Sustainable Energy in the Greater Bay Area of China: Lessons from the Cruise Industry

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Abstract Globalization, technological advancement and economic prosperity concertedly generate a significant demand for cruise. In a context of passenger transport, cruise is one of the key passenger modes to foster the regional economic growth and encourage the social mobility in a community. Recently, the development in Southern China and its emerging Greater Bay Area intends for the revitalization of high-end service innovation and boosting up its tourism development. However, the environmental impacts of the cruise shipping research are seriously overlooked. Cruise shipping activities are well recognized as one of the source of air pollution, but they impact the environment more broadly and the stakeholders often underestimated the associated costs and risks of cruising on the environment. International setting of cruising activity and the lack of policy support are still key barriers for the cruising industry to effectively implement renewable and green-energy strategies and sustainable management in general. In this chapter, we will try to estimate environmental impact of the different resources (i.e. energy, water and waste) used during cruising and explore what are the best practices to develop in order to move towards a greener cruising industries in particular in area of rapid development.

Keywords Energy · Water · Waste · Greater Bay Area · Cruise

1 Introduction

A cruise has been identified as the "transportation of pleasure-seeking travellers on ocean voyages offering one or more glamorous ports of calls" [15, p. 360]. Wild and Dearing [28, pp. 319–320] explained cruise is "any fare paying voyage for leisure onboard a vessel whose primary purpose is the accommodation of guests and not

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freight normally to visit a variety of destinations rather than to operate on a set route". In general, cruise ship are like "floating hotels", selecting specific ports to provide their customers with fantastic in-port experience [17]. In order to maintain customer service level, cruise ship operators need to provide sufficient resources such as potable water, food and energy to the cruisers onboard. Due to the size limitation and isolation of cruise ships, cruise activities rely on non-local resources and require outside intervention to supply water, food and energy to cruisers. In addition, cruise ship operators need to manage waste produced onboard. Resource's usage and waste management generate pollution which impacts the environment; however, such impact from the cruise ship industry has been regulated since 1973 by the International Convention for the Prevention of Pollution from Ships [14] (MARPOL). MARPOL Annex IV, V and VI are particularly important for the prevention of the pollution to the marine environment since they regulate the impact of wastewater, solid waste and air emission, respectively. However, the rapid growth of the cruise ship activities over the last two decades poses an increasing pressure on the marine environment, which is still poorly investigated especially in Asia. As detailed above, the Greater Bay Area (i.e. hereafter called GBA), which includes Shenzhen, Guangzhou and Hong Kong cruise ports, representing more than 11.94 million cruisers per year is a good example of the rapid growth of the cruise ship activities in these area. We have summarized the main cruise ports among GBA in Table 1. Despite the importance of the GBA environment (air and water quality, marine resources, etc.) on its technological and economic development, there is no evaluation of the cruise ship activities impacts on the environment. In the next sections, we will review the impact of cruise ship industry on the GBA by looking at the management of water, waste and energy done by ship sailing within the GBA. It is worth to note that the management of water and waste is closely linked to the need of energy; therefore, the use of water and management of waste produced onboard is closely tied up to the energy demand, and consequently, the development of sustainable energy use within the cruising industry will impact the global environmental footprint of cruisers.

Within GBA, there are four main cruise ports that are now located in Hong Kong (i.e. Ocean Terminal and Kai Tak Cruise Terminal), Shenzhen (i.e. Shekou) and Guangzhou (i.e. Nansha). Ocean Terminal was a first-class professional cruise terminal for liners and the first large-scale commercial shopping mall in Hong Kong. Due to a capacity limitation, HKSAR government decided to establish a new cruise terminal at Kai Tak to accommodate mega cruise ships and receive the increasing number of cruise liners calling during the peak season. However, a lack of transport connectivity and construction defects pose a problem to attracting cruise liners and cruisers from selecting a cruise terminal at Kai Tak in the final choice. Although Kai Tak cruise terminal strives to carry out comprehensive promotional campaign and progressively improve cruise terminal operations, the capacity underutilization problem still exists [17]. Regarding to Guangzhou, the Chinese government declared *Guangzhou Nansha New District City Master Plan* (*2012-2025*) to develop a large scale of cruise tourism through building Nansha new district, creating yachts products and upgrading cruise port facilities, and integrated with various tourism and

