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A preliminary study of the distributions of Cd in the South China Sea

Hung-Yu Chen[a,*], Tien-Hsi Fang[a], Liang-Saw Wen[b]

[a]*Department of Oceanography, National Taiwan Ocean University, 2, Pei-Ning Road, Keelung 202, Taiwan*
[b]*National Center for Ocean Research, National Taiwan University, Taipei 106, Taiwan*

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Abstract

The water column distributions of dissolved cadmium and supporting parameters were determined during a cruise in the South China Sea in October, 2002. The investigation was focused on waters of the shelf and the central basin which have depths of <200 m and >2000 m, respectively. In the surface waters, concentrations of Cd were 0.07–0.95 and 0.05–0.15 nM for the shelf and central basin, respectively. The spatial distributions in the surface waters show that concentrations of Cd were relatively high in the Pearl River Estuary. In contrast, Cd was totally depleted in surface waters of the deep water basin. This is attributed to the riverine inputs from the East Asian continent in the shelf regions. The influence of riverine input is reduced by dilution process with waters containing low concentrations of Cd waters. In the central basin, vertical profiles of Cd show a nutrient-like distribution which is depleted in the surface, increases with depth to about 1000 m, and that is finally maintained within a narrow concentration range of 0.94–0.99 nM in the deep water. Here, the Cd/PO_4 ratio was 0.369 ± 0.011 nM Cd/μM PO_4, indicating that the biogeochemical processes of Cd and PO_4 are similar to that in marginal seas of the western Pacific Ocean. However, the concentration gradients in surface waters show a southward increase. The results indicate that the relative enrichment of nutrients and the nutricline uplifted sharply in surface waters of the southern SCS.

Keywords: Cadmium; Phosphate; Trace metals; Nutrients; South China Sea

1. Introduction

The South China Sea (SCS) is one of the large marginal seas in the western Pacific Ocean (WPO) and is surrounded by the eastern Asian continent and several large marine islands. The sea has an area of approximate 3.3 million km^2 and is sometimes referred to as the Asian Mediterranean (Morton and Blackmore, 2001). The SCS mainly includes a wide continental shelf from the northwest to south, a basin 4700 m deep in the center, and two great islands, Taiwan and Luzon, in the

*Corresponding author. Tel.: +886 2 2462 0951; fax: +886 2 2462 1047.
E-mail address: hychen@mail.ntou.edu.tw (H.-Y. Chen).

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northeast and east, respectively. The SCS below 1000 m is an isolated basin which is connected with the Western Philippine Sea (WPS) by a major channel, the Luzon Straits (Broecker et al., 1986). The SCS is located in the low-latitude tropical region and the surface layer is characterized by high temperatures, low salinities, low nutrient concentrations, and low primary productivity (Yang, 2000).

The oceanography of the upper layer of the SCS is dominated by the strong monsoon system and considerable quantities of runoff from several great rivers such as the Mekong River and Pearl River (Zhujiang). Deep waters are mostly derived from the WPS waters (Gong et al., 1992) and so the waters below 2500 m are relatively uniform and with characteristics similar to the same depth water in the WPS (Chen and Hung, 1996). Therefore, the biogeochemical cycles in the deep water are significantly influenced by the WPS waters (Liu et al., 2002). In a previous study, Pai and Chen (1994) showed that the surface mixing layer was very shallow (<75 m) and that below it the concentration of oxygen decreased rapidly with a sharp increase in nutrient concentrations. Liu et al. (2002) reported that the surface chlorophyll level in the SCS was about two times higher than that in the WPS. Consequently, differences in hydrography and chemical properties between the SCS and WPS have been found that the middle layer (300–1000 m) of the SCS waters were higher in nutrients and lower in oxygen.

Cadmium (Cd) has been recognized as one of the most important nutrient-type trace metals in the biogeochemical oceanic cycles for two or three decades (Delgadillo-Hinojosa et al., 2001; Segovia-Zavala et al., 1998; Bruland et al., 1994; Pai and Chen, 1994). This behavior also suggests that Cd can become associated with the biogenic carriers either because it is specific to biological requirements or because it is taken up by analogy with essential elements (Chester, 1999). Cd in surface waters is absorbed by the organisms and promptly combined with the soft tissue phases (biogenic carriers). Hence, the vertical profiles of nutrient-type trace metals are completely depleted in surface layers, and the concentration increases with depth in mid-layer water columns, remaining at a steady concentration in deeper waters (Bruland, 1983).

The strong relationship between dissolved Cd and phosphate indicates that either both species play similar roles in the marine biogeochemical cycles (Segovia-Zavala et al., 1998) or that Cd can substitute for phosphorus in some metabolic processes. This close relationship has therefore been applied to describe water mass exchanges (Delgadillo-Hinojosa et al., 2001), biogeochemical processes in upwelling area (van der Loeff et al., 1997) and biological uptake (Löscher et al., 1998). Furthermore, this relationship is an important index for reconstructing Cd or PO_4 distributions in paleoceanography (Boyle, 1988; Löscher et al., 1997). Löscher et al. (1997) have inspected the Cd vs. PO_4 relationship in global deep ocean waters. The results show that the slopes between Cd and PO_4 varied from ocean to ocean according to the age of ocean. Overall, the slopes of Cd (nM)/PO_4 (μM) are about 0.17–0.27 and 0.29–0.37 for the Atlantic and Pacific Oceans, respectively. In the eastern North Pacific Ocean, the correlation equation between Cd and phosphate has been expressed as (Bruland, 1983):

$$[\mathrm{Cd}] = (0.347 \pm 0.007)[\mathrm{PO_4}] - (0.068 \pm 0.017) \quad (r^2 = 0.984),$$

where [Cd] is in units of nM and [PO_4] is in units of μM. In this equation, the slope is 0.347 ± 0.007 nM Cd/μM P, and the phosphate concentration is in excess of 0.068 ± 0.017 μM. Due to the differences in oceanic circulation patterns and sources, variations in the Cd/P ratio may occur (Löscher et al., 1998). Pai and Chen (1994) reported the Cd/P ratios in several marginal seas of the WPO and one of their stations was located in the SCS. The results showed that Cd also had a strong relationship with phosphate in this area. The Cd/P ratio was in the range of 0.372 ± 0.005 which was ca. 7% higher than that in the eastern North Pacific Ocean.

To date, many efforts have been devoted to the study of the global Cd distributions in seawater and the biogeochemical mechanisms. However, the biogeochemical processes of Cd in the SCS still