Estuarine, Coastal and Shelf Science 180 (2016) 59–68

Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

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

Effects of microbial transformation on dissolved organic matter in the east Taiwan Strait and implications for carbon and nutrient cycling

Liyang Yang [a, b], Chen-Tung Arthur Chen [b, c, d, *], Hon-Kit Lui [b], Wan-E Zhuang [e], Bing-Jye Wang [b]

[a] College of Environment and Resources, Fuzhou University, Fuzhou, Fujian, PR China
[b] Department of Oceanography, National Sun Yat-sen University, Kaohsiung, Taiwan, ROC
[c] The Second Institute of Oceanology, State Oceanic Administration, Hangzhou, PR China
[d] Institute of Marine Chemistry, Zhejiang University, Hangzhou, PR China
[e] College of Life Sciences, Fujian Agriculture and Forestry University, Fuzhou 350002, Fujian, PR China

ARTICLE INFO

Article history:
Received 29 January 2016
Received in revised form
7 June 2016
Accepted 23 June 2016
Available online 24 June 2016

Keywords:
Dissolved organic carbon
Dissolved organic matter
Dissolved inorganic carbon
Nutrient
EEM-PARAFAC

ABSTRACT

Dissolved inorganic and organic carbons (DIC and DOC) provide two of the largest pools of carbon in the ocean. However, limited information is available concerning the relationship between DIC and different constituents of dissolved organic matter (DOM), such as fluorescent compounds. This study investigates the dynamics of DOM and their implications for carbon and nutrient cycling in the east Taiwan Strait, using DOC, absorption spectroscopy, and fluorescence excitation-emission matrices-parallel factor analysis (EEM-PARAFAC). The study area was dominated by the waters from the South China Sea during the sampling period in summer 2013. The dynamics of DOM were influenced strongly by microbial activities, as indicated by the close correlations (the absolute value of r: 0.75–0.97, $p < 0.001$) between apparent oxygen utilization (AOU) and DOM parameters, including DOC, the absorption coefficient at 280 nm, the fluorescence intensity of protein-like component C3, and the humification index HIX. The contribution of DOC degradation to the net increase in DIC was approximately 15% and 21% in the north and the south of the east Taiwan Strait, respectively. The DIC was correlated negatively with protein-like fluorescence, revealing the production of DIC by the microbial degradation of labile components. The DIC was correlated positively with humic-like fluorescence and HIX, suggesting that the storage of carbon by produced refractory humic substances could not compensate for the release of DIC in the deeper waters. The correlations of nutrients with DOM parameters were similar to those of DIC, further indicating the profound impacts of the dynamics of labile DOM on nutrient cycling.

1. Introduction

Dissolved inorganic and organic carbons (DIC and DOC) are two of the largest pools of carbon in the ocean (~38,000 and ~662 Gt, Hansell and Carlson, 2015). The conversion between these two pools is critical to the global carbon cycle and climate change (Jiao et al., 2010; Ridgwell and Arndt, 2015), and influences the aquatic ecosystem via associated nutrient cycling (Stedmon et al., 2007). Therefore, the mechanisms that underlie changes in the DIC and DOC pools in the ocean should be investigated. In particular, DOC is bound within dissolved organic matter (DOM), which is a complex mixture of thousands of organic compounds with various chemical compositions and biogeochemical reactivities (Hansell et al., 2009; Flerus et al., 2012; Catalá et al., 2015). Absorption spectroscopy and fluorescence excitation-emission matrices-parallel factor analysis (EEM-PARAFAC) provide a series of indices for the quantity and quality of DOM (Stedmon et al., 2003; Helms et al., 2008; Huguet et al., 2009; Kowalczuk et al., 2009; Yang et al., 2012, 2013a). These methods have the potential to provide insights into the different roles of DOM components in the conversion between DOC and DIC. However, limited information on the relationships between DIC and DOM optical parameters is available.

The Taiwan Strait is located between Taiwan Island and southeast China, and is the only channel that directly connects the South China Sea to the East China Sea, which are the largest and the 11th

* Corresponding author. Department of Oceanography, National Sun Yat-sen University, Kaohsiung 804, Taiwan, ROC.
E-mail address: ctchen@mail.nsysu.edu.tw (C.-T.A. Chen).

http://dx.doi.org/10.1016/j.ecss.2016.06.021
0272-7714/

largest marginal seas in the world, respectively (Fig. 1). The seawater transport, biogeochemistry and ecosystem in the Taiwan Strait are of great interest to many researchers (Hu et al., 2010; Hong et al., 2011). Recently, a few studies have used absorption and fluorescence spectroscopy to study DOM in the west and middle Taiwan Strait (Du et al., 2010; Lin et al., 2012; Guo et al., 2012). In contrast, the biogeochemistry and environmental effects of DOM in the east Taiwan Strait are largely unknown, even though seawater transport in the Penghu Channel in the southeast Taiwan Strait and the intrusion of Kuroshio off northeast Taiwan provide two major seawater flows in the region (Liu et al., 1992; Chen et al., 1995; Hu et al., 2010; Hong et al., 2011; Huang et al., 2015).

Therefore, this study will (1) elucidate the spatial changes in the quantity and quality of DOM in two typical sections of the east Taiwan Strait, using DOC, absorption spectroscopy, and fluorescence EEM-PARAFAC; (2) identify the mechanisms that govern the DOM dynamics in the study area, by testing the correlations between DOM indices and basic biogeochemical parameters; and (3) reveal the effects of DOM dynamics on carbon and nutrient cycling, based on the relationships between DOM indices and DIC/nutrients.

