环境保护部机动车排污监控中心
Vehicle Emission Control Center
Ministry of Environmental Protection

Non-road mobile source emission inventory development

VECC of MEP
2014.6.10. Beijing

机动车环保网 www.vecc-mep.org.cn

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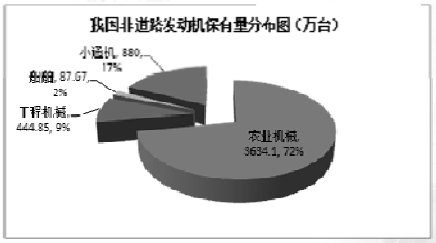
环境保护部机动车排污监控中心 Vehicle Emission Control Center Ministry of Environmental Protection 机动车环保网 www.vecc-mep.org.cn

1.Backgroud

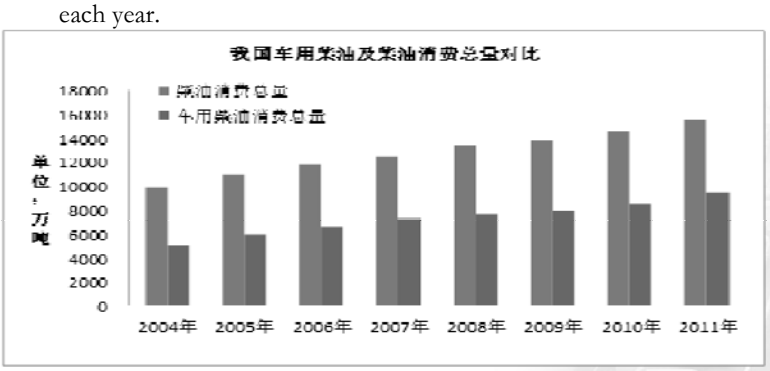
Current situation of non-road mobile source ownership

Variety of non-road engines have exceeded 50M in 2011. More than 14M diesel engines were produced in 2012（including 2M agricultural vehicles）。

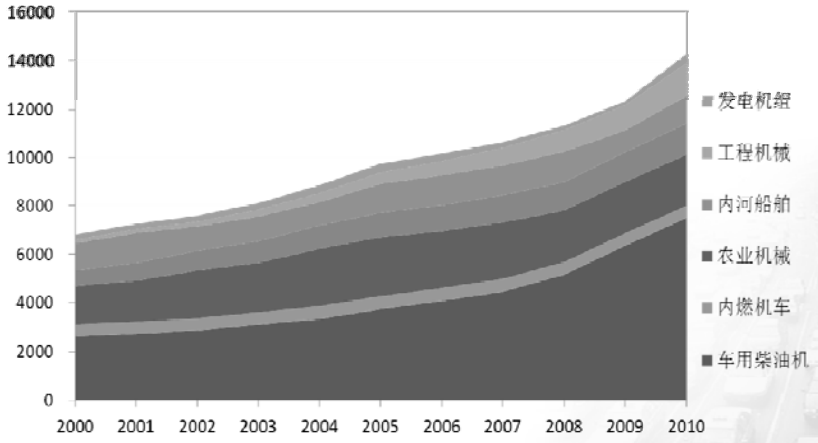


Consumption of non-road mobile source diesel

Annual diesel consumption is nearly 100 million tons. All kinds of diesel engines except diesel vehicles consume over 60million tons each year.



Consumption situation



Non-road mobile source management requirements

"The latest Five Year plan for pollution prevention in critical area"

implement non-road mobile source pollution prevention

- carry out non-road mobile source survey,
- master the pollution status of mobile source including construction machinery, locomotive, marine, agricultural machinery, industrial machinery and aircraft
- establish management of daily account for mobile source air pollution

"Air pollution prevention action plan"

carry out pollution control for non-road mobile machinery and marine

2.Non-road mobile source emission inventory development

Classification of non-road mobile source

Non-road mobile includes:

construction Machinery

agricultural machinery

small general machinery

marine

locomotive

aircraft

Calculation approach for engineering machinery emission inventory

* Discharge of engineering machinery:

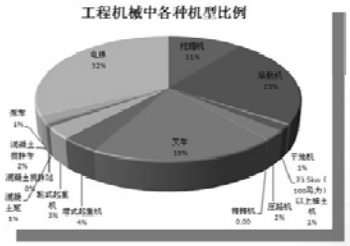
$$Q = EF \times Pop \times A \times 3600$$

Q: quantity, g/year
EF: emission factor, g/s
Pop: sorting device ownership
A: sorting device activity level, hour/year

Classification and ownership of engineering machinery

according to the China construction machinery industry yearbook, engineering machinery can be divided into 13 types.