Table 1 Summary of cruise ports and their activity in GBA

City	Number of cruise ports	Number of cruise ship/year	Number of cruisers/year	Companies of the cruise ship that go to that cruise port
Guangzhou	1	104	401,100	Costa, Star Cruises, Dream Cruises
Shenzhen	1	78	188,500	Royal Caribbean, Costa, MSC Cruises, Star Cruises, Silversea, Skysea
Hong Kong	2	249	604,300	Azamara, Costa, Crystal, Cunard, Fred. Olsen, Hapag-Lloyd, Holland America, Norwegian, Oceania and P&O, Princess, Regent Seven Seas, Royal Caribbean, Seabourn, Silversea, Star Cruise

Source Cruise Lines International Association [6], Pinchain [21], Ocean Terminal [20]

infrastructure projects within the Pearl River Delta. For Shenzhen, the Chinese government organized Shenzhen Cruise Carnival with different cruise companies and travel agencies in 2017. Different cruise tourism promotion activities are jointly conducted by travel agency, industry practitioners and cruise liners to promote the cruise tourism widely in the community [21].

The rise of middle class in China stimulates the growth of the cruise industry. Because of geographical advantages, GBA contains coastline cities to boost up the cruise economy. As a result, the numbers of cruisers and cruise ships have been increased dramatically in the past few decades [13]. In the forthcoming years, we expect cruise ports in GBA will progressively increase and occupy a key position in the Asia region. As CLIA (2018) indicated that the Hong Kong cruise passenger CAGR is 20%, we expect that Hong Kong cruise passengers will be reaching at 725,160 and 870,190 passengers in 2019 and 2020, respectively. In Shenzhen and Guangzhou, the cruise passenger CAGR is 29%; we predict that cruise passengers in Shenzhen will be reaching at 243,165 and 313,683 passengers in 2019 and 2020, respectively, while cruise passengers in Guangzhou will be reaching at 517,419 passengers in 2019 and 667,471 passengers in 2020. Sun et al. [26] indicated that cruise tourism produces various supporting industries like hospitality, exhibition, logistics, finance, education and training, marine insurance, ship registration, ship

repair and maintenance, and ship chartering. Since the cruise sector and its supporting industries are categorized as a high-end service, it can encourage the transformation and upgrading of the GBA regional economy and finance centre. However, impacts of cruising activities on the environment can also slow down the GBA rapid economic development.

2 Water Management

Cruise ship has a high demand on water to fulfil consumption, personal hygiene, food preparation, cleaning and recreation needs. Therefore, a large amount of good-quality water is needed onboard. Water is either loaded from land and store within the ship or produced via desalination plants. To ensure the quality of the water, several treatments such as filtration, disinfection, mineralization and softening are required, which increase the energy demand and its impact on the environment (see energy section). If the water supply has not a big impact on the environment apart from the energy consumption linked to its treatment, wastewaters, which are the waters collected after their use, are much more an environmental concern. Depending on their usage, wastewater will contain different types of substances such as soap residue, toxic chemical, bacteria, virus, organic matter, etc., which are potentially harmful for the marine environment and therefore require special attention.

Wastewaters are mostly separated between grey water and black water or sewage water. Black waters are produced in much lower volume than grey water but contain higher level of pollutant. Black water or sewage water is the wastewater from the use of toilet and medical facilities onboard the cruise ship. An average of 30 L of sewage per person and per day is produced onboard (EPA 2008a:2-1 see Klein [16]). The presence of harmful bacteria, pathogens, viruses and organic matter content within sewage water requires their treatment before any potential release into the environment to limit their impact. However, MARPOL Annex IV require the treatment of sewage water before their release within 4 nautical miles (7.4 km) of the coastline; outside this area, untreated sewage water is allowed. However, company members of the International Council of Cruise Lines (ICCL), which represent 16 major cruise lines, only allow treated sewage water to be discharged in high sea. Since the cruise ships sailing within GBA are also part of ICCL, no sewage water should be discharged within GBA waters.

