
Appendix 3.6

**Calculation of Emissions from Cruise
Terminal**

Marine Emissions from Cruise Terminal

1. With reference to the approved EIA study “Kai Tak Development” 2008 (KTD EIA), the emission sources in Kai Tak Cruise Terminal includes two cruise ships and the tugboats which are used to assist cruise vessels during berthing. The emission rate from cruise ships and tugboats are calculated from their engine power and the fuel type.
2. The methodology of marine emission in KTD EIA is based on the approach stipulated in “Current Methodologies and Best Practices in Preparing Port Emission Inventories, Final Report, January 2006” prepared by ICF Consulting for USEPA (ICF2006). In April 2009, USEPA updated the final report and named as “Current Methodologies in Preparing Mobile Source Port-related Emission inventories, Final Report” (ICF2009). The related emission factors have been updated.
3. Based on the “Study on Marine Vessels Emission Inventory” which is published by Institute for the Environment, The Hong Kong University of Science & Technology, the weighted fuel sulphur content of residual oil used in the ocean going vessels (OGVs) trend to be decreasing. The average sulphur content of vessel oil is adopted as 3.8% in the calculation of KTD EIA and was down to be 2.8% in the calculation of the approved EIA study for “Kai Tak Development – Roads D3A & D4A” in 2012. From the authority press release on 11th March 2015, the newest average sulphur content used by OGVs in Hong Kong is 2.6%¹.
4. “Air Pollution Control (Marine Light Diesel) Regulation” (Cap. 311Y) started to operate from 2014. The local vessels in Hong Kong are required to use the fuel of marine light diesel which has a sulphur content not exceeding 0.05% by weight.
5. The newest “Air Pollution Control (Ocean Going Vessels) (Fuel at Berth) Regulation” (Cap. 311 AA) has been passed in March 2015 and will operate on 1st July 2015. The OGV will be required to switch-over to low-sulphur fuel (not exceeding 0.5%) except for the first hour after berthing and the last hour before departure. Therefore, in this assessment, the OGVs are proposed to use the fuel with sulphur contents of 0.5% in the hotelling mode and 2.6 % in the berthing mode.
6. As the emission factors and fuel qualities have been changed from approved KTD EIA, the emission from the cruise ships and tugboats are reviewed and re-calculated in this section.

Cruise

7. According to KTD EIA, four size class of cruise ships would berth in Kai Tak Cruise Terminal. The largest power one is Panamax vessels and therefore the worst case should be that the two cruise ships berthing space are used by two Panamax vessels. Their corresponding stack height, emission temperature, exhaust velocity and stack diameter are 48 mPD, 537k, 24.6m/s and 1.9 m. The basic information of the main engine, auxiliary engine and boiler for cruise ships are listed in **Table 1**.

¹ New regulation to require ocean-going vessels to switch to clean fuel while at berth
<http://www.info.gov.hk/gia/general/201503/11/P201503110549.htm>

Table 1 Engine Information of OGV – Panamax-Queen Elizabeth II

Information	Engine Power (kw)	Operation	Load Factor
Main Engine	88000 ^[1]	Manoeuvring	0.02 ^[2]
Auxiliary Engine	14843.75 ^[1]	Manoeuvring	0.8 ^[3]
		Hotelling	0.64 ^[3]
Boiler	1000 ^[4]	Hotelling	-

1. Refer to Appendix 6.4 in the approved KTD EIA
 2. Refer to Section 2.5 of USEPA: Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories (ICF2009): Load Factor = (Actual Speed / Maximum Speed)³, or minimum of 2%, (4/21.5)³ is less than 2% so that 2% is adopted.
 3. Refer to Table 2-7 of USEPA ICF2009
 4. Refer to Table 2-17 of USEPA ICF2009.
8. Nitrogen dioxide (NO₂); sulphur dioxide (SO₂), respirable suspended particulates (RSP (PM₁₀)) are the main pollutants from the ocean passenger cruise. The emission factor and emission rate for OGVs are shown in **Table 2**.

