Pollution Issues and Prevention and Control Measures in China' s Coastal Zones: Postprint

Authors: Lü Jian, Luo Yongming, Zhang Haibo

Date: 2016-11-04T00:00:00+00:00

Abstract

In recent years, China' s coastal zones have been subjected to varying degrees of pollution, which has affected their development. This article addresses the current status, causes, international management practices, and prevention and control measures of coastal zone pollution in China, briefly introducing the distribution of pollutants across different media in these regions. It proposes prevention and control measures including pollution source control, ecological barrier construction, ecological restoration of polluted environments, and regional planning, aiming to provide insights for the formulation of environmental protection and management policies in China' s coastal zones.

Full Text

Feature: Coastal Science and Sustainable Development

Coastal Zone Pollution and Its Prevention and Treatment Measures in China

Lü Jian, Luo Yongming, Zhang Haibo
Yantai Institute of Coastal Zone Research, Chinese Academy of Sciences, Yantai 264003, China

Abstract

In recent years, China' s coastal zones have experienced varying degrees of pollution, affecting regional development. This article addresses the current pollution status, causes, international management practices, and prevention and treatment measures for China' s coastal zones. It provides an overview of pollutant distribution across different coastal media and proposes measures including pollution source control, ecological barrier construction, ecological restoration of

polluted environments, and regional planning, aiming to inform environmental protection and management policy development for China' s coastal zones.

Keywords: coastal zone, current pollution situation, prevention and treatment
DOI: 10.16418/j.issn.1000-3045.2016.010.006

Coastal zones are densely populated and economically developed, with over half of the world' s population living within approximately 60 km of the coast, making them an extremely important Earth critical zone for human societal development. As human activities intensify, large quantities of pollutants are discharged into coastal zones through various pathways. Environmental pollution caused by high-intensity human activities has led to functional degradation of this critical Earth zone. Therefore, investigating the current pollution status of China' s coastal zones and proposing rational and effective pollution control strategies are crucial for ensuring coastal ecological security, protecting public health, and maintaining sustainable development in coastal regions. This paper elaborates on the current pollution status, causes, international management practices, and prevention and treatment measures for China' s coastal zones, aiming to provide effective and feasible ideas for coastal environmental protection and management.

1.1 Current Status of Conventional Pollutant Pollution

Nutrients, petroleum substances, and heavy metals are the primary conventional pollutants currently affecting water and soil quality in China' s coastal zones. According to data from recent environmental status bulletins, severely eutrophic waters in recent years have been concentrated mainly in nearshore areas such as Liaodong Bay, the Yangtze River Estuary, Hangzhou Bay, and the Pearl River Estuary [1-3], with eutrophication triggering periodic outbreaks of *Enteromorpha* prolifera (Figure 1 [Figure 1: see original paper]).

Inorganic nitrogen and active phosphate are distributed mainly in nearshore areas including the Yangtze River Estuary, Hangzhou Bay, the coast of Zhejiang, and the Pearl River Estuary, while petroleum substances are found primarily in nearshore areas such as Liaodong Bay, the coast of Guangdong, Laizhou Bay, and Taizhou Bay [2,3]. In coastal sediments, copper, sulfides, and arsenic at individual monitoring sites exceed standard limits [3]; heavy metal concentrations are relatively high in sediments from nearshore areas including Jinzhou Bay, Jiaozhou Bay, Hangzhou Bay, the Yangtze River Estuary, Lianyungang, Hainan, Hong Kong, and the Pearl River Estuary [4,5]. In 2015, red tide occurrences reached their lowest level in five years, with 35 incidents detected and total affected area reduced by 2,835 km^2 [3].

Funding: Hundred Talents Program of Chinese Academy of Sciences (Y629041021), Key and General Projects of National Natural Science Foundation of China (41230858, 41671319), Key Laboratory Project of CAS

for Coastal Environmental Processes and Ecological Remediation (1189010002). Received: September 2016.

1.2 Current Status of Persistent Organic Pollutant Pollution

Persistent organic pollutants (POPs) have long attracted widespread attention due to their environmental persistence, bioaccumulation potential, and strong biological toxicity. POPs have been detected in water, sediments, coastal soils, and aquatic organisms throughout China' s coastal zones (Table 1). Concentrations of organochlorine pesticides and polychlorinated biphenyls (PCBs) in coastal nearshore waters reach maximum levels of 854 ng/L and 476.9 ng/L, respectively—tens or even hundreds of times higher than in coastal waters of other global regions. Correspondingly, concentrations of organochlorine pesticides and PCBs in coastal sediments are also significantly higher than elsewhere globally, with maximum concentrations reaching 7,350 μg/kg and 169.26 μg/kg, respectively. Polycyclic aromatic hydrocarbon (PAH) concentrations in coastal sediments are significantly higher than in the United States and other Asian countries and regions, but lower than in Europe.

