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Process study of biogeochemical cycling of dissolved inorganic arsenic during spring phytoplankton bloom, southern Yellow Sea

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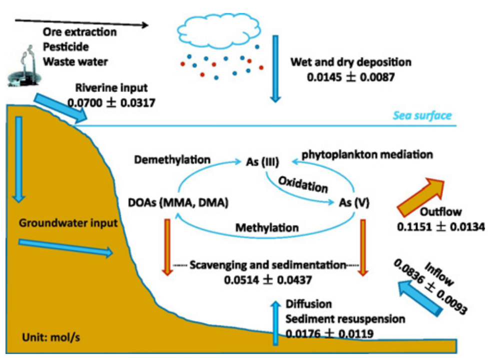
HIGHLIGHTS

- As cycling in the Yellow Sea, an important fishery, was studied.
- Dissolved inorganic As behaved non-conservatively during a phytoplankton bloom
- ~15.1% As(5+) in the euphotic zone was converted to As (3+) at 0.53 nmol/L/d.
- Dissolved As (7.1%) was scavenged from the water column by uptake of phytoplankton.
- As conversion efficiency per unit of diatom was >5-fold higher than dinoflagellates.

GRAPHICAL ABSTRACT



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ABSTRACT

Previous studies in the southern Yellow Sea (SYS) suggest that large spring phytoplankton blooms (SPBs) have occurred in recent decades. Elevated primary production in the water column can lead to the accumulation and transformation of trace elements. Two field study cruises (including two drifting anchor surveys) were conducted on 12–19 February and from 24 March to 15 April 2009, to investigate the impact of different SPB development periods on the concentrations of total dissolved inorganic arsenic (TDIAs: [TDIAs] = [As(V)] + [As(III)]) and As(III) (arsenite) in the SYS. The distribution of TDIAs in the study area was similar between the two field studies, with concentrations increasing from coastal to offshore areas. High arsenite concentrations and As(III)/TDIAs ratios were found in areas having high concentrations of chlorophyll-*a*, particularly in the subsurface waters of the central SYS during the drifting surveys, where a significant SPB occurred. Results show that the integrated arsenite concentrations increased at an average transformation rate of 0.53 ± 0.24 nmol/L/d within the 15 days during the bloom, and data from the anchor drifting surveys indicated that approximately 15.1% of the arsenate in the euphotic zone (~30 m depth) was converted to arsenite. In addition, 7.1% of TDIAs was scavenged from the water column by phytoplankton forming the blooms (a factor of 5 higher than expected). A preliminary box model was established to estimate the budget for TDIAs in the SYS in early spring (February to April). This showed that biological scavenging is an important sink for TDIAs, which may promote the transformation and migration of inorganic arsenic species, and thus have a substantial impact on the biogeochemical cycling of this element in the SYS. Depletion of arsenate in the upper waters could lead to arsenate stress, potentially damaging fisheries and the ecosystem.

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1. Introduction

The southern Yellow Sea (SYS) is a semi-enclosed marginal sea bordered by China and the Korean Peninsula, in the western Pacific Ocean. It has area of approximately 3.09×10^5 km^2 and an average depth of 45.3 m, and is an important fishing ground for many species of fishes and prawns (Su and Yuan, 2005; Lu et al., 2013; Shan et al., 2013). The fisheries and mariculture in the SYS make a significant contribution to the development of adjacent coastal economies, providing annual production equivalent to nearly 300 billion dollars (Yu et al., 2012; Zhang et al., 2014). However, the SYS has been negatively impacted by natural and anthropogenic factors (e.g. climate change and eutrophication), and the structure and function of its ecosystem have changed markedly; the changes in recent years have the potential to restrict economic development, and affect human health (Lin et al., 2005; Zhang et al., 2008; Fu et al., 2009; Sun et al., 2015; Wu et al., 2015).

