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Impacts of burial by sediment on decomposition and heavy metal concentrations of *Suaeda salsa* in intertidal zone of the Yellow River estuary, China

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ABSTRACT

Three one-off burial treatments were designed in intertidal zone of the Yellow River estuary to determine the effects of sediment burial on decomposition and heavy metal levels of *Suaeda salsa*. Sediment burial showed significant effect on decomposition rate of *S. salsa*. With increasing burial depth, Cu, Zn, Cd and Co levels generally increased, while Cr and Mn levels decreased. Except for Zn, Mn, Cd and Co, stocks of Pb, Cr, Cu, Ni and V in *S. salsa* among burials were greatly different. The *S. salsa* in three burials was particular efficient in binding V and Co and releasing Pb, Zn and Cd, and, with increasing burial depth, stocks of Cr, Cu, Ni and Mn shifted from accumulation to release. In future, the eco-toxic risk of Pb, Cr, Cu, Zn, Ni, Mn and Cd exposure might be serious as the strong burial episodes occurred in *S. salsa* marsh.

1. Introduction

Heavy metal has become one of the most serious pollutants in coastal regions due to their toxicity, persistence in natural conditions and ability to be incorporated into food chains (Idaszkin et al., 2014; Pejman et al., 2015). Pant detritus may be a sink of metals if, during decomposition, metals could be bound to the litter by passive sorption onto organic surfaces or by physiological mechanism of microbial colonizers. Also, plant detritus may act as a metal source as microbial activity mobilizes metals or as it becomes available to deposit feeders (Weis and Weis, 2004; Lu et al., 2016). Litter decomposition in intertidal zone is generally exposed to many extreme conditions such as frequent ebb and flow of tide, inundation by seawater and burial in sediment (Maun, 1998; Deng et al., 2008). Among them, sediment burial has been recognized as a major selective force affecting the decomposition rate of litters in coastal marsh (Vargo et al., 1998; Mou and Sun, 2011). Sediment burials can result in the litters being buried within the sediment to different extent, which significantly influence the processes of material cycle and energy flow in coastal marsh.

Presently, considerable efforts have been carried out to explore the decomposition of plant detritus in coastal lagoons (Scarton et al., 2002; Menéndez, 2009), mangrove swamps (Ramos e Silva et al., 2007; Keuskamp et al., 2015), and estuarine/salt marshes (Menéndez and Sanmartí, 2007; Simões et al., 2011). These studies mainly focus on investigating the nutrient variations in decomposing litters and the key factors on decomposition, while information on the influences of sediment burial on decomposition remains scarce. Moreover, few studies discuss the variations of heavy metals in decomposing litters in coastal marshes (Weis and Weis, 2004; Du Laing et al., 2006; Pereira et al., 2007) and, particularly, information on the impacts of sediment burial on metal variations in decomposing litters is very limited. The related studies in China mainly focus on the mangrove swamps (Chen, 2013; Duan, 2014; Li and Ye, 2014) and the coastal/estuarine marshes (Mou, 2013; Shao et al., 2014) in the tropical and subtropical regions, whereas information on the coastal marshes in the warm temperate regions remains scarce. Particularly, information on metal dynamics in decomposing litters as affected by different sediment burial disturbances is still very lacking.

The Yellow River, located in warm temperate region, is the second largest river in China and, in recent years, approximately 1.68×10^8 tons of sediment is discharged into the estuary and deposited in the slow flowing delta. *Suaeda salsa* is the most prevalent plant in the coastal marsh of the Yellow River estuary. It generally germinates in late April, blooms in July, matures in late September and completely dies in late November (Gu, 1998). As a pioneer plant, it is often affected by the

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sediment of tide physical disturbance, which is generally dependent on the prevailing wind velocities. The annual runoff of the Yellow River reached the maximum of 49.1 billion m^3 in 1983 and then decreased and fluctuated at 20.0 billion m^3 until 1996. Even more serious, the annual runoff was below 10.0 billion m^3 during 1997–2002. Low flows exhibited by the Yellow River resulted in significant decrease in freshwater and sediment input to the estuary and the *S. salsa* marsh presented severely degraded status due to the salinity level over the optimum ecological threshold for the plants (Cui et al., 2008). To restore degraded marsh, the 'flow-sediment regulation project' (FSRP) was initiated by the nation since 2002. Previous studies have indicated that, before the implementation of FSRP, lower concentrations of As and heavy metals were observed in marsh soils (Rui et al., 2008), however, after the regulation, the levels of some heavy metals such as As, Cr, Pb and Cd in the restored marsh were greatly increased compared to the degraded marsh, implying that the metal pollution might become severe (Bai et al., 2012). Moreover, during FSRP, the river flooded *S. salsa* marsh and resulted in the litters being buried within the sediment to a considerable thick, which might significantly affect litter decomposition rate and metal levels in decomposing litters (Mou, 2010). However, little is known about the effects of sediment burial on metal stocks in *S. salsa* marsh of the Yellow River estuary.

