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Greening Chinese chemical industrial park by implementing industrial ecology strategies: A case study

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ABSTRACT

China has witnessed a rapid development of the chemical industry and has become the largest chemicals producing country in the last decade, where more than 45% of the companies above designated-size have been clustered into a large number of chemical industrial parks. Greening the development of chemical industrial parks in China is crucial to local environment and has long been a big challenge. Deploying industrial ecology strategies in chemical industrial park will enhance both economic and environmental performances. This study reviewed the eco-industrial development in the Shanghai Chemical Industrial Park (SCIP) and its performance. SCIP is a newly established industrial park producing petrochemicals and downstream fine chemicals and is considered as a hallmark of the chemical industrial parks in China, in regards to eco-industrial development from the scratch and its good economic and environmental performances. The key lessons drawn from SCIP are as follows: (1) Its design and construction complies with a top-down and environmentally friendly pattern in line with industrial ecology strategy by integrating upstream and downstream chemicals, utilities and infrastructure, logistics, safety and environmental management, and public services within the park holistically, (2) SCIP created a vertically integrated chemicals manufacturing network, from naphtha to polymers, to extend the value chain as much as possible, via the geographical proximity of upstream-downstream linkage and economy of scale, (3) A delicately designed infrastructure and utility symbiotic network, logistic system, and 24-7 online safety and environmental management system sustained the food web efficiently. The implementation of top-down eco-industrial development planning and rich experience cumulated thereof in SCIP will be a benchmark and enlightenment of key factors for facilitating green development of other chemical industrial parks in China.

1. Introduction

China has witnessed a rapid development of the chemical industry and became the largest chemicals producing country since 2010 (UNEP, 2013), and chemical industry has been one of the pillar industries in China. Development of chemical industrial parks has become an efficient way to improve Chinese chemical industry. In 2000, the Chinese government started to regroup chemical firms geographically by establishing chemical industrial parks to improve management of chemical sector. Consequently, in 2004, China Petroleum and the Chemical Industry Federation (CPCIF) established 17 chemical industrial parks (Ding and Hua, 2012). From 2009 to 2013, the number of chemical industrial parks increased from 200 to more than 500 (CPCIF, 2015). In 2014, more than 45% of the chemical companies above the designated size were settled down in CIPs, of which 51 were national level, 279 were provincial level (CPCIF, 2015), and the rest city level. However, clustering chemical production in a park presents both benefits and risks (Ketels, 2007). In regards to benefits, firstly, sharing of centralized infrastructure in a park can improve competitive advantage (Yuan et al., 2010). Secondly, inter-firm collaboration is enhanced due to geographical proximity and business strategy consensus (Felzensztein et al., 2010), which in turn will foster innovation and overall competitiveness. Finally, clustering of the chemical industry allows efficient environmental monitoring and control for local government. Concerning risks, concentrating chemical materials and products potentially increases risks and threats to the environment and human health if environmental, safety, and security

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measures are not adequate (Wang et al., 2012). China has experienced some serious chemical accidents and has been in great need for safe and environmentally friendly development in chemical industrial parks (Duan et al., 2011; Liu et al., 2012a,b; UNEP, 2013).

The Yangtze Delta region, including Shanghai Municipality, Zhejiang, and Jiangsu provinces, is one of the key areas of the chemical industry in China, and Shanghai has long been one of the most important chemical hubs for both the Yangtze Delta region and the whole country since 1983 (Shanghai Statistic Yearbook, 2014). Particularly, after the 1997 Asian financial crisis, the government attached major importance to traditional and labor-intensive industries, including the chemical industry, in this region (Zeng and Bathelt, 2011). The Yangtze Delta region accounts for more than 30% of the overall economic output of the national chemical industry and has developed many chemical industrial parks. However, concerns about environmental issues also arise more and more in this region (Chan et al., 2012; Huang et al., 2011a; Liu et al., 2012a,b; Fu et al., 2013). The CIPs are witnessing daunting challenges in light of resource depletion and environmental deterioration, and the public generally has a negative perception of the chemical industry and chemical industrial parks. More reports on public protests against chemical projects 'not-in-my-backyard' are released especially after the far-reaching public protest against the *p*-xylene (PX) project in Xiamen City in 2007 (The Economist, 2014). However, chemicals are everywhere in our life, and the chemical industry is a strategic pillar industry in the national economy. Thus, greening the development of chemical industrial parks is very crucial to China.