Loaders, excavators and forklift is the main model of engineering machinery in China, it occupies 80.1% of total. Besides, road roller, bulldozer, grader also account for about 4.4% population. This research divide engineering machinery into seven types.



Average working time

美国NONROAD模型全负荷寿命与负载因子表

	全负荷寿命（hr_f）	负载因子（LF）
装载机	5000	0.21
挖掘机	5000	0.59
叉车	5000	0.59
压路机	5000	0.59
推土机	5000	0.21
平地机	5000	0.59
摊铺机	5000	0.59

Construction machinery working hours per year

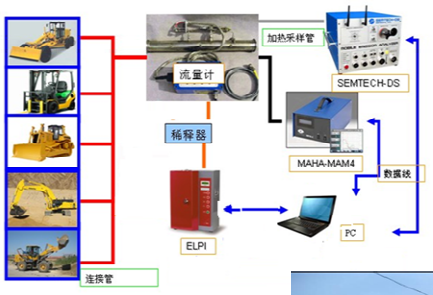
	工程机械类别	年均工作时间（ h）
1	挖掘机	565
2	装载机	1587
3	叉车	565
4	推土机	1587
5	平地机	565
6	压路机	565
7	其他	565

工程机械年均工作小时数由公式(3-7)获得。

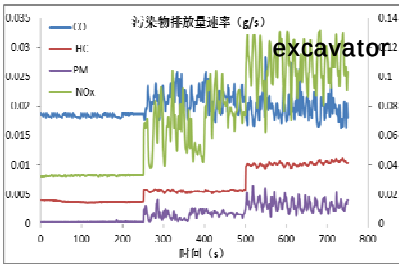
$$hr_n = \frac{hr_f}{LF * Y_n} \quad (3\text{-}7)$$

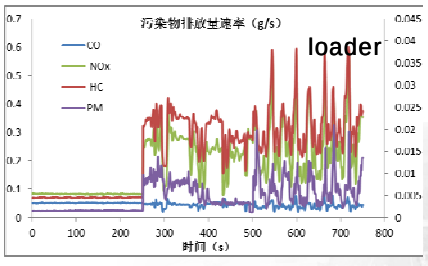
其中：hr_m 实际年工作小时数；
hr_f 全负荷设计寿命；
LF 工程机械负载因子；
Y_m 平均使用年限，假设 15 年。