In this study, the impacts of sediment burial on heavy metal (Pb, Cr, Cu, Zn, Ni, Mn, Cd, V and Co) levels in decomposing litters of *S. salsa* were explored. Objectives of this paper were *i*) to determine whether sediment burials would have great effects on decomposition rate of *S. salsa*, *ii*) to investigate the variations of metal levels in decomposing litters of different burial treatments, and *iii*) to examine the effects of sediment burials on heavy metal stocks in decomposing litters.

2. Materials and methods

2.1. Study region

The field experiment was carried out in intertidal zone of the Yellow River estuary (Fig. 1), located in the Nature Reserve of Yellow River Delta in Dongying City, Shandong Province, China. The nature reserve is of typical warm temperate monsoon climate with distinctive seasons. Annual evaporation is 1962 mm and annual precipitation is 551.6 mm, with about 70% of precipitation occurring between June and August. The sequence of geomorphic units is complete in intertidal zone, which generally comprises three areas in a seaward direction: river bank (high marsh), middle marsh and low marsh, at the elevations of 2.4– 3.5 m, 1.0– 2.5 m and −1.0– 0.9 m, respectively (Song et al., 2010). The soils are dominated by intrazonal tide soil and the main vegetations include *Phragmites australis*, *S. salsa*, *Triarrhena sacchariflora* and *Tamarix chinensis*. As the most prevalent plant in intertidal zone, *S. salsa* is often distributed in middle marsh, which is generally influenced by sediment deposition of tidal disturbance, bioturbation and FSRP. The annual sediment burial depth in *S. salsa* marsh is about 9– 10 cm and approximately 6– 7 cm occurs from June to July due to the influences of both tidally induced sediment and FSRP (Mou, 2010). The experimental plot was laid in the middle marsh and three subplots were laid in it along the contour line (with the similar elevation).

2.2. Experimental methods

2.2.1. Field decomposition experiment

The standing litters were sampled from *S. salsa* community on 20 March 2008. Each 20 cm × 20 cm litterbag was made of nylon netting

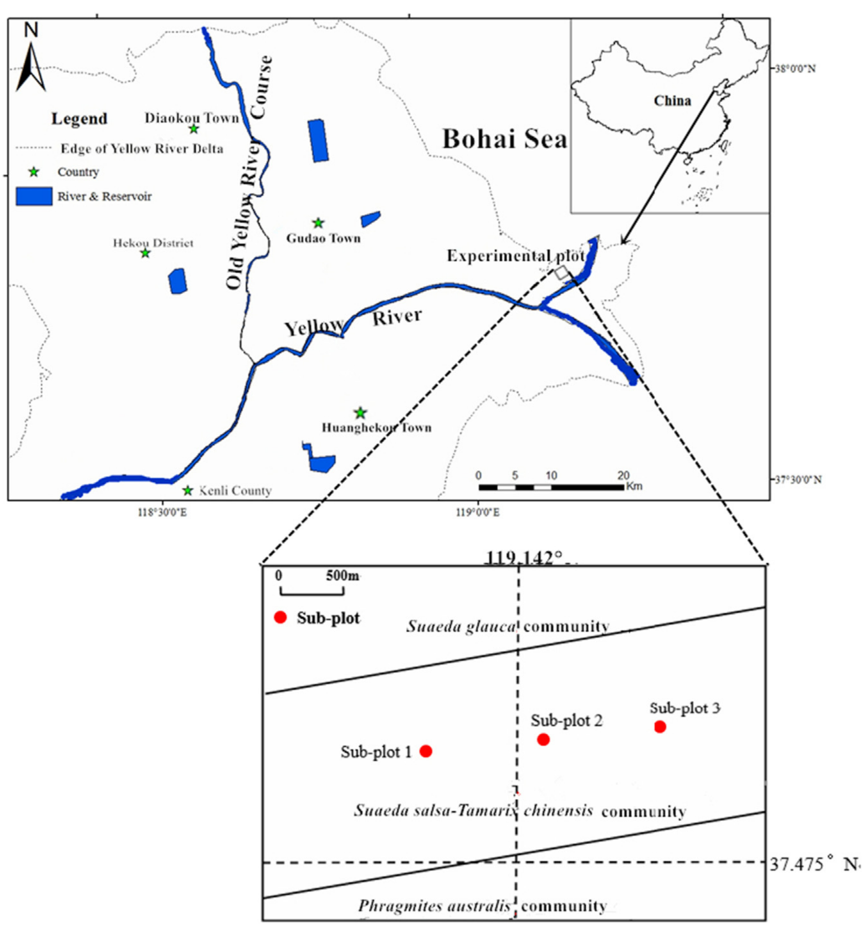

Fig. 1. Sketch of the Yellow River estuary and the experimental sub-plots (red circle). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

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