Table 1 Pollution status of persistent organic pollutants in coastal zones of typical countries and regions worldwide

1.3 Current Status of Emerging Pollutant Pollution

Research on emerging pollutant pollution in coastal zones primarily involves endocrine disrupting chemicals (EDCs), microplastics, pharmaceuticals and personal care products (PPCPs), perfluorinated compounds, and brominated flame retardants. As shown in Table 2 , concentrations of pharmaceuticals/antibiotics in China' s coastal waters and sediments are significantly higher than in other countries and regions; EDC concentrations are comparable to or lower than other regions, but EDC concentrations in rivers entering the sea can be as high as 28,600 ng/L, representing an important pollution source. Concentrations of brominated compounds and microplastics in coastal sediments are lower than in other Asian countries/regions and Europe; perfluorinated compound concentrations in water are comparable to Europe and lower than other Asian countries/regions. Overall, emerging pollutant pollution in China' s coastal zones warrants greater attention, particularly antibiotic pollution, while other pollutants including microplastics should not be neglected (Figure 2 [Figure 2: see original paper]).

2 Analysis of Causes of Coastal Zone Pollution

China' s coastal zones support multiple functions including urbanization, port and coastal industrial zone construction, oil and gas development, and aquaculture, leading to resource overexploitation and intensified unhealthy spatial competition. Rapid urbanization and port/coastal industrial park construction have caused pollutant emissions to increase dramatically, placing greater pressure on coastal environmental carrying capacity. China' s coastal urbanization rate has increased by more than one percentage point annually. According to investigation reports from the State Oceanic Administration, the Penglai 19-3 oilfield spill accident contaminated approximately 6,200 km^2 of seawater in areas surrounding and northwest of the Penglai 19-3 oilfield.

China is a major aquaculture nation. Since 1992, China' s total marine product output has consistently ranked first globally, reaching 9.34 million tons in 1992, including 2.42 million tons from marine aquaculture. According to projections, China' s aquaculture output will exceed 40 million tons by 2020, with increased production depending primarily on marine aquaculture. The rapidly developing marine aquaculture industry has imposed enormous impacts on coastal wetlands, nearshore waters, and other coastal environments, becoming an important pollution source in nearshore areas.

Coastal wetlands serve as the most important ecological barrier for intercepting pollutants in coastal zones. However, protection of coastal wetlands in China is typically subordinated to economic development and regional growth. Over the past 50 years, China has lost 53% of its temperate coastal wetlands, 73% of its mangroves, and 80% of its coral reefs. This loss of coastal wetlands has caused a sharp decline in the self-purification capacity of coastal zones.

2.2 Unreasonable Regional Industrial Structure and Increasing Total Pollution Emissions

The characteristics of low-end, resource- and energy-intensive industrial structures in China' s coastal zones have not fundamentally changed. Marine development and utilization remain extensive, and the situation of low-quality, inefficient, and low-benefit resource exploitation persists. Coastal industrial park construction predominantly involves "heavy," "land-intensive," and "pollution-intensive" enterprises, with relatively few tertiary industry establishments. High-energy-consumption, high-pollution projects inevitably intensify resource and environmental pressures on coastal zones, causing atmospheric, water, and soil pollution. Over the past decade, wastewater, waste gas, and solid waste emissions in southeast coastal regions have increased by 60%, 120%, and 190%, respectively, posing serious threats to coastal environmental quality.

Marine aquaculture in China remains primarily extensive, resulting in widespread direct discharge of wastewater from aquaculture operations and

zones.

2.3 Prominent Cross-Administrative Region Characteristics and Difficulties in Monitoring and Governance

Rivers constitute the primary input source of pollutants to coastal seas. According to surveys, land-based pollutants account for 87% of total pollutants entering the Bohai Sea, with pollutants discharged through estuaries representing 95% of land-based pollutants. Among China' s rivers entering the sea, those flowing into the Pacific, Indian, and Arctic Oceans cover approximately 65.2% of China' s total land area. This vast watershed area encompasses numerous administrative divisions. Additionally, China' s coastline extends from the Yalu River estuary at the China-Korea border in the north to the Beilun River estuary at the China-Vietnam border in the south, with a total length of approximately 18,100 km. These factors substantially increase the difficulty of monitoring and governing coastal zone pollution.