2. Materials and methods

2.1. Collection of samples and measurement of basic biogeochemical parameters

Water samples were collected using Niskin bottles from two typical sections in the east Taiwan Strait (Fig. 1). The south section (stations S1-S6) was located south of the Penghu Island, where water depths range from 45 to 143 m. The north section spanned the region from the station N1 at the shelf break to station N6 in the middle of the Taiwan Strait, and the water depth in this section was 72–232 m. The south section was sampled at three to four depths during the cruise ORIII-1698 on July 2nd–3rd, 2013, and the north section was sampled at four to seven depths during the cruise ORII-1953 on July 7th–8th, 2013.

Salinity (S) and temperature (θ) were measured *in-situ* using a CTD (conductivity-temperature-depth/pressure) profiling system (Sea-Bird Electronics Inc., USA). Nitrate plus nitrite ($NO_3^- + NO_2^-$), phosphate (PO_4^{3-}), and silicate (SiO_2) concentrations were measured using the pink azo dye, molybdenum blue, and silicomolybdenum blue methods, respectively (Chen and Wang, 2006, and references therein). Dissolved oxygen (DO) was measured by spectrophotometry (Pai et al., 1993), and the apparent oxygen utilization (AOU) was calculated based on the oxygen solubility equation (Chen, 1981). Chlorophyll *a* (Chl. *a*) was extracted using acetone (90%) and its concentration was determined by measuring fluorescence at the excitation/emission wavelength of 428/668 nm, using Chl. *a* from Anacystis nidulans algae (Sigma-Aldrich) as the calibration standard (Yang et al., 2013a). The DOC was measured using the high-temperature catalytic oxidation method after inorganic carbon was removed by acidification and oxygen purging, using a high TOC II analyzer (Elementar, Germany, Yang et al., 2012; 2013a). The DIC was measured with the coulometric method using a single operator multi-parameter metabolic analyzer (SOMMA) and a coulometric detector (model 5011 from UIC, Coulometrics, Inc.) (Chen and Wang, 2006). The normalized DIC (NDIC) was

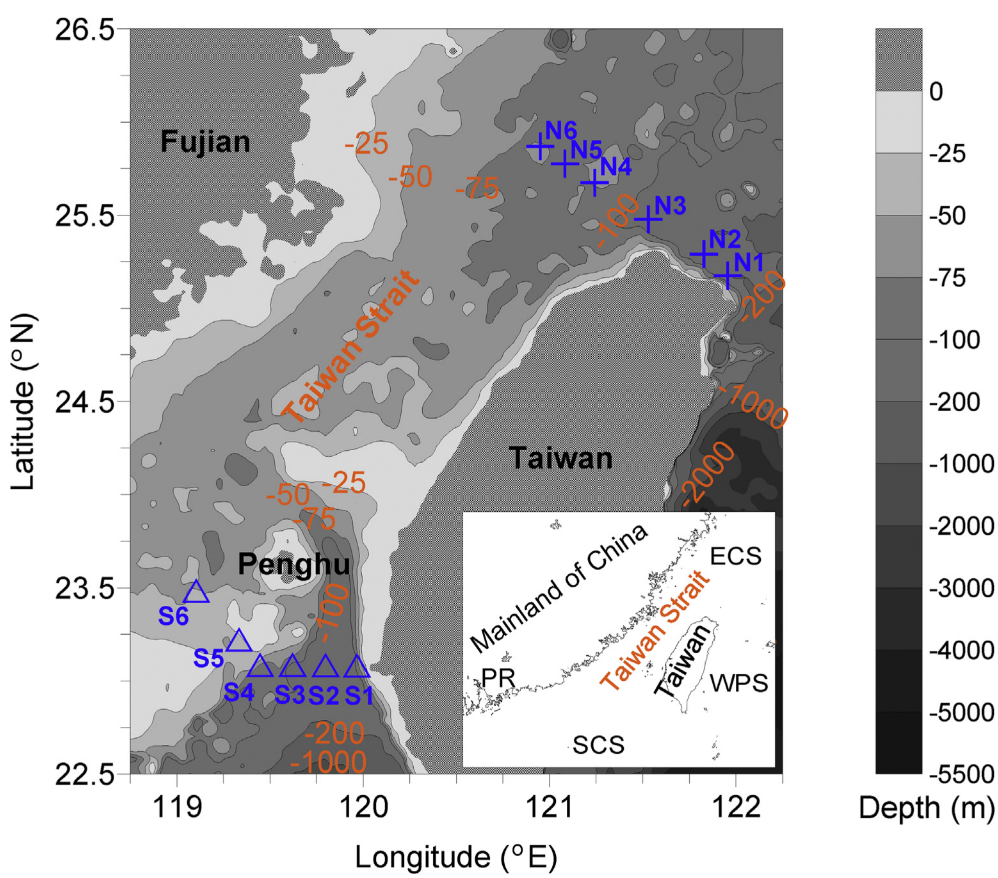

Fig. 1. Study area and sampling stations, with the inserted panel showing the adjacent seas (SCS: South China Sea; ECS: East China Sea; WPS: West Philippine Sea) and the Pearl River (PR).