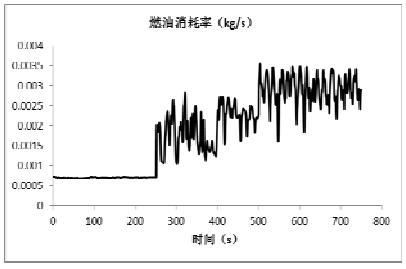
The actual emission test

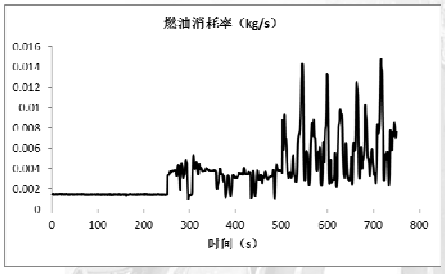


Transient emission characteristics of excavators and loaders

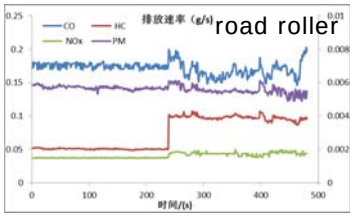


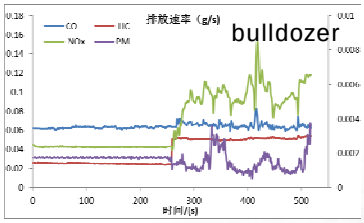


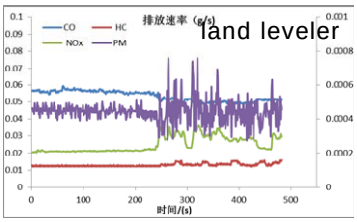


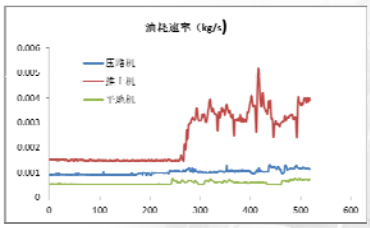


Transient emission characteristics of road roller, land leveler & bulldozer

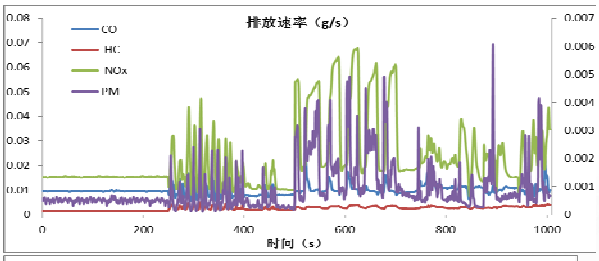


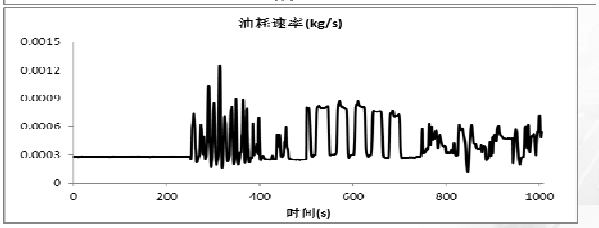




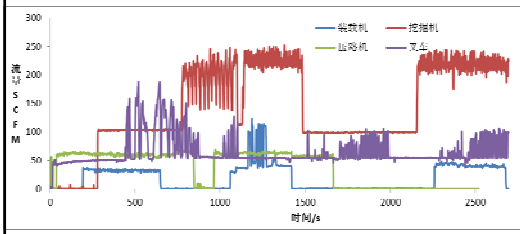


Transient emission characteristics of forklift



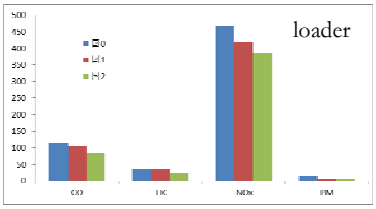


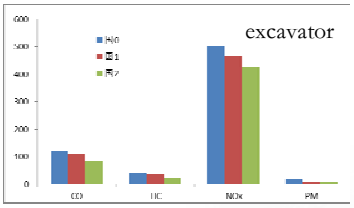
Operating conditions of engineering machinery

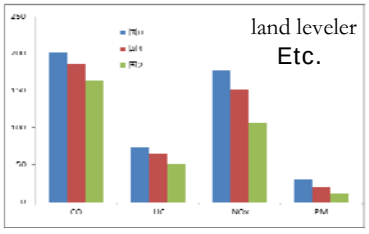


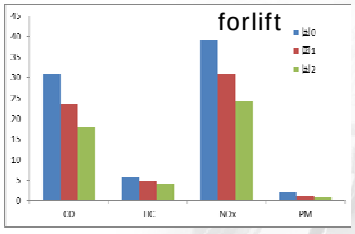
机械类型	测试工况	测试工况	时间比例加权系数 (%)
挖掘机	怠速	发动机低转速(通常为 600-800r/min)，挖掘机处于静止状态，对外无功率输出	0.05
	行走	在测试地点移动， 但作业部分保持静止。	0.15
	作业	工程机械处于行走状态，并利用铲斗进行挖掘、动斗，翻斗等作业活动。	0.80
装载机	怠速	发动机低转速(通常为 600-800r/min)，装载机处于静止，对外无功率输出	0.05
	行走	装载机在测试地点自由移动，但机械作业部分保持静止状态。	0.35
	作业	行走及利用铲斗进行起斗，掘进，翻斗等作业	0.60
压路机	怠速	发动机低转速(通常为 600—800r/min)，压路机处于静止状态，对外无功率输出	0.10
	作业	压路机开始行走同时利用碾轮进行碾压作业。	0.90
推土机	怠速	发动机处于低转速状态(通常为 600—800r/min)，推土机处于静止状态，对外无功率输出	0.10
	作业	推土机开始行走同时利用推土刀铲削并推送作业	0.90
平地机	怠速	发动机处于低转速状态(通常为 600—800r/min)，平地机处于静止状态，无功率输出	0.10
	作业	平地机行走同时利用刮刀平整作业	0.90
叉车	怠速	发动机低转速(通常为 600-800r/min)，货叉处于最低位置，并保持静止状态。	0.05
	空载行走	叉车在测试地点前行或后移，货叉处于空载状况。	0.30
		叉车处于静止状况，利用货叉对货物进行上升下	0.30