The SYS is influenced by complex shelf circulation systems, involving several major hydrological features (Fig. 1a, b) including: the Yellow Sea Warm Current (YSWC), which transports warm and relatively high salinity water from the open ocean into the SYS; the cold and low salinity Yellow Sea Coastal Current (YSCC) and the Korea Coastal Current (KCC), which move along the coasts of China and Korea, respectively (Su, 1998; Naimie et al., 2001; Xu et al., 2009); and the moderate temperature and salinity Yellow Sea Central Water (YSCW), which mainly occurs in the broad shelf region of the SYS and has hydrographic properties that are related to distinctive source water masses (Zhou et al., 2013). Although

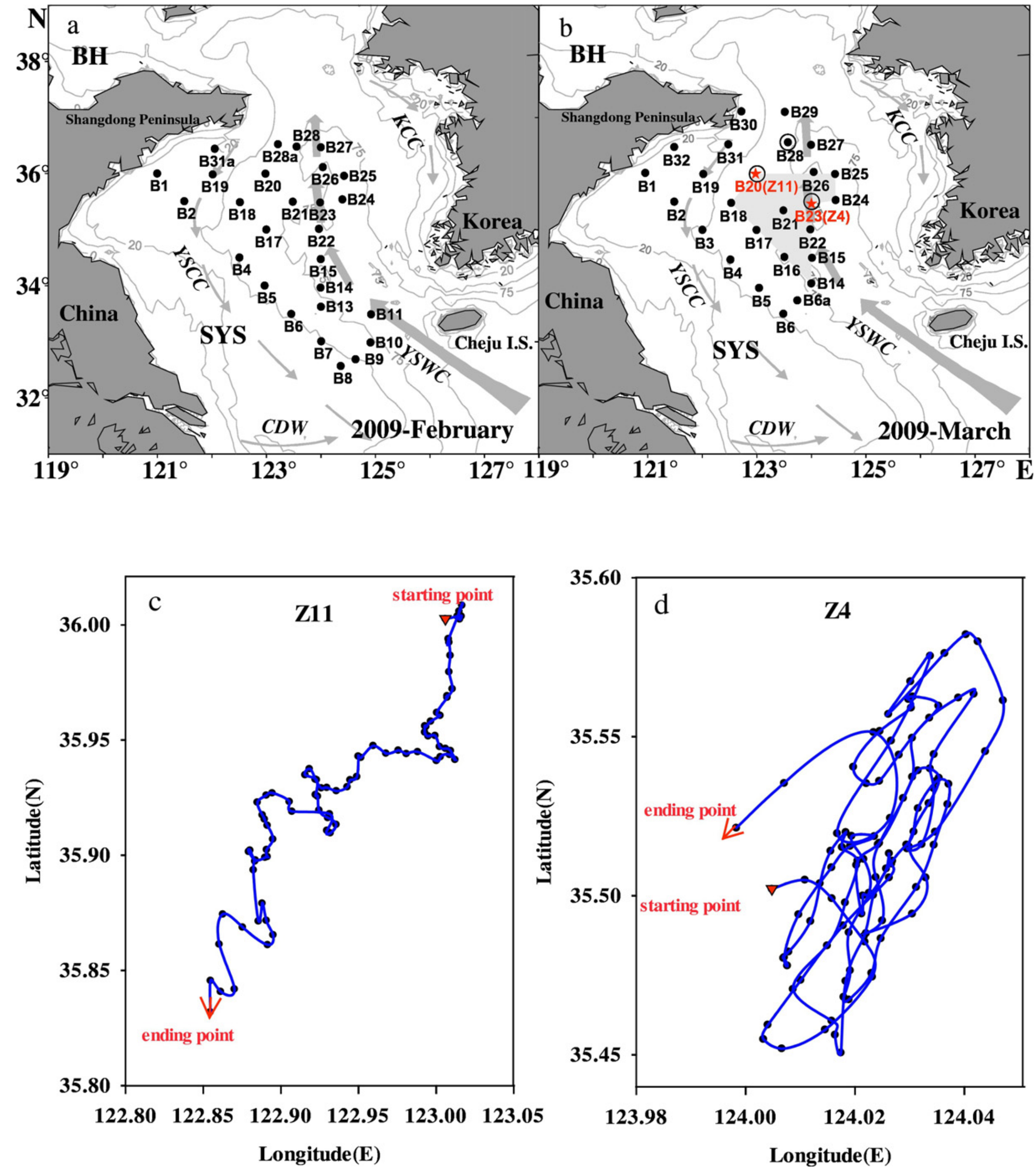

Fig. 1. Sampling locations in the southern Yellow Sea. (a) 12–19 February 2009; (b) 24 March to 15 April 2009; (c) and (d) drifting anchor sampling trajectory conducted at stations Z11 (tracing time 102 h, tracing distance 53.7 km) and Z4 (tracing time 126 h, tracing distance 119.2 km), respectively. The shadowed region in Fig. 1(b) is the estimated high frequency bloom region; ★ drifting anchor stations; ○ SPB stations.