Treatment of black water from cruise ship is mostly done by a type II marine sanitation device (MSD), which consists of a flow-through system that breaks up and disinfects (chemically or biologically) waste before discharge. More recent ships have been equipped with advanced wastewater treatment system (AWTS) or even more recently with advanced wastewater purification systems (AWPPS). Most MSD type II and AWTS system filter solids from sewage water as part of the treatment. However, neither MSD nor AWTS do adequately address nutrients loading as nitrogen and phosphorus [16]. Generally, sewage sludge from AWTS can be dumped into the sea beyond the 4 miles' limit; however, its decomposition will induce high

oxygen consumption, affecting marine life. Sewage sludge can also be dewatered and then incinerated onboard, which will affect air quality emission from the ship or stored onboard for treatment in port. AWPPS are used to treat black water and grey water before their discharge into the ocean by producing a clean effluent, with limited nutrient concentration, that can be discharged within the 4 nautical miles' limit [16, 27]. In GBA, there are different action plans for tackling water-related pollution problems including the establishment of adequate sewage infrastructure to serve the planned facilities in Kai Tak cruise terminal development [11]; creating Harbour Area Treatment Scheme surrounding Ocean Terminal [10]; adopting advanced waste treatment technology and optimizing waste treatment system in major China cruise terminals [12]. Basically, cruise ports usually grant permit to some cruise liners providing reception facilities to handle wastewater and sewage. To a certain extent, most of the cruise ship sailing within the GBA mainly uses cruise port facilities.

Grey water represents the wastewater from sinks, showers, laundry and cleaning activity of the ship. An average of 120–300 L of grey water per person and per day is produced onboard cruise ship. Even if grey water may contain similar harmful component for the environment as black water, MARPOL does not restrict their discharge in coastal water [3]. GBA also faces the same situation. However, EU and some countries have set restrictions for grey water discharge within their territorial water. To overcome the shortcomings, GBA plans to boost environmental collaboration to reduce emissions, achieve resource efficiency, reduce waste and protect biodiversity [24]. For further protection of the marine environment and nature conservation in the region, Guangdong and Hong Kong signed the 2016–2020 Cooperation Agreement between Guangdong and Hong Kong on Environmental Protection in September 2016. In 2016, Hong Kong and Guangdong established the Hong Kong-Guangdong Marine Environmental Management Special Panel to strengthen communication on marine environmental issues (Great Bay Area, 2018).

Finally, oily bilge water waste is also produced in a significant amount onboard cruise ship. This wastewater contains fuel, oil and wastewater from the engine. Based on MARPOL Annex I regulation, oily bilge water waste can be discharged within the 12 nautical miles, if oil content is less than 15 ppm. Collection and treatment of oil wastewater exist in most of the important port; however, they are located within port facilities and not at the cruising terminal, making the collection of such wastewater during cruise difficult. However, more and more cruise liners perform environmental responsibility to install cruise ship bilge water treatment to remove oil leaking from machinery in accordance with all international, regional and national laws and regulations covered by the GBA [22].

The presence of harmful bacteria, virus or pathogens within wastewater and their release into the environment can be easily recognized, and its impact is well recognized by the impact on marine organisms or humans if the release happens close to the coast. However, the release of high amount of organic matter does not have a direct impact on human health; however, the high demand in oxygen linked to the decomposition of the organic matter is also an important threat to the marine environment. In fact, the high demand in oxygen will lead to the decrease of the oxygen present in the water and the formation of hypoxic to anoxic water, which cannot

sustain marine life. Within the GBA, the high nutrient concentration release by the Pearl River itself and the sewage water from the surrounding cities already affect the oxygen level of water of the GBA. Two zones of hypoxia are presently observed seasonally within the PRGBA [1, 23, 25]. The expansion of the cruise ship industry and the potential release of higher concentration of nutrient link to wastewater will potentially further increase spatial extend and/or duration of hypoxia event, leading to more pronounced impact of the marine environment. On top of the impact of low oxygen content on marine life, large and long hypoxia period will also affect human life quality by the presence of smelly water. Such impact could also affect the economy of the region by creating a less attractive area for innovation and technology development.