real emission factors of engineering machinery

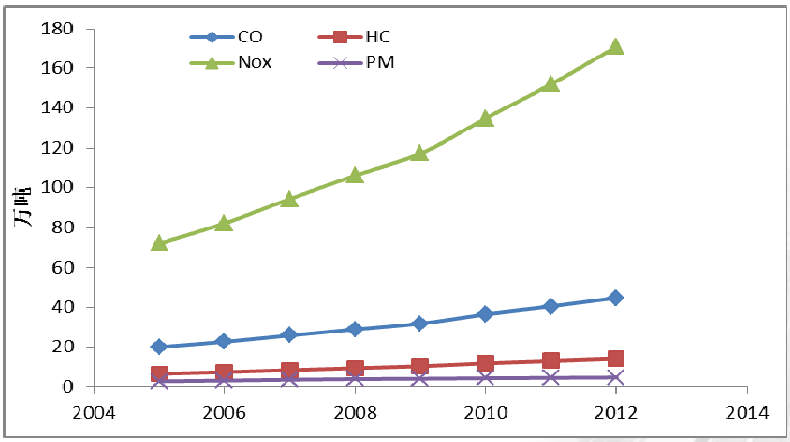








Emission inventory of engineering machinery



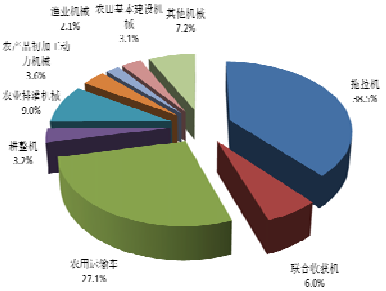
Calculation approach for agricultural machinery emission inventory

* Discharge of agricultural machinery:

$$Q = EF \times Pop \times A \times 3600$$

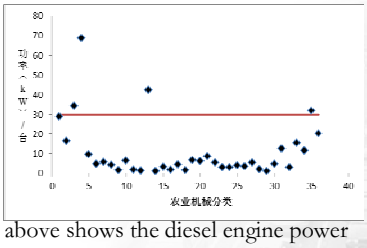
Q: quantity, g/y
EF: emission factor, g/s
Pop: sorting device ownership
A: sorting device activity level, hour/year

Classification of agricultural machinery



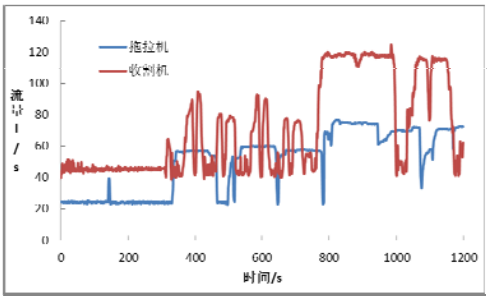
- Tractor
- Harvester
- Other

According to the 《The agricultural machinery industry yearbook》, agricultural machinery can be divided into 9 types and 38 classes.



The photo above shows the diesel engine power of the 38 classes of agricultural machinery in 2011. A single average power more than 30 kW are 18.4 to 58.8 and 58.8 kW+ large & medium-sized tractors, combine harvesters

Typical operating condition & activity level of agricultural machinery

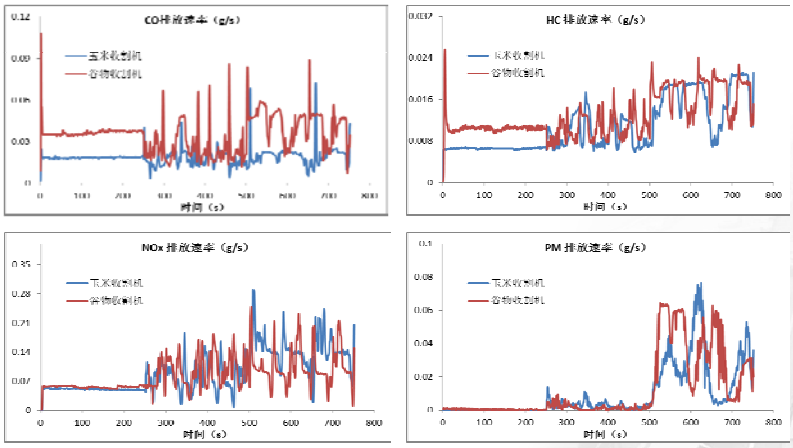


Working time of agricultural machinery

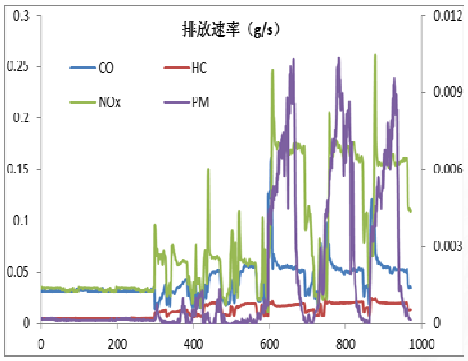
Types	time (hours)
1 Tractor	500
2 Combine	150
3 Others	380

机械类型	测试工况	工况介绍
旋耕拖拉机	怠速	发动机低转速状态(通常为600-800r/min)，拖拉机处于静止状态，对外无功率输出。
	行走	拖拉机在农田中自由行走，旋耕犁处于提升或静止状况，作业机构对外无功率输出。
	作业	拖拉机在农田一边行走，一边为旋耕犁提供动力，使其逐行对土壤进行细碎和平整地面作业。
联合收割机	怠速	发动机低转速状态(通常为600-800r/min)，且联合收割机处于静止状态，对外无功率输出。
	行走	联合收割机在农田中自由行走，且收割、脱粒等作业部件处于静止状态，主要作业机构无功率输出。
	作业	联合收割机在农田一边行走，一边进行作物的收割、分离茎杆、脱粒和清除杂物等作业工序。