2.4 Weak Environmental and Legal Awareness, Inadequate Science and Technology, Unable to Meet Regional Sustainable Development Planning and Administrative Regulation Needs

Weak environmental and legal awareness has led to prominent problems of exceeding-standard discharge into the sea and direct sewage discharge in coastal areas. In November 2013, China's marine environmental monitoring department monitored 156 land-based sewage outfalls, finding that half discharged sewage exceeding standards into adjacent sea areas. According to information from the Guangxi Environmental Protection Department, the coastal cities of Qinzhou, Beihai, and Fangchenggang discharge over 30 million tons of untreated sewage directly into the sea annually.

Regional sustainable development planning and administrative regulation for coastal zones require in-depth understanding of coastal processes and cultivation of relevant scientific research personnel. China' s coastal zone discipline development started late, with insufficient research investment and weak scientific foundations. The country lacks scientific and technical personnel and training institutions in coastal zone disciplines, and scientific innovation provides inadequate guidance and support for coastal zone development and utilization. These limitations restrict national decision-making capabilities in regional sustainable development planning and administrative regulation for coastal zones, causing blind regional development and consequent environmental pollution problems.

3 International Coastal Zone Management Practices

The United States is one of the earliest countries to conduct coastal zone planning and management. In 1972, the U.S. Congress passed the Coastal Zone Management Act (CZMA), revised in 2000, covering coastal habitats and biodiversity, hazards, water quality, dependent uses, public access, and community development [25]. The U.S. emphasizes cooperative management between federal and state governments in coastal zone management, essentially implemented by coastal states and local governments, while actively developing coastal environmental assessment programs using multi-agency data .

The European Union initiated coastal zone management pilot projects in 1996, establishing corresponding indicators for sustainable coastal development, and has recently shifted focus toward "land-sea coordination" in integrated coastal zone management, emphasizing coordinated development of various activities in coastal zones [26, 27].

The Asia-Pacific region, with its long coastlines and vast coastal zones, has consistently emphasized coastal environmental management, particularly strengthening coastal management legislation and comprehensive practices since 1995. Asia-Pacific countries and regions adopt Integrated Coastal Zone Management (ICZM) as their basic concept, gradually developing multi-level management practices including coastal vulnerability assessment, embedding advanced assessment and management methods in traditional coastal systems, and intra-governmental and inter-governmental cooperation [28].

In addition to governments and the United Nations, non-governmental organizations such as Future Earth Coasts (FEC), Mangrove Action Project (MAP), and The Nature Conservancy (TNC) also play important roles in coastal zone management.

https://www.epa.gov/national-aquatic-resource-surveys/national-coastal-condition-reports

---

4 Suggestions for Coastal Zone Pollution Prevention and Treatment Measures in China

---

4.1 Pollution Source Control

Pollution source control is the most effective and economical prevention and treatment measure for coastal zone pollution. Land-based and sea-based sources are the two major pollution sources, with land-based pollution—primarily from river input, sewage discharge, and agricultural non-point sources—dominating. Pollution source control should coordinate both land and sea.

For land-based pollution control: (1) Advocate for green production-oriented industrial layout in policy, actively promote clean production technologies, and eliminate technologically backward, heavily polluting enterprises; (2) Strengthen centralized sewage treatment and total quantity control, calculate environmental capacity of sea-entering rivers and marine areas based on pollutant concentrations and distribution, and reasonably establish pollution acceptance capacity and non-point source pollutant reduction targets for each sea area; (3) Emphasize and strengthen effective control of agricultural non-point source pollution, promote rational application technologies for pesticides and fertilizers to improve utilization efficiency, and develop environmentally friendly pesticides and fertilizers; (4) Effectively monitor all land-based pollution sources, strengthen regional pollution prevention and control coordination, enhance environmental monitoring, and gradually establish a comprehensive coastal zone environmental monitoring and management system to strengthen environmental monitoring and early warning capabilities.

For sea-based pollution control: (1) Effectively monitor offshore oil and gas platforms, vessels, and port-adjacent industries, strictly control pollutant emissions, establish emergency response mechanisms and contingency plans for sudden pollution incidents (such as oil spills), and develop and gradually improve real-time offshore pollution monitoring, emergency monitoring, and corresponding information support systems; (2) Strengthen dynamic tracking and monitoring of offshore dumping activities, strictly control total dumping quantities, increase law enforcement against dumping activities, regularly assess environmental quality of dumping areas, and establish and improve offshore dumping monitoring and management systems; (3) Rationally plan and manage nearshore aquaculture activities, promote and encourage ecological aquaculture, strictly monitor seedling, feed, and drug inputs, promote development of environmentally friendly feeding drugs, and plan and implement environmental monitoring and ecological restoration projects for nearshore aquaculture zones.