3 Source of Waste and Their Management

Cruise ship has been estimated to produce almost 25% of the waste from merchant fleet even if cruise ship represents only 1% of the fleet [9]. The high number of passengers is responsible for this overrepresentation of the cruise ship activities. Herz and Davis [9] estimated that at the end of 90s, each passenger produces an average of 3.5 kg of solid waste per day. However, active waste reduction practices in the recent years allowed the decrease by more than half of the solid waste production per person onboard cruise ships [16]. In addition to wastewater, a large amount of waste such as plastic, paper, cardboard, food waste, cans and glass are produced by passengers of cruise ships.

Historically, waste produced onboard ships were disposed over the side of the vessel while at sea. Waste management from ship started in the late 60s, when the potential impact on the marine environment of the indiscriminate dumping into the ocean was first recognized. Under MARPOL Annex V, no solid waste in any form can be released in coastal water within three nautical miles of the coastline. Grounded solid waste, capable to pass through a 2.5-cm screen, can be discharged in water between 3 and 12 nautical miles, and most solid waste can be released into the water beyond the 12 nautical miles' limit. Plastic waste is one of the exceptions, and there is a complete ban on their release into the marine environment, and certain types of plastic are also prohibited to be incinerated.

The management of waste produced onboard cruise ships is linked to onboard facilities (i.e. presence of incinerator) and management plans and facilities at home ports and ports of call. Different methods are used to reduce and management solid waste onboard cruise ship (see Table 2). Recyclable items such as glass and aluminium are increasingly separated and stored for onshore disposal and recycling, whereas the remaining waste, which represent 75–85%, are incinerated. Ashes produced by the incineration can be discharged at sea following MARPOL Annex V guidelines [16]. It is worth to mention that the use of incinerators onboard are far less regulated than that the one on land. MARPOL Annex VI only bans incineration of certain harmful substance from contaminated plastic packaging and polychlorinated

Table 2 Possible shipboard waste treatment processes

Treatment	Method	Management	Type of waste
Compactor	Reduce volume by compaction	Storage then discard at port	Plastic
Commuters	Shred to pieces smaller than 2.5 cm	Discharged at sea	Food
Pulpers	Reduces paper and cardboard to papier mache	Discharged at sea	Paper/cardboard
Shredders	Use to grind	Stored or discharged at sea	Bone, metal, glass
Incinerators	Burn	Ashes are discarded at sea or store for discharge at port	Material than cannot be recycled under MARPOL Annex V

Source Butt [3]

biphenyls (PCBs), and no national or international regulations limit the emission from ship incinerators. New waste management facilities such as Plasma Arc Waste Destruction Systems (PAWDS), which allow for the elimination of paper, cardboard, plastic, textiles and food waste, are potentially accessible but require huge capital investment and operating cost like human resources management, repair and maintenance, information systems and administration. Cruise liners strive to carry out waste management best practices including invest in design and implement comprehensive waste minimization processes and procedures, environmental training and sustainable wastewater operations [7]. However, the sophisticated cruise ship structure and increasing sizes of cruise vessels impose important questions regarding the waste management. In order to bringing cruisers towards a multifaceted recreational shipboard experience, cruise liners provide a wide variety of onboard facilities consisting of adventurous souls, casino, shops, buffet restaurant, theatre, fun activities, entertainment, spa and fitness, just to name a few [17], which add to the daily-life activities related to waste production.

Finally, the different hazardous waste produced onboard cruise ships such as dry cleaning waste, used paint, solvents, expired pharmaceuticals, batteries, etc., are stored and discarded on port following the port country legislation.