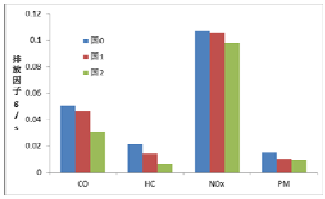
Transient emission characteristics of combine



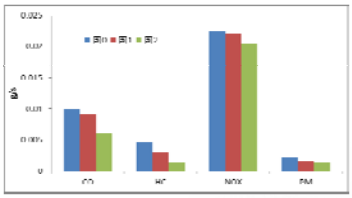
Transient emission characteristics of tractor



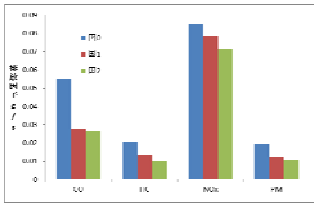
Emission factors of tractors and harvesters



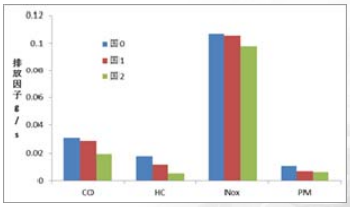
medium & large tractor



small tractor

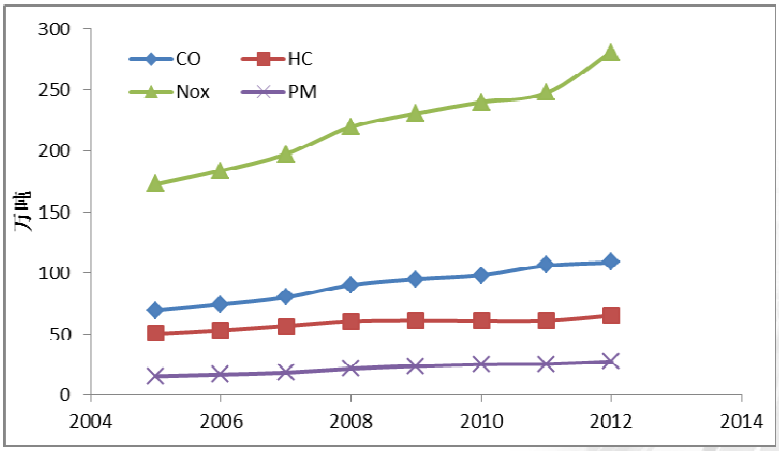


combine



other

Emission inventory of agricultural machinery



Calculation approach for inland ship emission

* Calculating approach for marine emission:

* E=V×EF。

V: annual turnover volume of passenger and goods(ton. km/year, people.km/year)

* EF:Comprehensive pollutant emission factor

Testing program

- testing area and route

Route 1:The Jiangsu section of the Beijing-Hangzhou grand canal

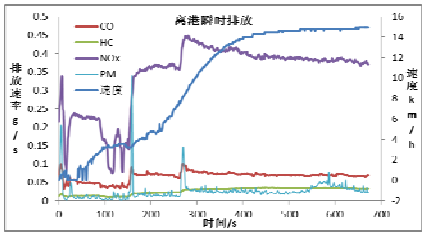
Route 2: Zhujiang&Guangzhou section

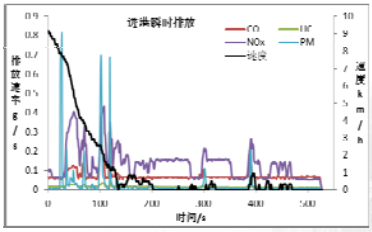
Test equipment installation

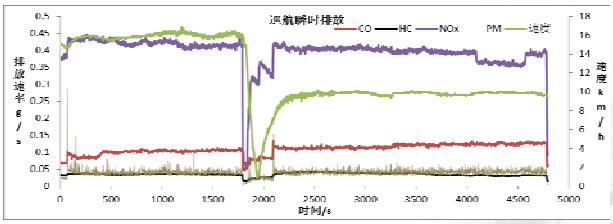
Testing operation for inland ship

测试工况	工况介绍
进港	指从船舶巡航速度开始减速到靠岸为止
巡航	船舶以一定的速度平稳行驶
离港	静止开始加速到巡航速度为止
停泊	船舶靠岸后利用发动机为船上日常生活供电

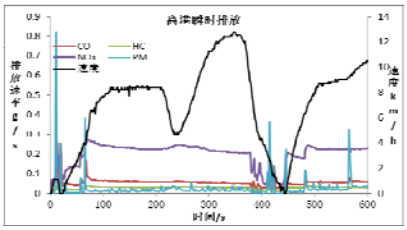
Transient emission characteristics of Zhujiang cargo ships

