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Hg bioaccumulation in marine copepods around hydrothermal vents and the adjacent marine environment in northeastern Taiwan

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ABSTRACT

The Hg concentration in seawater and copepod samples collected from the area around hydrothermal vents at Kueishan Island and the adjacent marine environment in northeastern Taiwan were analyzed to study Hg bioaccumulation in copepods living in polluted and clean marine environments. The seawater collected from the hydrothermal vent area had an extremely high concentration of dissolved Hg, 50.6–256 ng l^{-1}. There was slightly higher Hg content in the copepods, 0.08–0.88 μg g^{-1}. The dissolved Hg concentration in the hydrothermal vent seawater was two to three orders of magnitude higher than that in the adjacent environment. The bioconcentration factor of the studied copepods ranged within 10^3–10^6, and showed higher dissolved concentration as the bioconcentration factor was lower. A substantial abundance, but with less copepod diversity was recorded in the seawater around the hydrothermal vent area. *Temora turbinata* was the species of opportunity under the hydrothermal vent influence.

1. Introduction

Copepods and other zooplankton are the most numerous primary consumers and are widely distributed throughout the ocean. Many studies have shown that marine copepods have a great ability to accumulate trace metals (Ritterhoff and Zauke, 1997; Wang and Fisher, 1998; Fang et al., 2006; Hsiao et al., 2006, 2010). The trace metal bioconcentration factor in marine copepods is quite high and ranges from 5 to 7 orders of magnitude (Fang et al., 2006). Compared with other trace metals, the Hg bioaccumulation in zooplankton is relatively limited (Foster et al., 2012). However, mercury is a non-essential metal for organisms and its toxicity to aquatic organisms ranks first among trace metals (Kennish, 1997). Mercury is ubiquitously present in the aquatic environment because it is volatile and highly mobile through atmospheric transportation (Neff, 2002). The trophic transfer and biomagnification of mercury in aquatic food chains was evidenced with the Minamata Disaster. Mercury therefore became one of the most critical trace metals examined in environmental studies (e.g. Costa et al., 2012). Mercury accumulation in phytoplankton and zooplankton is of great concern to marine scientists interested in the biomagnification and effects of contaminants (Hook and Fisher, 2002; Foster et al., 2012). Such knowledge provides a fundamental understanding of the first step in trophic transfer.

The major source of Hg anthropogenic activity is from fossil combustion emissions, especially coal, which spreads out worldwide through atmospheric transportation (Wilson et al., 2006). The largest natural source of Hg in the environment comes from Earth's crust degassing, emissions from volcanoes and erosion or leaching from cinnabar deposits in the environment (Neff, 2002). Hydrothermal vents also release a great amount of chemical constituents into the marine environment, elevating the concentrations of chemical compounds around the environment (Chen et al., 2005; Colaco et al., 2006). It was found that mussels, *Bathymodiolus azoricus*, collected from the Menez Gwen hydrothermal vent field located on the Mid Atlantic Ridge, contained a much higher concentration of Hg, ca. 4.5 μg g^{-1} dry weight (Colaco et al., 2006). This concentration is higher by one to two orders of magnitude than that in mussels collected from heavily polluted marine environments, such as Minamata Bay (Haraguchi et al., 2000) and the Kastela Bay (Kljakovic-Gaspic et al., 2006). Benthic organisms living in hydrothermal vent areas were also found to have higher concentrations of trace metals (Colaco et al., 2006; Peng et al., 2011).

The hydrothermal vents around Kueishan Island, located in northeastern Taiwan near the southern end of the Okinawa Trough, releases hydrothermal fluids which contain higher concentrations of major and trace elements, pure sulfur and extremely acidic thermal fluids, with pH values as low as 1.52, into the seawater (Chen et al., 2005). The marine environment adjacent to Kueishan Island provides a natural laboratory for the study of trace metals. Such habitats are naturally enriched in terms of trace metals, and thus provide valuable examples of naturally polluted sites to compare with those affected by anthropogenic pollution. Although there have been many studies on the availability of trace metals in this

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type of environment (Ruelas-Inzunza et al., 2005; Colaco et al., 2006; Kádár et al., 2007; Wallenstein et al., 2009), zooplankton communities have not been the main object of study. In order to understand the bioaccumulation of Hg by marine copepods under polluted and clean marine environments, seawater and zooplankton samples were collected from the hydrothermal vent area at Kueishan Island to study the hydrothermal vent influence on Hg bioaccumulation in zooplankton and the marine ecosystem.

2. Materials and methods

2.1. Sampling

The seawater and zooplankton samples were collected from four stations at Kueishan Island extending northeast to the Okinawa Trough onboard the R/V Ocean Research-II on August 10–12, 2011, as shown in Fig. 1. The seawater samples were collected from different depths at each station using Go-Flo bottles mounted on a Rosette sampling assembly. Samples were stored in acid cleaned 1-l Nalgene polyethylene terephthalate bottles (PET). The PET bottles were rigorously cleaned prior to use by sequentially soaking them in a detergent solution followed by a mixture consisting of 50% (v/v) hydrochloric acid and 50% (v/v) nitric acid. Samples were frozen immediately on board ship to prevent the adsorption of dissolved compounds on the inner walls of the bottles.