The impact of solid waste is multiple depending on their type and management. Waste brings direct biological impacts influenced by ingestion and entanglements. Also, waste restrained coastal marine life and accumulated on the seafloor. Besides, waste produces negative economic influences in case of washing up on beaches, destroying the aesthetical qualities and lowers tourism revenues [19]. For example, the discharge of grounded solid waste such as glass can potentially physically harm marine organisms, but the size of the grounded pieces limits such threat. However, grounded food waste contains organic matter which once in the water will be decomposed by marine organisms. This decomposition requires the consumption of high level of oxygen, which will affect the availability of oxygen in the water. As described

above, for wastewater, the release of material with high content of organic matter within the PRGBA will enhance the hypoxic zone already present, and therefore, such release needs to be monitored to avoid severe consequence on the marine environment. The incineration of these solid wastes as paper or food waste appears then as a good alternative, as it allows a rapid reduction of the volume of waste that needs to be stored onboard. The bottom ashes are the results of the incineration of the solid waste. They are composed mostly of mineral fraction and metals, which are non-reactive within the marine environment. However, the incineration will release several components in the air such as carbon dioxide, nitrogen oxides and particulate matter (PM10 and PM2.5), which are responsible for low air quality. Hazardous waste and plastic cannot be incinerated, and special management is required; therefore, such waste are usually stored onboard until discharged at port to be properly managed within land waste treatment plant of the local facilities at home ports and ports of call. Due to plastic ubiquitous usage in human daily life, plastic wastes are numerous onboard cruise ships. Based on MARPOL Annex V, plastic are prohibited from being released into the sea and certain types of plastic are also prohibited from being incinerated, meaning that plastic waste need to be stored and are further treated following the waste management practice of the city home port of each cruise ship.

4 Energy Needs and Its Environmental Impact

Fuel consumption for engine is the main need of energy for cruise ship. In addition to engine energy consumption, cruise ships have a need of auxiliary energy to support light, ventilation, etc., which is produced by onboard generator. [2] identify that 46% of the energy consumed by a cruise ship is linked to its propulsion, 27% is linked to heat and 27% lined to electric power generation. As ships use a "low-quality" fuel (remains from the crude oil after gasoline and distillate fuel oils are extracted), which contain very high sulphur content, for engines and incinerators, they emit air pollutants such as GHG and sulphur and nitrous oxides. Air pollution linked to cruise ships or shipping activities in general is recognized since early 2000s and have been one of the first environmental impacts tackled by the shipping industry and government. There are two types of pollutants emitted by the consumption of fuel. The ones that impact climate are greenhouse gases (CO_2, CO, NOx or HC), and the ones that have an impact on human health are SO_2, PM10 and PM2.5. International regulations are looking at both types of pollutants. For example, the International Maritime Organization (IMO) has officially adopted a strategy to reduce the greenhouse gas emissions from shipping by 50% by 2050 in comparison to the 2008 levels. In addition, MARPOL Annex VI is regularly decreasing the level of sulphur allowed in fuel used by ships. Until 2012, 4.5% sulphur content was allowed in most of the area, except within the Emission Control Areas (ECAs), where only 1% sulphur was accepted and in EU ports where the sulphur content needs to be lower than 0.1%. In 2020, the IMO will enforce a maximum of 0.5% sulphur content

in fuel, whereas ECAs and EU ports will continue with sulphur content lower than 0.1%.

The Chinese government designated a series of Domestic Emission Control Areas (DECAs) in its three busiest port regions (Yangtze River Delta, Pearl River Delta and Bohai Bay) as part of a plan to phase in a low-sulphur marine fuel mandate. Starting in 2017, all ships calling at the three regions will be required to use fuels containing no more than 0.5% sulphur when berthing in port. In 2019, they will have to use this cleaner fuel anywhere within 12 nautical miles of coastlines within the DECAs. Since early 2019, Shenzhen ports and all the ports within the Pearl River Delta require the use of fuel with less than 0.5% sulphur content within the DECA. Hong Kong ports follow the same regulation since 2015. [4] estimated that cruise ships are responsible for 2%, 2.3% and 2.2% of sulphur dioxide, nitrous oxide and PM 2.5 emissions, respectively, of the total emission from shipping activities. We therefore estimated that PRGBA cruising activities emitted, respectively, 3441 t per year, 6182 t per year and 196 t per year of sulphur dioxide, nitrous oxide and PM 2.5, using emissions data from 2007 to 2010. Despite the recent changes in the regulation of the greenhouse gas emission from shipping detailed above, the increase of the cruising activities (number of ship cruise and cruisers, which visit PRGBA's ports) is responsible for the augmentation of cruising-related greenhouse gas emissions in the PRGBA.