Table 2 Emission Factor and Emission Rate for OGV

Parameter	Main Engine ^[1]	Auxiliary Engine ^[2]		Boiler ^[1]	
		Manoeuvring	Hotelling		
Emission Factor (g/kwh)	NO _x	14	14.7	2.1	
	SO ₂	11.24	11.98	16.1	
	RSP	1.43	1.44	1.47	
	FSP	1.32	1.32	1.35	
Emissions Rate ^[3] (kg/hr)	NO _x	24.64	174.56	139.65	2.10
	SO ₂	19.78	142.26	113.81	16.10
	RSP	2.517	17.10	13.68	1.47
	FSP	2.323	15.68	12.54	1.35

1. Refer to Table 2-9 of USEPA ICF2009, EF for engine type of Medium-speed diesel (MSD) with the Residual Oil (RO) is adopted for main engine, and EF for ST with RO is adopted for boiler. Please noted that the RO with 2.7% Sulphur used in the mentioned above table.
 2. Refer to Table 2-16 of USEPA ICF2009
 3. Emission Rate = emission factor × engine power × load factor
9. The total emission rate of the cruise ships during manoeuvring and hotelling are summarized in **Table 3**.

Table 3 Total Emission per Hour for OGVs

Pollutants	Hourly Emission Rate (kg/hr)	
	Manoeuvring ^[1]	Hotelling ^[2]
NO _x	199.203	141.750
SO ₂	162.045	129.910
RSP	19.617	15.150
FSP	17.998	13.890

1. The total emission from a manoeuvring cruise ship includes the emission from main engine and auxiliary engine
 2. The total emission from a hotelling cruise ship includes the emission from auxiliary engine and boiler.
10. In the approved KTD EIA, the cruise ships have two modes in a 24 hour period in a day: berthing at the cruise terminal and hotelling at the cruise terminal. The berthing mode includes 15 minutes for manoeuvring motions of the cruise vessels from the navigation channel to near the cruise terminal, 15 minutes for final manoeuvring around the berth and 30 minutes for hotelling. In this assessment, the fuel with sulphur contents of 2.6% is adopted for the berthing mode while 0.5% is adopted for the hotelling mode. The emission parameters of the OGVs with berthing mode and hotelling mode are summarized in the **Table 4**:

Table 4 Total Emission from OGVs

Pollutants	Emission Rate (g/s)		
	Berthing Mode ^[1]		Hotelling Mode ^[2]
	Manoeuvring (15 mins per hour)	Hotelling (30 mins per hour)	Hotelling
NO _x	1.3834E+01	1.9688E+01	3.9375E+01
SO ₂ ^[3]	1.0836E+01	1.7375E+01	6.6826E+00
RSP ^[3]	1.3118E+00	2.0262E+00	7.7932E-01
FSP ^[3]	1.2036E+00	1.8577E+00	7.1451E-01

1. In an hour period of berthing mode, 15 minutes are manoeuvring motions of the cruise vessels from the navigation channel to near the cruise terminal; 15 minutes are final manoeuvring around the berth; and 30 minutes are hotelling at the cruise terminal. The emissions are weighted by ¼, ¼ and ½ for one hour, respectively.
2. Hotelling mode includes one hour hotelling operation in one hour period.
3. The emission factors of SO₂ and RSP are proportional to the Sulphur content in the fuel. The emission factor from Table 2-9 and Table 2-16 in USEPA ICF2009 is obtained from an engine burning residual oil with 2.7% Sulphur content. A correction factor of 0.963 (=2.6/2.7) is adopted for berthing mode (manoeuvring in 15 minutes and hotelling in 30 minutes) while 0.185 (=0.5/2.7) is adopted for hotelling mode.

11. As the fuel with higher sulphur content in the berthing mode, the emission impact due to cruise terminal during berthing mode is higher than berthing mode (see **Table 4**). Considering the worst case of cumulative air quality assessment, it is assumed that the two cruise ships would operate berthing mode sequentially in 17:00-19:00 and 19:00-21:00 which period is overlapped with the peak hour of traffic flow.

Tugboat

12. According to KTD EIA, two tugboats are used to assist the cruise ships during the 30 minutes berthing motion. The main emission pollutants are NO₂, RSP and SO₂. The emission factors are based on USEPA ICF2009. The emission factors and emission rates for tugboats are summarised in **Table 5**.