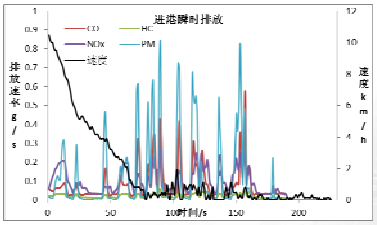


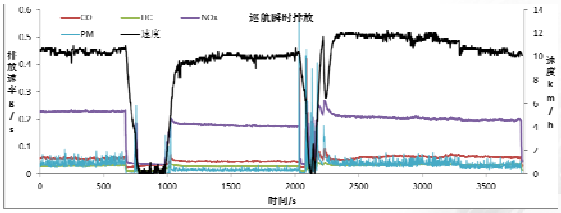




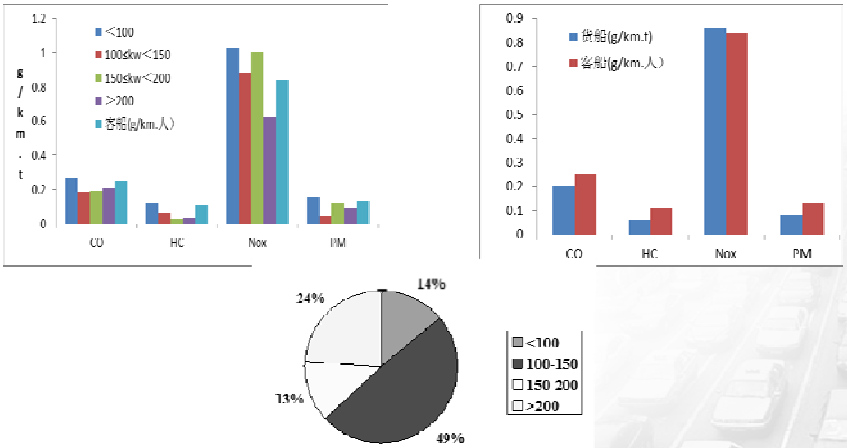
Transient emission of Zhujiang cargo ships



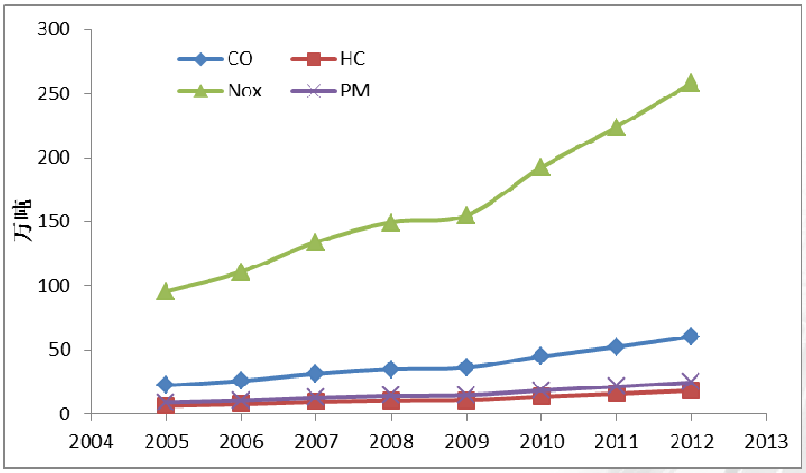




Emission factors of inland ships



Marine emission inventory



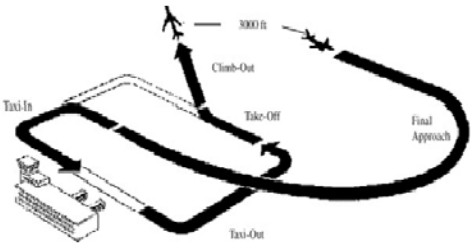
Calculation approach for aircraft and locomotive emission

* Aircraft LTO emission calculation:
  $T=EF_{LTO} \times LTO$

  T: quantity of pollutant emission
  EFLTO: pollutant emission factor，kg/LTO
  LTO，LTO amount of civil aircraft
* Locomotive emission calculation:
  $T=EF \times W$

  T: quantity of pollutant emission
  EF: pollutant emission factor，g/kg fuel
  W: fuel consumption of locomotive，ton

Emission of civil aircraft



Standard LTO cycle regulated by ICAO

engine operation	engine operation	Operating time/min
take off	100%	0.7
climb	85%	2.2
approach	30%	4.0
taxi	7%	26.0

