). Besides, weak communication between scientists and managers, lack of cooperation between local public and private sectors are the other major concerns (Williams, 1996).

The concentrations of heavy metals required to damage the plant growth are several folds higher in mangroves than those in aquatic and terrestrial floral counterparts (MacFarlane et al., 2007). For instance, in *Kandelia candel,* the concentration at which leaf and root are inhibited is observed to be only at high concentrations of metals (400 mg kg^{-1} Cu and Zn) (Chiu et al., 1995). However chlorophyll biosynthesis and degradation are important results of metal-induced stress in mangrove flora (MacFarlane et al., 2001). Indeed, knowledge of bioavailability of heavy metals in natural condition is complex since it is affected by more than 22 geochemical, hydrological and physicochemical factors (Lacerda et al., 1993; Eggleton and Thomas, 2004; Rai, 2008).

Obviously, loss of mangroves may cause their sediment soil to lose its metal binding capacity resulting in mobilization or releasing of heavy metals and it is important to mention that, gradually mangroves shift from a sink of heavy metals to the source of them (Lacerda, 1998). In this context mangrove soil sediments are reported to contain 90% of Manganese and Copper and almost 100% of the Iron, Zinc, Chromium, Lead and Cadmium (Silva et al., 1990) which will move in all direction through water current and marine food.

2. Asian mangroves

Asia supports the largest global mangroves such as Sundarbans, which is also known for its high biodiversity (FAO, 2007). The Asian region is an ideal habitat for mangroves due to its longest coastline, wide range of climatic conditions from arid (the Arabian Peninsula) to subtropical (China, Japan) and to humid tropical (Southeast Asia) and multitude of islands, sheltered bays, alluvial flats, deltas and estuaries (FAO, 2007). Besides, high rainfall and significant riverine inputs are particularly favorable for the development of well-structured mangrove forests in this region. Interestingly more than 20 Asian countries support sizeable areas of mangrove forests (Table 1) and some of the mangrove species are endemic to the region (e.g. *Aegiceras floridum, Camptostemon philippinensis*, *Heritiera globosa*) (FAO, 2007).

Table 1
Mangrove surface area of top Asian countries.

S. No	Country	Area (ha)
1	Indonesia	3,112,989
2	Malaysia	505,386
3	Myanmar	494,584
4	Bangladesh	436,570
5	India	368,276
6	Philippines	263,137
7	Thailand	244,085
8	Pakistan	158,000
9	Viet Nam	157,500
10	Cambodia	72,835
11	China	22,480
12	Saudi Arabia	20,400
13	Sri Lanka	9,530
14	United Arab Emirates	4000
15	Timor–Leste	1,802
16	Yemen	927
17	Japan	800
18	Singapore	500
19	Qatar	500

Source. FAO, 2007; Giri et al. 2011.

2.1. Heavy metal pollution in Asian mangroves

According to several benchmark studies from the Asian region, the mangrove system is severely polluted by heavy metals including Mercury (Hg), Lead (Pb), Tin (Sn), Cobalt (Co), Copper (Cu), Chromium (Cr), Cadmium (Cd), Manganese (Mn), Zinc (Zn), Nickel (Ni) and Iron (Fe) (Tam and Wong, 1995; Lian et al., 1999; Sarangi et al., 2002; Tam and Wong, 2000; Cuong et al., 2005; Agoramoorthy et al., 2008; Nazli and Hashim, 2010). Some of the heavy metals including Hg, Cd, Ni, Pb, Cu, Cr, and Zn are lethal to several marine organisms even in low concentration (Davies, 1978).

In general mangrove environments are enriched with metals, resulting from urban and agricultural runoff, sewage treatment plants, industrial effluents, boating and recreational use of water bodies, chemical spills, leaching from domestic garbage dumps and mining operations (Peters et al., 1997). Inter alia, most of the Asian mangroves have experienced significant direct input of contaminants as a consequence of their close proximity to urban and coastal developments. The major pollutants from anthropogenic inputs are heavy metals (MacFarlane and Burchett, 2002). A number of Asian literature has clearly stated that heavy metal pollution in Asian mangroves is mainly due to the growth of industries in and around coastal areas in the recent past (e.g. Thomas and Fernandez, 1997; Sarangi et al., 2002; Agorammoorthy et al., 2008; Rajan et al., 2008). Due to mushrooming of industries, every year the pollution load is spiraling up. For instance, it is estimated about 37,000 tons of industrial waste are being dumped yearly in coastal environment of Karachi, Pakistan, especially mercury and lead are more from tanneries (Shah et al., 2007). Furthermore, 70% of international trade is Karachi based and it is reported that in about 25 years the number of industries has increased from 10,000 to about 30,000 (Shah et al., 2007).

Furthermore, there is an acute lack of systematic studies related to the monitoring and control of heavy metal accumulation and its impacts on Asian marine diversity (Agoramoorthy et al., 2008). However, the available literature have clearly emphasized the accumulation of heavy metals in Asian mangroves which are higher than normal thresholds. For instance, an average concentration of mercury in the mangrove plants (0.068 $\mu g\ g^{-1}$) is 11.3 times greater than that in inland counterparts (0.006 $\mu g\ g^{-1}$) (Agoramoorthy et al., 2009). A study by Kumar et al. (2011) in India has stated that, heavy metal concentrations are detected in all parts of mangrove flora. The accumulations of different heavy metals in a number of Asian mangrove floras are given in Table 2. Of particular concern is that most of mangroves in Asia have higher salinity level due to poor freshwater influx in recent past (Kathiresan, 2000; Sandilyan et al., 2010a) and the synergism between mercury and salinity is shown to have a significant impact on population of mangrove invertebrates. It is established that even a low concentration of mercury has a deep impact on animals in areas of high salinity and it causes a notable increase in the mortality rate of animals in that habitat (Sandilyan et al., 2010a). Some heavy metals can be transported through the marine food chain and reach considerable distance from the place of their origin and the possible ways are shown in Fig. 1.

2.2. Declining Asian mangroves

The global mangrove area has been lost between 20% and 35% for the past two decades and only 6.9% of the mangroves are currently protected (Giri et al., 2011). A number of benchmark