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Potential release of PCBs from plastic scientific gear to fringing coral reef sediments in the Gulf of Thailand

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ABSTRACT

A status on environmental contamination of the coral reefs on the islands of Samui and Katen of the western part of the Gulf of Thailand was investigated with a preliminarily analysis of bottom sediment samples. Coral reef bed sediments were characterized as relatively uncontaminated by human activities in terms of selected metals and PCBs. Potential release of PCBs to the ambient seawater from scientific equipment made of plastic materials placed into the coral reef waters for an extended period was investigated because the sedimentary PCBs concentrations were very low in the region. Eight plastics – acrylic, mono cast nylon, polycarbonate, polyethylene, polypropylene, ivory and grey-colored polyvinyl chloride, and Teflon® – were subjected to leaching in seawater after being thoroughly washed with laboratory detergent and distilled water. All plastics were found to release PCBs at highly variable rates to seawater in the initial 60 days. Grey-colored PVC, Teflon, and polycarbonate after rinsing with *n*-hexane were found to release less than 50 ng PCBs/kg of plastics and they could therefore be used to make scientific equipment to be deployed on the relatively PCBs-free coral reef beds.

1. Introduction

Corals are harboring symbiotic algae (*Symbiodinium* sp.) in the endodermal cells and reef building scleractinian corals are among the most diverse (Huang et al., 2011) and productive ecosystems on our planet. Scleractinian corals serve as the reef building agent as well as a habitat for all other coral reef-associated organisms. Their ecosystem services in tropical developing countries are far reaching from attenuation of incoming offshore waves to economical resources of food and tourism (Yeemin et al., 2006). However, pressures on these valuable coral reefs have increased recently due to the tourism activities such as anchor damage, garbage accumulation, diver damage, eutrophication and toxic material associated with wastewater discharge from hotels and resorts located at the coast, collection of shell and ornamental fish with the use of chemicals, sediment supply associated with construction of jetties and navigation channels (Brown et al., 1990; Yeemin et al., 2009). The human pressure and abnormally high water temperature often lead to bleaching of corals (Li et al., 2012). Coral reefs are also damaged by tsunamis caused by tectonic movement of the Earth's crust (e.g., 2004 Indian Ocean tsunami, Stoddart, 2007). As restoring damaged coral reefs by transplanting and/or reattaching coral fragments would be very costly (e.g., 75 million USD km^{-2} in Thailand, Yeemin et al., 2006), the assessment of human pressure and environmental conditions on the existing coral reefs is of paramount importance to protect the coral reef ecosystems.

A preliminary investigation on the status of chemical contamination in two coral reefs located in the western part of the Gulf of Thailand was conducted as a part of the IOC/WESTPAC Training Course: "Impact of Sedimentary Dynamics and Biogeochemistry on Coral Reefs" held in 15–18 June 2010 in Samui Island of Thailand. Some 20 post-graduate students from China, Indonesia, Malaysia, Philippines, South Korea, Vietnam, and Thailand observed coral reefs in the relatively turbid water of Samui Island (9°25′N 99°56′E) and relatively clear water of Katen Island (9°23′N 99°56′E). Several colonies were observed to be undergoing bleaching at both sites (Yeemin et al., 2009). It is believed that sediment load in the coral reefs has increased recently due to frequent dredging activities to secure tour boat navigation channels adjacent to the coral reefs and various construction activities for meeting the increasing demand of tourism activities of Samui

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Island in recent years. The continued increase in sediment load poses chronic stress to corals (Rogers, 1990; Fabricus and Wolanksi, 2000; Dikou and van Woesik, 2006).

Most environment including marine environment adjacent to human dwellings or activities are contaminated with heavy metals and persistent synthetic organic chemicals. For example, copper and zinc are major components of antifouling paints for ships and artificial structures at sea and port (Jones, 2007). Metals are found in the sewer discharges. Heavy metals are toxic both to the plant and animals in the sea. Cu and Zn are found to inhibit its cell growth of zooxanthella, a symbiotic plant in reef building scleractinian corals (Goh and Chou, 1997) and Cu to reduce fertilization success of reef coral *Acropora surculosa* (Victor and Richmond, 2005) and *Goniastrea aspera* (Reichelt-Brushett and Harrison, 1999). Coral cover appears to decrease with increasing metal concentration in a Hawaiian coral reef (Hédouin et al., 2011).