The zooplankton samples were collected using a zooplankton net with a 45-cm mouth diameter and 333 μm mesh size. The net was towed obliquely 1 m below the surface layer (surface tows) and at a deeper layer (deeper tows), depending on the topography of the studied stations. The deeper layer at stations 1, 3 and 4 was approximately 100 m depth and at station 2 was about 35 m depth. The sampling time was approximately 10 min at a vessel cruising speed of 2 knots. The zooplankton samples were immediately preserved in a freezer at −20 °C on aboard. The sampled area is located primarily at the Okinawa Trough, which is the back arc basin of the Ryukyu subduction zone extending westward through an E–W trending graben caused by the subduction of the Luzon Plate beneath the Eurasian Plate (Chen et al., 2005). The collision system, with its tectonic activity, extends about 1000 km from southwestern Kyushu in Japan to northeastern Taiwan (Wang, 2002). Many volcanic islands dot this region, with one of the youngest Kueishan Island, experiencing its' last major eruption 7000 years ago (Chen et al., 2001). The Kuroshio Current is the major current flowing through the Okinawa Trough. A portion of it intrudes into the East China Sea. The Kuroshio Current originates from the equatorial region east of the Philippines and diverges from the North Equatorial Current in the area east of the Philippines, forming a western boundary current flowing along the gyre margin (Nitani, 1972; Kawai, 1998). It flows northward along the east coast of Taiwan. The upper waters (0–500 m) of this boundary current flow northward into the Okinawa Trough through the Yonaguni Depression and pass along the outer edge of the continental shelf of the East China Sea, forming the main track of the Kuroshio Current (Ujiié et al., 2003). High salinity and temperature characterize the Kuroshio waters as well as low nutrients in the surface layer (Liu et al., 2003).

The northern shelf of Taiwan is an extremely dynamic oceanic region because Taiwan lies in a monsoonal region affected by southwesterly winds in summer (June–August; SW monsoon) and northeasterly winds in winter (December–February; NE monsoon) (Chen, 2003). During the SW monsoon, surface currents everywhere in the Taiwan Strait are directed northward carrying South China Sea surface waters and a branch of Kuroshio Water to Northern Taiwan. In winter, the northeast winds drive the China Coastal Water southward into the northern Taiwan Strait (Naik and Chen, 2008). The Kuroshio Current runs into the continental shelf-break off of northeastern Taiwan and forms a year-round upwelling that brings high nutrient loads into the euphotic zone at the shelf break (Liu et al., 2003). As a result, a high zooplankton biomass is generally observed in the seawater around northeastern Taiwan (Hsiao et al., 2010, 2011a,b).

2.2. Analysis

The copepod species were identified under a microscope after thawing. The copepods, *Cosmocalanus darwini*, *Oncaea venusta*, *Temora turbinata*, and *Undinula vulgaris*, were found as the dominant species at the four studied stations. The males and females of these copepod species were collected separately. Each sample

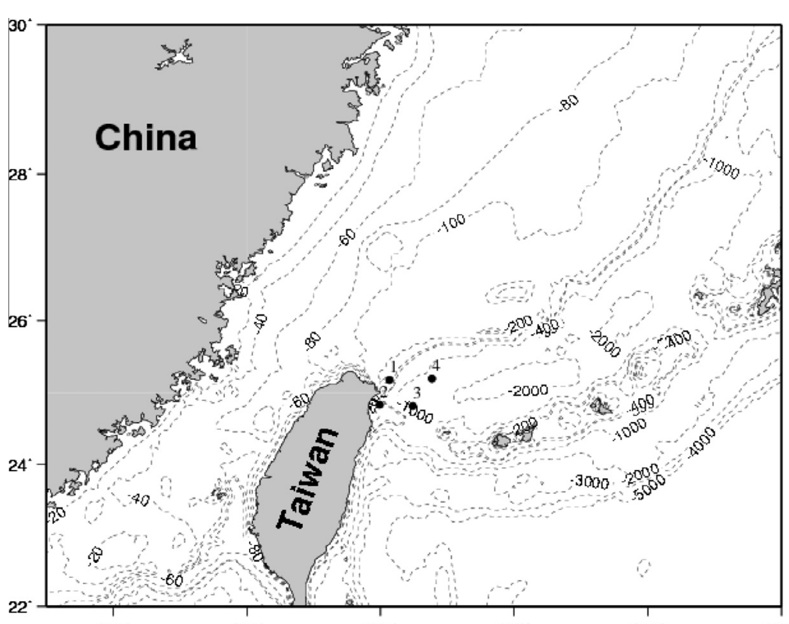

Fig. 1. The sampling stations were located the coastal waters off northeastern Taiwan.