4.2 Ecological Barrier Construction

Coastal zone ecological barriers currently consist primarily of coastal shelterbelts and coastal wetlands, functioning mainly to improve coastal ecological environments, resist natural disasters, intercept land-based pollutants, improve soil (particularly saline-alkali soil) habitats, and conserve water sources. Construction of coastal ecological barriers will have considerable potential for preventing and controlling pollution caused by nutrients and heavy metals in coastal zones. For example, typical coastal wetlands (such as tropical mangroves) can effectively reduce heavy metal inputs into soils and oceans.

4.3 Ecological Restoration Technical Measures for Coastal Zone Polluted Environments

Microbial remediation plays an important role in coastal zone pollution treatment, particularly for petroleum and pesticide contaminated environments. Microbial degradation of organic pollutants offers advantages of high efficiency, low cost, and no secondary pollution.

Phytoremediation of coastal zone polluted environments is achieved primarily through cultivation of salt-tolerant and marine plants. Currently identified salt-tolerant plants with strong pollutant absorption and degradation capabilities include *Salicornia*, *Suaeda*, reed, Jerusalem artichoke, and oil sunflower. Marine plants usable for pollution remediation are mainly seagrass and macroalgae. Macroalgae are more commonly used in nearshore aquaculture, particularly co-cultivation in fish farming areas, effectively absorbing N and P nutrients while improving aquaculture economic benefits. Seagrass has high heavy metal absorption capacity and shows potential for heavy metal pollution remediation in coastal zones.

Compared with bioremediation methods, photodegradation has advantages of fewer limiting conditions and wider application range, and is considered an effective method for degrading and removing pollutants in coastal nearshore waters and soils.

4.4 Regional Scientific Planning for Sustainable Development

Future coastal zone development requires transforming economic growth patterns, strengthening regional scientific planning, promoting industrial structure adjustment, and paying close attention to regional environmental quality and protection issues, with emphasis on regional development and environmental regulation formulation. Taking the national "Belt and Road" strategy as an opportunity, China should vigorously develop the "blue carbon economy" [29]. Coastal zone scientific development should be incorporated into government performance assessment, implementing sustainable development strategies and ecological compensation mechanisms. Meanwhile, basic science and key technology research in coastal zone disciplines should be strengthened, along with research investment and personnel training. Through these multiple measures, China can achieve stable, safe, and healthy sustainable development of its coastal zones.

References

1. Ministry of Environmental Protection. 2014 China Environmental Quality Status Bulletin. Beijing, 2015.
2. State Oceanic Administration. 2014 China Marine Environmental Status Bulletin. Beijing, 2015.

3. State Oceanic Administration. 2015 China Marine Environmental Status Bulletin. Beijing, 2016.
4. Pan K, Wang W X. Trace metal contamination in estuarine and coastal environments in China. Science of the Total Environment, 2012, (421-422): 3-16.
5. Gao A G, Wang W X. Heavy metal contamination in estuarine and coastal areas of South China: A review. Marine Pollution Bulletin, 2013, 76: 7-15.
6. Bao L J, Maruya K A, Snyder S A, et al. China' s water pollution by persistent organic pollutants. Environmental Pollution, 2012, 163: 100-108.
7. Xu E G, Bui C, Lamerdin C, et al. Spatial and temporal assessment of environmental contaminants in water, sediments and fish of the Salton Sea and its two primary tributaries, California, USA, from 2002 to 2012. Science of the Total Environment, 2016, 559: 130-140.
8. Wurl O, Obbard J P. Chlorinated pesticides and PCBs in the sea-surface microlayer and seawater samples of Singapore. Marine Pollution Bulletin, 2005, 50: 1233-1243.
9. Castro-Jiménez J, Deviller G, Ghiani M, et al. PCDD/F and PCB multimedia ambient concentrations, congener patterns and occurrence in a Mediterranean coastal lagoon (Etang de Thau, France). Environmental Pollution, 2008, 156: 123-135.
10. Lin T, Hu Z, Zhang G, et al. Levels and Mass Burden of DDTs in Sediments from Fishing Harbors: The Importance of DDT-Containing Antifouling Paint to the Coastal Environment of China. Environmental Science & Technology, 2009, 43(21): 8033-8038.
11. Pan S, Kadokami K, Li X, et al. Target and screening analysis of 940 micro-pollutants in sediments in Tokyo Bay, Japan. Chemosphere, 2014, 99: 109-116.
12. Zhao Q, Bai J, Lu Q, et al. Polychlorinated biphenyls (PCBs) in sediments/soils of different wetlands along 100-year coastal reclamation chronosequence in the Pearl River Estuary, China. Environmental Pollution, 2016, 213: 860-869.
13. Li X, Hou L, Li Y, et al. Polycyclic aromatic hydrocarbons and black carbon in intertidal sediments of China coastal zones: Concentration, ecological risk, source and their relationship. Science of the Total Environment, 2016, 566-567: 1387-1397.
14. Culotta L, De Stefano C, Gianguzza A, et al. The PAH composition of surface sediments from Stagnone coastal lagoon, Marsala (Italy). Marine Chemistry, 2006, 99: 117-127.
15. Wang T, Lu Y, Chen C, et al. Perfluorinated compounds in estuarine and coastal areas of north Bohai Sea, China. Marine Pollution Bulletin, 2011, 62: 1905-1914.
16. Chen H, Liu S, Xu X R, et al. Antibiotics in the coastal environment of the Hailing Bay region, South China Sea: Spatial distribution, source analysis and ecological risks. Marine Pollution Bulletin, 2015, 95: 365-373.
17. Klosterhaus S L, Grace R, Hamilton M C, et al. Method validation and re-

