Change of salt-water dynamics in the Changjiang River estuary and its impacts on soil salinity

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Abstract
Long term field monitoring has been carried out for investigating change of salt-water dynamics in the Changjiang River estuary since late 1990s. Causes of salt-water dynamic change and its impacts on soil salinity are discussed and assessed in the present study. Certain regularities on salt-water dynamic change are found and possible causes of the changes are suggested, based on analyses of the salt-water data during typical years for the estuary. Decrease of the Changjiang River water level in the estuary in recent years was observed compared with that before 2003. Consequently, Electrical conductivity (EC) of the Changjiang water in the estuary increased, especially during autumn period. Electrical conductivity of both branch water of the river and ground water also trended towards increase in the estuary. Soil salinity has similar trends as water salinity in the estuary during the observed period. The Three-Gorges Project (TGP) has started operation and the reservoir water level has progressively increased since 2003. Process of the reservoir running may have certain impacts on change of salt-water dynamics in the estuary, as the coordination relation between the change and the reservoir running are observed. Considering the salt-water dynamics can also be influenced by meteorological and hydrological factors, however, contribution of the Three-Gorges Project on salt-water dynamics and soil salinity in the estuary should still be further quantitatively assessed.

Key Words
Salt-water dynamics, salinity, estuary, Three-Gorges Project, Changjiang River.

Introduction

Study on the impacts of hydropower project on environment has been conducted in some countries, e.g. the environment and social impacts assessment of the Aswan High Dam in Egypt (Abu 1989; Rashad and Ismail 2000), the impacts assessment of Livingston Dam on Trinity River in SE Texas on the dam-to-delta sediment movement (Phillips *et al*. 2004), the impacts assessment of Alqueva Dam on Guadiana River in south Portugal on the water and ecosystem in the Guadiana estuary (Luis *et al*. 2006), the impacts assessment of dams and other man-made structures on Vietnam's Mekong River on the floods and saline water intrusion in Mekong River delta (Le *et al*. 2007). Yangtze River Delta is one of the most important areas in China. With low and flat landform, however, Changjiang River estuary is affected by waterlogging and salinization threats (Xi 1994). Therefore, changes of salt-water dynamics in the Changjiang River estuary under natural and anthropogenic influences should be studied. As the largest hydropower project in the world, the Three-Gorges reservoir's regulation of water storing started in 2003. The reservoir's water level reached 135 m in 2003, 156 m in 2006 and 172 m in 2008. Previous study indicated that the project may have certain impacts on the estuary (Yu and Yang *et al*. 2008). The present paper mainly discusses changes of salt-water dynamics and possible causes of such change in the Changjiang River estuary during recent years.

Methods

Nine monitoring sites of water-salt dynamics are located along the north branch of the Changjiang River's entrance. The water level and EC (ms/cm) of the river water, branch-river water EC, groundwater EC and soil EC have been monitored every 5 day since 1998. The daily data of rainfall (mm) and evaporation (mm) in the estuary have also been collected. Seventeen sites along the north branch of the river's entrance were selected for soil sampling in autumn of each year during 1998-2008. Electrical conductivity and pH of soil extracts of the samples were measured.

Results

Water levels of the Changjiang River during some typical years are shown in Figure 1. Basically, water level of the Changjiang River continuously decreased from 2002 to 2008. Changes of the water level in autumn season were greater those of other seasons, especially during September to November. Annual average water level in 2003, year 2006 and year 2008 were all lower than during 1998-2002. Comparing with average water level during 1998-2002, water level dropped 28 cm in 2008, 25 cm in 2006, and 17 cm in 2003, respectively.

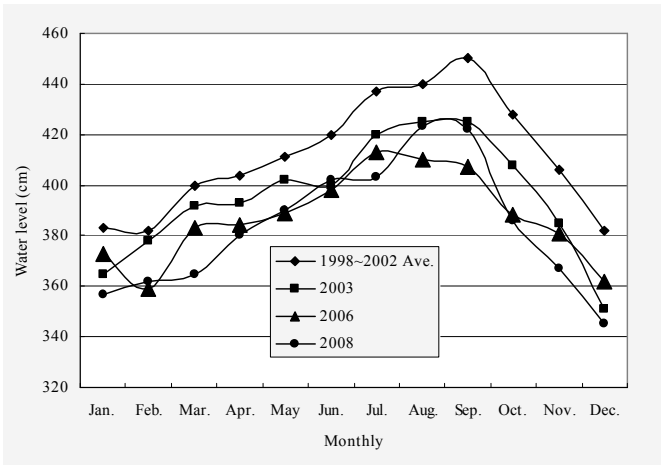

Figure 1. Water levels of the Changjiang River during different years.