Polychlorinated biphenyls (PCBs) belong to a broad family of man-made organic chemicals known as chlorinated hydrocarbons. PCBs were manufactured from 1929 to 1979. Their production and use were banned in 1979 due to carcinogenic and non-carcinogenic health effects to the animals including immune system, reproductive system, nervous system, endocrine system. PCBs are widely distributed in the global environment due to the earlier global use of PCBs in various industrial activities. Although, the production of PCBs largely halted in 1970 s around the world but continued in some locations until 1990 s, however, they have been used widely in "totally enclosed uses" for transformers and capacitors, which, in some cases, are able to currently leak to the environment. Apart from intentional manufacture, PCBs could be also generated incidentally as byproducts, e.g. in production of chlorinated solvents, chlorinated alkanes, chloronaphthalenes, chlorophenylsiloxane adhesives, organosilicone drugs, organic intermediates and pigments, PVC production, during thermal processes including waste incineration, and volcanic eruptions (Breivik et al., 2002; Costner et al., 1995; Wyrzykowska et al., 2006) as well as in thermal and combustion operations (Joung et al., 2006; Altarawneh et al., 2009). Therefore, PCBs are widely present on the surface of the Earth. PCBs appear not acutely toxic to aquatic biota in natural environment due to the low solubility of PCBs in water and large volume of their molecules, but likely to exert sublethal and chronic toxicity to mixed-function oxygenase system of coral (McFarland and Clarke, 1989) once accumulated in coral (Miao et al., 2000). Recently Chen et al. (2012) observed the PCBs altered expression of certain genes performing various important cellular functions in a scleractinian coral (*Stylophora pistillata*). Moreover, the predominant environmental sources of metals and PCBs in the coastal population diet are contaminated marine organisms (e.g., Bordajandi et al., 2004; Choi et al., 2011). However, the region has not yet received any serious scientific investigation on its chemical contamination status. Therefore a preliminary investigation on the level of selected metals and PCBs in the coral reefs of Samui and Katen islands was attempted based on bottom sediment samples taken during the training course as they contain evidence of industrial intervention (e.g., Hédouin et al., 2011; Jones, 2010) and potential accumulation in biota (e.g., WHO, 2001; Van den Berg et al., 2006; Choi et al., 2010). Water borne plastic particles were also known to absorb PCBs from surrounding seawater (e.g., Teuten et al., 2009; Mato et al., 2001; Hale et al., 2010). Therefore, the possibility of PCB leaching to seawater and concentration of PCBs from the surrounding seawater is of paramount concern, considering that various home-made scientific gear, such as, recruitment plates/tiles, sediment traps, quadrant, used in the coral ecosystem observation are made of PVC and other plastics (Harriott and Fisk, 1987). We attempted here to evaluate in situ PCB contamination originating from the plastic scientific gear placed onto the sea floor of the coral reef area in order to provide information necessary to select plastic ware for use in the coral reef beds or other relatively PCBs-sensitive ecosystems. Basin scale observation on the sea surface temperature, chlorophyll *a* and particulate organic carbon concentration in seawater *via* satellite was also utilized to provide some general oceanographic features of Samui and Katen coral reefs in the context of wider Gulf of Thailand.

2. Materials and methods

2.1. Sampling

Divers collected bottom sediment samples from the coral reef beds and one soil sample in a coastal resort in Samui Island in 15–18 June 2010, and placed them in low-density polyethylene (LDPE) bags and transported then to Ansan, S. Korea *via* air. Samples were subsequently dried and ground in mortar and petal.

2.2. Chemical analysis

For the analysis of metals, aliquots of 20 mg of homogenized sediments were placed in screw-capped Teflon bombs and 3 mL of conc. HNO_3 (Merck, Suprapur®), 0.5 mL of conc. $HClO_4$ (Merck, Suprapur®), and 1 mL of conc. HF (Merck, Suprapur®) were added. The closed bombs were placed on a hot plate and heated for 12 h at 180 °C. After cooling, 1 mL of the clear liquid sample was taken and diluted to 10 mL with 1% HNO_3 (Merck, Suprapur®). Analytical measurements were performed using a quadroplole ICP-MS spectrometer (Thermo X series) with cross flow

Table 1
MDL values of individual PCB congeners employed.

IUPAC #	Sediment (μg/kg)	Seawater (ng/kg)
8	0.10	0.58
15	0.09	5.27
18	0.08	1.69
28	0.06	1.40
31	0.06	2.51
37	0.04	0.76
44	0.03	0.21
49	0.07	1.04
52	0.04	0.34
60	0.03	0.32
70	0.05	0.53
77	0.02	0.80
81	0.03	3.41
87	0.02	0.36
101	0.03	0.16
105	0.02	0.78
114	0.03	0.55
118	0.04	1.10
123	0.02	0.45
126	0.03	0.81
128	0.02	0.77
138	0.02	0.54
149	0.02	0.81
153	0.02	0.33
156	0.02	0.69
157	0.03	2.77
167	0.03	0.51
169	0.03	3.87
170	0.03	1.03
180	0.03	0.32
187	0.02	0.15
189	0.03	0.84
194	0.01	0.98
195	0.02	0.53
206	0.02	1.29