Civil aircraft LTO cycle emission factor/kg·LTO^{-1}

Tpyes	CO	HC	NOx	PM	SO_2
China2001	10.12	—	18.29	0.13	1.17
China2003	9.75	—	17.52	0.13	1.13
China2005	9.40	—	16.71	0.12	1.09
China2007	9.35	—	16.47	0.11	1.08
China2009	9.26	—	16.33	0.11	1.07
China2011	9.14	—	16.29	0.11	1.06
中国 香港	15.17	—	20.11	0.16	1.29

Aircraft movements (/ 10k times) in China's major airports

Year	Airports in China	Beijing	Guangzhou	Shanghai(Pudong)	Shenzhen	Shanghai(Hongqiao)	Chengdu	Kunming	Xi' an	Chongqing	Hangzhou	Hongkong
2000	175.95	20.10	12.45	7.03	7.97	10.56	6.03	6.48	5.54	3.73	3.31	—
2001	194.08	22.16	13.74	7.76	8.79	11.65	6.65	7.14	6.11	4.12	3.65	—
2002	211.70	24.23	14.77	10.73	10.67	11.79	7.78	7.99	6.82	4.90	4.49	—
2003	229.12	26.46	15.24	17.27	15.45	10.96	8.50	8.09	6.19	5.65	5.22	—
2004	266.63	30.49	18.28	17.87	14.05	15.08	11.02	9.24	7.77	6.48	6.70	24.77
2005	305.65	34.17	21.13	20.50	15.14	17.00	13.29	10.90	9.14	7.27	7.93	27.34
2006	348.64	37.89	23.24	23.20	16.95	17.76	15.55	13.56	9.93	8.89	10.08	29.02
2007	394.08	39.92	26.08	25.35	18.15	18.70	16.63	14.81	11.93	10.51	11.47	30.50
2008	422.67	42.96	28.04	26.57	18.79	18.53	15.86	15.04	12.20	11.26	11.86	33.26
2009	484.07	48.79	30.89	28.79	20.26	18.91	19.01	17.26	14.63	13.26	13.41	30.97
2010	553.17	51.76	32.92	33.21	21.69	21.90	20.55	18.15	16.44	14.57	14.63	31.60
2011	597.97	53.32	34.93	34.41	22.43	22.98	22.24	19.17	18.51	16.68	14.95	34.44
2012	660.32	55.72	37.33	36.17	24.01	23.49	24.27	20.13	20.44	19.53	16.63	37.54

Calculation of diesel locomotive consumption

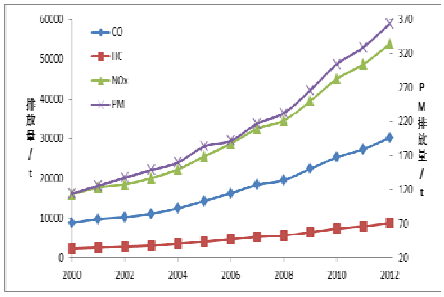
- daily output of freight locomotive = total freight volume/ (unit * day)
- total freight volume ≈ rotation volume of goods transport
  - ✓ total freight volume = rotation volume of goods transport + Vehicle weight
  - ✓ Vehicle weight is about 117.41 billion ton-km in 2011, less than 4% of rotation volume of goods transport.

$$Z_{货合} = 365 \times (RC_{货内} \times T_{货内} + RC_{货电} \times T_{货电})$$

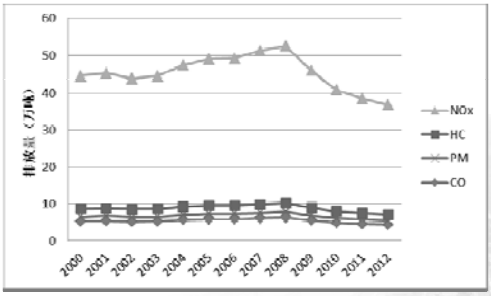
$$Z_{货合}/RC_{货合} = 365 \times (T_{货内} + T_{货电})$$

- ✓ $Z_{货合}$: total daily output of electric freight locomotive
- ✓ $RC_{货合}$: total daily output of freight locomotive ; $RC_{货电}$: daily output of electric freight locomotive; $RC_{货内}$: daily output of diesel freight locomotive
- ✓ $T_{货电}$: unit * day of electric freight; $T_{货内}$: unit * day of diesel freight locomotive;
- ✓ $Z_{货合}$、$RC_{货合}$、$RC_{货电}$、$RC_{货电}$ are known parameters, can be obtained by related yearbooks

Emission inventory of Aircraft and Locomotive



Aircraft LTO emission



Locomotive emission

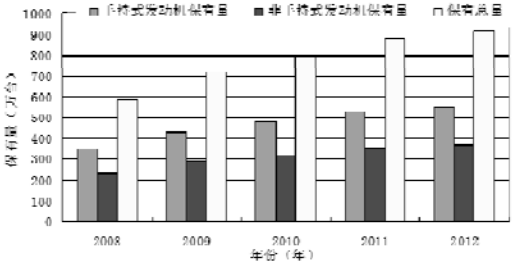
Calculation approach

* Calculation approach for the quantity of small general machinery pollutant:

$$Q=EF*Pop*Power*A*LF/10^6$$

Q: discharge, ton
Pop: ownerships
Power: rated power, kW;
A: activity level, hour;
EF: emission factor, g/kW.h;
LF: load factor。

Ownership and classification of small general machinery



Considering the small ownership of handheld engine (SH1&SH3) and hands-free engine (FSH1&FSH2), This study only involves SH2,FSH3 and FSH4.