Table 5 Emission Information for Tugboats

Parameter		Main Engine	Auxiliary Engine
Engine Power ^[1] (kw)		1532	82
Load Factor ^[2]		31%	
Emission Factor ^[3] (g/kwh)	NO _x	13.2	
	SO ₂	1.3	
	RSP	0.72	
Emissions Rate (kg/hr)	NO _x	6.269	0.336
	SO ₂	0.617	0.033
	RSP	0.342	0.018

1. Refer to Appendix 6.4 in the approved KTD EIA
2. Refer to Table 3-4 of USEPA ICF2009
3. Refer to Table 3-8 of USEPA ICF2009

13. The total emissions rates for tugboats are listed in **Table 6**. The emission of SO₂ and RSP are proportional to the fuel sulphur content. According to Air Pollution Control (Marine Light Diesel) Regulation (Cap. 311Y), the tugboat in Hong Kong are required to use the fuels with sulphur content of not exceeding 0.05%. The emission factor listed in USEPA ICF2009 is considering a fuel with a sulphur content of 1.5%. Therefore the emission rate of RSP and SO₂ from the tugboat are corrected by a ratio of 0.05/1.5=0.033.

Table 6 Total Emissions for Tugboats

Pollutants	Total Emission Rate		
	Hourly (kg/hr)	15mins per hour (1.5% Sulphur) (g/s)	15mins per hour (0.05% Sulphur) (g/s)
NO _x	6.6045	4.5865E-01	4.5865E-01
SO ₂ ^[1]	0.6504	4.5170E-02	1.5057E-03
RSP ^[1]	0.3602	2.5017E-02	8.3390E-04
FSP ^[2]	0.3494	2.4266E-02	8.0888E-04

1. The emission factors of SO₂ and RSP are proportional to the Sulphur content in the fuel. The emission factor in Table 3-8 of USEPA ICF2009 is based on an engine burning residual oil with 1.5% Sulphur content. A correction factor of 0.333 (=0.05/1.5) is adopted.
 2. Based on the Section 3.4.2 of USEPA ICF2009, FSP (PM_{2.5}) is assumed to be 97% of RSP (PM₁₀).
14. Following the assumptions in KTD EIA, the corresponding stack height, emission temperature, exhaust velocity and stack diameter of tugboat are 2 mPD, 537k, 24.6m/s and 0.2 m, respectively.
15. The locations of the emission sources for tugboats and OGVs are summarised in the **Table 7**.

Table 7 Emissions Parameters for ISCST Model

Emission Source ID	Emission Rate (g/s)		
	X	Y	Description
T1a	839940.3	818008.1	Tugboat 1 for OGV1 from the navigation channel to near the cruise terminal
T1b	840040.2	818011.4	Tugboat 2 for OGV1 from the navigation channel to near the cruise terminal
T1c	839917.8	818487.5	Tugboat 1 for OGV1 for final manoeuvring around the berth
T1d	839989.9	818418.2	Tugboat 2 for OGV1 for final manoeuvring around the berth
T2a	839669.4	818203.0	Tugboat 1 for OGV2 from the navigation channel to near the cruise terminal
T2b	839769.2	818209.6	Tugboat 2 for OGV2 from the navigation channel to near the cruise terminal
T2c	839626.3	818769.6	Tugboat 1 for OGV2 for final manoeuvring around the berth
T2d	839698.4	818700.2	Tugboat 2 for OGV2 for final manoeuvring around the berth
M1a	839989.2	818039.7	OGV1 manoeuvring from the navigation channel to near the cruise terminal
M1b	839974.7	818474.4	OGV1 manoeuvring for final manoeuvring around the berth
M2a	839717.3	818236.2	OGV2 manoeuvring from the navigation channel to near the cruise terminal
M2b	839683.2	818756.5	OGV2 manoeuvring for final manoeuvring around the berth
H1a	839974.7	818474.4	OVG1 hotelling (30mins)
H2a	839683.2	818756.5	OVG2 hotelling (30mins)
H1	839974.7	818474.4	OVG1 hotelling (60mins)
H2	839683.2	818756.5	OVG2 hotelling (60mins)