Monthly water EC of the Changjiang River in Yinyang during some typical years are shown in Figure 2. Water EC of the Changjiang River showed increasing trends in 2006 and 2008, comparing average water EC during 1998 to 2002. More significant difference of the river water EC during September to October were observed between 1998-2002 and 2006-2008.

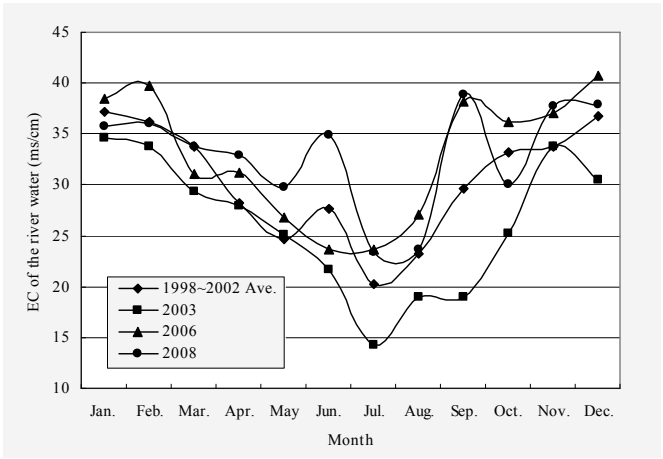

Figure 2. Monthly water EC of the Changjiang River in Yinyang during different years

Monthly water EC of the Changjiang River's branch and ground water EC during different years are listed in table 1 and table 2, respectively. Branch river water EC and ground water EC showed similar trends as the Changjiang River water. The river water EC and ground water EC in 2006 and 2008 had significant increase comparing with those during 1998 to 2002. However, both river water EC and ground water EC decreased in 2003. Soil salinity has similar trends to water salinity in the estuary during the observed period. Soil EC in the Yinyang sample site increased to 1.81 ms/cm in 2008 from 1.07 ms/cm in 2003.

Table 1. Monthly water EC of the Changjiang River's branch at Yinyang during different years (ms/cm)

Water EC of the branch	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
1998-2002 Ave.	2.88	2.79	2.95	3.14	3.13	2.47	1.87	1.55	1.67	2.40	2.97	2.55	2.53
2003	2.21	2.37	2.63	2.76	2.65	2.03	1.81	1.39	1.32	1.55	2.10	4.48	2.28
2006	2.85	2.67	3.16	2.82	2.57	2.25	1.65	2.27	2.70	3.92	4.42	2.81	2.84
2008	3.32	3.00	3.90	4.27	3.61	2.02	1.56	2.06	2.93	2.30	2.31	2.52	2.82

According to the seasonal regulation mode of the TGP (Cai *et al*. 1997), the reservoir maintains different water level by discharge during different months. At the end of flood season (October), the reservoir starts of water storing for winter electricity generation and discharge water is reduced, which may induce a decrease of river water level and may enhance seawater intrusion in the estuary during autumn. Greater increases of water and soil EC were observed in 2006 and 2008, which correspond to the reservoir's regulation processes. It may be suggested that the Three-Gorges reservoir operating may have certain impacts on change of salt-water dynamics and soil salinity in the estuary. Autumn is the major reservoir regulation season and the estuarine high-tide season. Therefore, the study of salt-water dynamics in the Changjiang River estuary and

its impacts on soil salinity should be further focused in autumn. Besides Three-Gorges reservoir regulation, changes of salt-water dynamics in the estuary are also affected by other meteorological and hydrological factors. Contribution of the Three-Gorges Project to salt-water dynamics and soil salinity in the estuary should still be further quantitatively assessed.

Table 2. Monthly ground water EC during different years (ms/cm).

Ground water EC	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
1998-2002 Ave.	2.90	2.74	2.04	2.42	2.45	1.44	2.04	2.38	2.87	2.80	3.30	3.33	2.56
2003	3.34	2.63	1.75	1.75	1.70	2.00	1.69	2.03	2.50	2.75	3.02	3.06	2.35
2006	1.32	2.41	2.81	2.65	2.79	2.36	1.15	3.64	3.35	3.93	3.14	3.69	2.77
2008	3.36	1.65	3.11	3.30	3.60	1.72	1.74	3.04	2.91	3.81	3.55	3.64	2.95

Conclusion

The water level of the Changjiang River decreased in the estuary recent years, compared with the level before 2003. Electrical conductivity (EC) of the Changjiang water in the estuary increased, especially during the autumn period. Electrical conductivity of both branch water of the river and ground water also increased in the estuary. Soil salinity had similar trends to water salinity in the estuary during the observed period. Operation of the Three-Gorges reservoir may impact on salt-water dynamics in the estuary. Salt-water dynamics can also be influenced by meteorological and hydrological factors, however, impacts of the Three-Gorges Project on salt-water dynamics and soil salinity in the estuary should be further quantitatively assessed.

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