The extension of the use of low sulphur content fuel to larger area is largely disapproved by shipping industry due to the cost of such low sulphur content fuel. It has been estimated that it will add 15 to 20 USD per passenger per day to use only low sulphur content fuel (Seatrade Insider 2009). Another alternative to reduce the emissions of air pollutant is to reduce the speed limits as cruise ships approach ports. Several ports in California used this approach in 2009, such as San Diego, Los Angeles and Long Beach have shown a significant reduction in emission of nitrous and sulphur oxide, particulate matter and CO_2 (California EPA, 2009).

Some cruise ships are now trying to use gas turbines as greener alternatives to reduce air pollutant emissions; however, such turbines will reduce the emissions of sulphur and nitrous oxide but produce significantly higher volume of CO_2 [16]. An alternative of air pollutant emission linked to fuel consumption is the Alternative Maritime Power (AMP), which allows ship to use energy produced on land and stored by port authorities. However, AMP is still not in application in China since ports are not allowed to sell electricity; in addition, there is another legal aspect linked to invoices, tax for berthed ship in China port as well as safety issues linked to AMP [5]. In addition, cruise liners (e.g. Royal Caribbean, Costa Cruises and Carnival) develop clean energy and nuclear power to power the cruise ships in the forthcoming years [12].

5 Conclusion

The cruising industry is developing rapidly around the world. An increase of more than 20% of cruise passengers over the last 5 years worldwide has been observed, and 27 new ships have been scheduled to be deployed in 2018, resulting in the presence of 476 cruise ships sailing mostly in coastal water. The PRGBA is not an exception, and a rapid increase in cruise ship and cruise passengers is observed. The cruise tourism generates a large amount of revenues from (1) spending of passengers and crew members on land; (2) fees from other services that the ship has been offered by different parties in and out; (3) fees for repair and maintenance of the waterway; (4) fees for services for the boat recognized at port where the boat docked [18]. As a result, cruise industry boosts up regional economic development, social mobility and job employment.

By its nature, cruise ship activities are not sustainable since they required the external input of most of the resources needed for cruisers to have a multifaceted recreational shipboard experience; therefore, the environmental cost needs to be evaluated in order to fully understand the benefit and impact of cruise ship activities within a specific area. Water, waste and energy are the three "resources" that need to be evaluated in order to estimate the environmental impact of the cruise ships. In fact, both water and waste management require energy; therefore, energy is a key resource to examine. In general, precise evaluation of the production and treatment of water or waste onboard cruise ships is limited. Energy production is a little bit more accessible, but to fully assess the impact of cruise ships on air quality, it is necessary to measure and characterize the emission from shipboard engine and incinerators of several ships directly.

Waste management and emissions from cruise ships are regulated by MARPOL Annex IV, V and VI, which aim to limit the discharge of waste and gas emission within few nautical miles' limit from the coast. However, regulations are still quite permissive but most importantly often violated leading to a non-negligible impact of cruise ship on coastal marine environment. Finally, beyond the few miles' limit, there is barely any regulatory enforcement on waste discharge or gas emissions.

The GBA aims to mitigate environmental pollution, support environmental technology and green buildings, advocate energy saving, waste reduction, and encourage environmental education to establish a sustainable future for GBA [8]. However, until now there is no direct information on the environmental impact of cruise ship industry with the area, knowing the exponential growth of this sector, it is now clear that its environmental impact needs to be investigated in order to develop the best practice which will benefit the economic growth and sustainability of the development of the GBA. In the future, we will conduct an in-depth interview with various stakeholders' attitude towards sustainable energy in GBA and contribute the policy paper in the future.

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