connaissance of pharmaceuticals, personal care products, and alkylphenols in surface waters, sediments, and mussels in an urban estuary. Environment International, 2013, 54: 92-99.
18. Moreno-González R, Rodriguez-Mozaz S, Gros M, et al. Seasonal distribution of pharmaceuticals in marine water and sediment from a mediterranean coastal lagoon (SE Spain). Environmental Research, 2015, 138: 326-344.
19. Bayen S, Estrada E S, Juhel G, et al. Pharmaceutically active compounds and endocrine disrupting chemicals in water, sediments and mollusks in mangrove ecosystems from Singapore. Marine Pollution Bulletin, 2016, 109: 716-722.
20. Wang T, Lu Y, Chen C, et al. Perfluorinated compounds in estuarine and coastal areas of north Bohai Sea, China. Marine Pollution Bulletin, 2011, 62: 1905-1914.
21. Pico Y, Blasco C, Farré M, et al. Occurrence of perfluorinated compounds in water and sediment of L' Albufera Natural Park (València, Spain). Environmental Science and Pollution Research, 2012, 19: 946-957.
22. Pan S, Kadokami K, Li X, et al. Target and screening analysis of 940 micro-pollutants in sediments in Tokyo Bay, Japan. Chemosphere, 2014, 99: 109-116.
23. Vane C H, Ma Y J, Chen S J, et al. Increasing polybrominated diphenyl ether (PBDE) contamination in sediment cores from the inner Clyde Estuary, UK. Environmental Geochemistry and Health, 2010, 32: 13-21.
24. Zhou Q, Zhang H B, Li Y, et al. Microplastic pollution in coastal environments and its ecological effects. Chinese Science Bulletin, 2015, 60: 3210-3220.
25. U.S. Congress. Coastal Zone Management Act (as amended through P.L. 106-580, 2000). Washington D.C.: USA Congress, 1972 & 2000.
26. Deboudt P, Dauvin J C, Lozachmeur O. Recent developments in coastal zone management in France: The transition towards integrated coastal zone management (1973–2007). Ocean & Coastal Management, 2008, 51(3): 212-228.
27. Sorensen J. The international proliferation of integrated coastal management efforts. Ocean & Coastal Management, 1993, 21: 45-80.
28. Harvey N (eds). Global Change and Integrated Coastal Management: The Asia-Pacific Region. Netherland: Springer, 2006: 39-58.
29. Science Net. "Belt and Road" strategy and "Blue Carbon Economy" . [2016-7-28]. http://news.sciencenet.cn/htmlnews/2015/3/316107.shtm

---

Lü Jian is a professor and Ph.D. supervisor at the Yantai Institute of Coastal Zone Research, Chinese Academy of Sciences. He serves as the coordinator of the East Asia Node of the International Future Earth Coasts (FEC) Project and is a committee member of the IWA Specialist Group on Pretreatment of Industrial Waste Waters. His research focuses on coastal water resources and environment. Dr. Lü has headed or participated in more than 10 national and

international research projects funded by the Hundred-Talent Program of CAS, National Natural Science Foundation of China, American National Food and Agriculture Research Institute (NIFA), the National Water Pollution Control and Treatment Science and Technology Major Project, and the CAS Key Laboratory Research Program.
E-mail: jlu@yic.ac.cn

Note: Figure translations are in progress. See original paper for figures.