Industrial ecology is a concept that aims to conciliate social progress, environmental preservation, and economic growth by perceiving the industrial system as an ecosystem in which consumption of energy and materials are optimized and where the overall system waste is minimized through notably a food-chain cycle, as observed in nature (Frosch and Gallopoulos, 1989; Graedel, 1996). EIP is an important experimental field in Industrial Ecology, which is defined as "a community of businesses that cooperate with each other and with the local community to efficiently share resources (information, materials, water, energy, infrastructure, and natural habitat), leading to economic benefits, gains in environmental quality, and equitable enhancement of human resources for the business and local community" (Chertow 2000). EIP development is widely considered and there is a large body of publications on practice of EIP development in many countries (see the latest review by Chertow and Park, 2015). The key Industrial Ecology strategies implemented in EIP development include infrastructure sharing, byproduct exchange, inter-firm linkage via supply chain, energy efficiency improvement, eco-design at firm level, and integrated waste management (such as Chertow and Park, 2015; Shi et al., 2010; Tian et al., 2014). Implementing industrial ecology and Eco-Industrial Park concepts in specific sector, such as chemical industrial parks, has been the subject of increasing interest worldwide (Genserik et al., 2013; Taddeo et al., 2012; Casavant and Côté, 2004; Shi et al., 2012) owing to its significantly potential benefits, such as improvement of resources efficiency (Reniers et al., 2010), risk management (Huang et al., 2011b; Li et al., 2010; Ma et al., 2008), as well as expense reduction through utilities and services sharing (Heeres et al., 2004).

Presently, some studies of Chinese chemical industrial parks were reported, such as on measures and potentials of energy saving (Tian et al., 2012a), materials metabolism (Ding and Hua, 2012), and substance flows analysis, including carbon (Tian et al., 2013), sulfur (Tian et al., 2012b; Zhang et al., 2015), and chlorine (Ma et al., 2016; Han et al., 2014), However, less attention has been focused on eco-industrial development of chemical industrial park from the scratch by applying Industrial Ecology strategies and measures systematically. Shanghai Chemical industrial Park (SCIP) is one of such example. SCIP started operation in 2005 and had an ambitious vision to be the hub of Asia's chemical industry and demonstration chemical industrial parks for a win-win-win of economic development, environmental benefits, and safety in production at the very beginning of its construction. SCIP implemented the strategies of industrial ecology through a top-down planning of eco-industrial development (Lowe et al., 2005; Zhang et al., 2009). SCIP had been considered as a hallmark of Chinese chemical industrial parks in regards to eco-industrial development, economic, and environmental performances, and has been approved as a national demonstration Eco-Industrial Park (EIP) in 2013 (MEP, 2014). Thus, a careful review of the eco-industrial development in SCIP is useful for facilitating the eco-transformation of many other Chinese chemical industrial parks in China. It is therefore the purpose of this study to review the key industrial ecology strategies and measures implemented in SCIP towards enabling green development, which will be helpful for developing a model to be deployed in other Chinese chemical industry parks. SCIP is also a good example to examine the practice of facilitating EIP development from top-down planning rather than retrofitting an existing industrial park. The key lessons drawn from SCIP will be meaningful practically and theoretically.

This paper is organized as follows: Section 2 introduces the materials and methodology; Section 3 describes the Industrial Ecology strategies and measures implemented in SCIP, including the

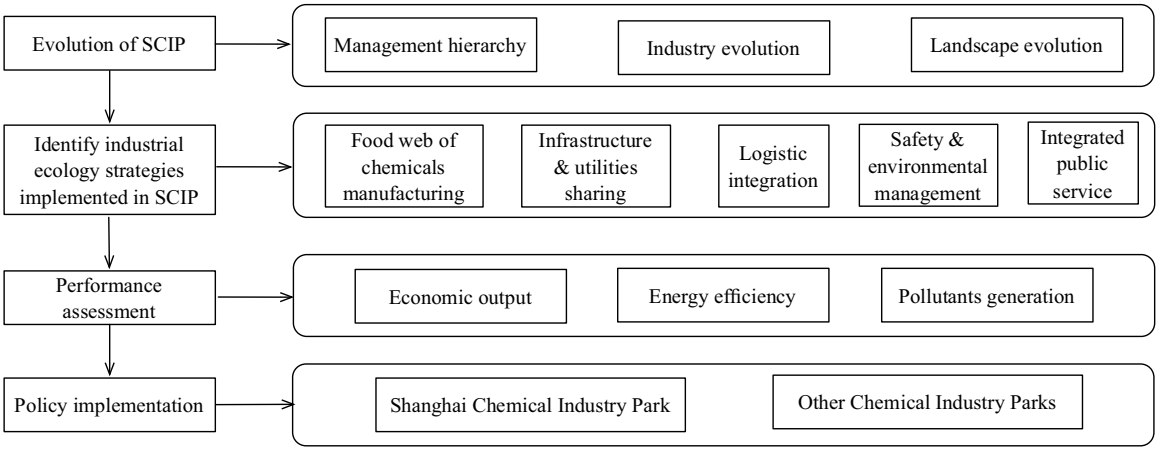

Fig. 1. Schematic framework of research procedure.