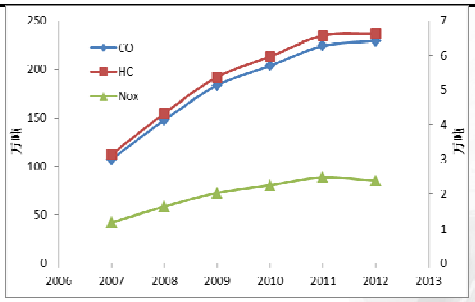
The average working time of SH2, FSH3 and FSH4 are 300, 500 and 1000 respectively.

发动机类别代号	工作容积 V/cm^3
SH1	V＜20
SH2	20≤V＜50
SH3	V≥50
FSH1	V＜66
FSH2	66≤V＜100
FSH3	100≤V＜225
FSH4	V≥225

Small general machinery emission factors & inventory

小型通用汽油 发动机排放因子

	HC(g/kW.h)			CO(g/kW.h)			NOx (g/kW.h)		
	SH2	FSH3	FSH4	SH2	FSH3	FSH4	SH2	FSH3	FSH4
Pre China	39.74	8.69	6.64	300.94	370.40	344.11	5.48	3.96	3.57
China Ⅰ	37.49	7.75	6.00	269.82	357.94	324.86	2.87	3.68	2.84
China Ⅱ	31.34	7.51	5.60	231.84	346.27	303.34	2.12	3.09	2.48



Non-road mobile source emission contribution

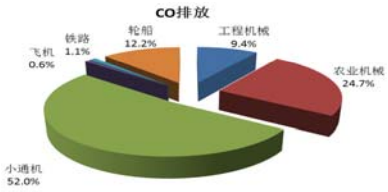


图 8.1 2011 年非道路移动源排放比例（CO）

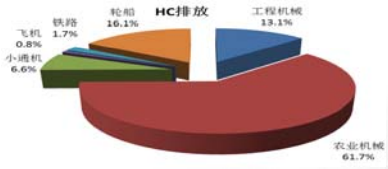


图 8.2 2011 年非道路移动源排放比例（HC）

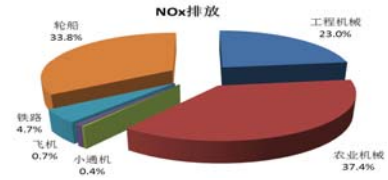


图 8.3 2011 年非道路移动源排放比例（NOx）

图 8.4 2011 年非道路移动源排放比例（PM）

Contribution proportion

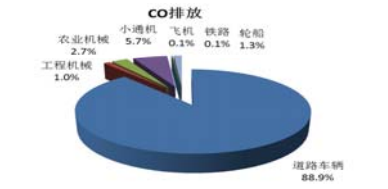


图 8.1　2011 年移动源排放比例（CO）

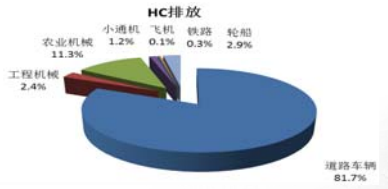


图 8.2　2011 年移动源排放比例（HC）

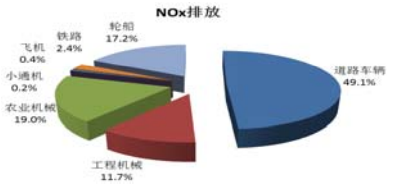


图 8.3　2011 年移动源排放比例（NOx）

图 8.4　2011 年移动源排放比例（PM）

Further works

- Engineering machinery, agricultural machinery, marine emission factor test are lack of test data of different power section. Currently, there no program for coastal vessel emission test. We need to constantly carry out non-road machinery emission test, and improve emission factor database.
- Considering the policy requirements for evaluating non-road mobile source GHG and PM2.5 emission effect, we should utilize existing data to supplement CO2 and PM2.5 emissions factor.
- We should establish contextual models for different emission standards, carry out emission inventory forecast, and provide policy suggestions for non-road mobile source emission control.

谢 谢 聆 听!

Thanks for your attention!