

Emission inventory of airport activities in Lombardy (Italy): methodologies and results

S.Caserini, A. M. Monguzzi, A. Fraccaroli, M. Moretti, E. Angelino.

ARPA Lombardia – Lombardy Regional Environmental Protection Agency – Viale
Restelli 3/1 20124 Milan, Italy, s.caserini@arpalombardia.it

Within the framework of the atmospheric emission inventory of the Lombardy Region, a region with 9 million inhabitants in Northern Italy, a detailed assessment of emissions from aircrafts and airport land activities in the three main airports of the region has been made for the year 2001, 2003 and 2005.

The inventory is based on a daily evaluation of LTO (Landing and Take-Off) cycle for each aircraft category, derived from data recorded in every airport, and on emission factors proposed by the EMEP/CORINAIR Emission Inventory Guidebook for the main aircraft types.

The paper shows hourly, daily and monthly emission patterns computed for every airport, as well as average emission factors.

Results point out that airports in Lombardy represent an interesting source of NO_x emissions (about 1% of total NO_x emissions in Lombardy in 2005), whereas for PM and other pollutants the contribution is lower.

A critical point of the emission assessment is the availability of reliable emission factors: for 35% of flights the emission factors were not available for the exact aircraft model and were hence based on similar types in size and engine characteristics.

Ground support equipments are also considered basing on fleet data and fuel consumption in every airport, as well as average emission factors proposed by the reference methodology for airport land activities.

LTO emissions are far higher than emissions from diesel vehicles used in land activities. NO_x emission density for airport area is comparable to those in urban areas, although emission elevation is far higher.

1. Introduction

Within the framework of the Regional Air Quality Management Plan (PRQA), the detailed atmospheric emissions inventory INEMAR (Regione Lombardia, 2007) has been set up by the Environmental Department of the Lombardy Region for the years 1997, 2001, 2003 and 2005; since the 2001 edition the inventory includes a thorough assessment of the atmospheric emissions from aircrafts and land activities in the three main airports of the region, Malpensa, Linate and Orio al Serio.

Please cite this article as: Caserini S., Monguzzi A.M., Fraccaroli A., Moretti M. and Angelino E., (2008), Emission inventory of airport activities in lombardy (italy): methodologies and results, Chemical Engineering Transactions, 16, 217-224

2. Methodology

Estimation of air traffic contribution

Combustion emissions from air traffic depend on the type of aircraft, the type of engines and fuel used, location (altitude) of operation and traffic volume (number of flights and distance travelled). Emissions come from use of kerosene and aviation gasoline (for small piston engines only) that are used as fuel by the aircraft. Aircraft can be categorized by use: commercial aircraft, used for scheduled service and transporting passengers, freight, or both; air taxis also fly for scheduled service carrying passengers and/or freight but they are usually smaller and operating on a more limited basis than the commercial carriers; business, usually on an unscheduled basis; general aviation, used for recreational flying, personal transportation, and various other activities.

The air traffic inventory is based on aircraft movement data about landing/take-off (LTO) cycle, that includes all activities near the airport taking place below the altitude of 1000 m (3000 feet): taxi-in and out, take-off, climb-out and approach-landing (Figure 1). Hourly flights data were provided by SEA (Società Esercizi Aeroportuali) and SACBO (Società per l'Aeroporto Civile di Bergamo – Orio al Serio), for each ICAO (International Civil Aviation Organization) category and nationality.

The distinction between national and international aviation is made as follows: all traffic between two airports in the same country is considered domestic no matter the nationality of the carrier. The air traffic is considered international if it takes place between airports in two different countries.

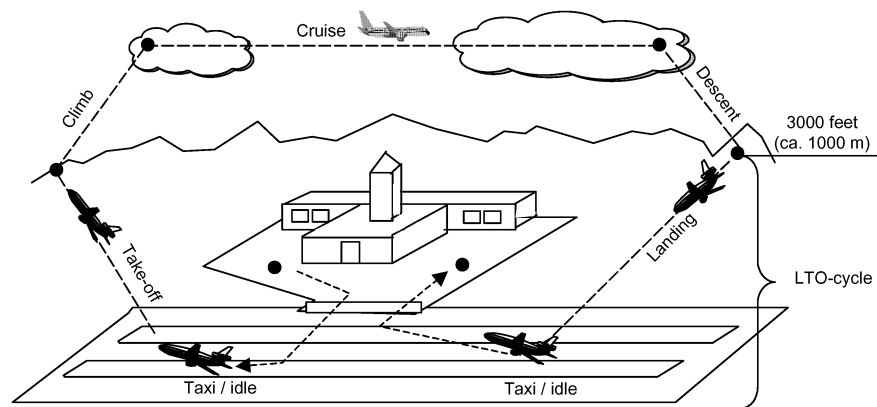


Figure 1. Standard flying cycles (EEA,2007).

Emission factors used in the inventory, derived from the European Atmospheric Inventory Guidebook (EEA, 2007), are expressed as mass of pollutant emitted during every stage of LTO cycle and are available for 45 aircraft types and 8 pollutants (SO_2 , NO_x , COV , CO , CO_2 and TSP). PM_{10} and $\text{PM}_{2.5}$ has been assessed using their ratio on TSP emissions, basing on data provided by the US-EPA Air CHIEF (US-EPA, 2004). Emission factors were not available for 80% of the aircraft categories, mostly small models, in operation in Lombardy, corresponding to 35% of total flights in 2005.

Emissions from these aircrafts have been assessed grouping them into representative categories, taking into account their size and engine characteristics (power and type: piston, turbojet and turboprop), and using emission factors from the most similar type of aircraft available.

Estimation of ground support equipment contribution

The terms “ground support equipment” or GSE, usually refer to the transport of passengers, crews and luggage inside the airport, service vehicles and machines for catering and other services for aircrafts (anti-icing and de-icing of aircraft, fuelling and fuel handling, maintenance of aircraft engines) and for the airport runways (clearing of snow, mowing of grass).

Emission valuation is based on fleet data (type and number of vehicles, fuel feeding, total working hours) and annual fuels consumption in every airport, as well as average emission factors proposed by the reference methodology for off-road vehicles and machines of European Atmospheric Inventory Guidebook (EEA, 2007).

As ground support equipments are often similar for different aircraft models, they have been split in seven categories basing on their engine power and fuel type; for each LTO cycle the number of vehicle used by each category, the annual working hours and typical load factors (ratio of really consumed and maximum load used fuel) has been defined.

Figure 2 shows the percentage distribution of ground support equipments for the power ranges considered: Linate fleet, traced in the innermost ring, has a fairly homogeneous structure with only 2% of diesel vehicles bigger than 130 kW and the lack of the ones of 20-37 kW category; Malpensa fleet, in the outer ring, has a remarkable presence of gasoline cars.

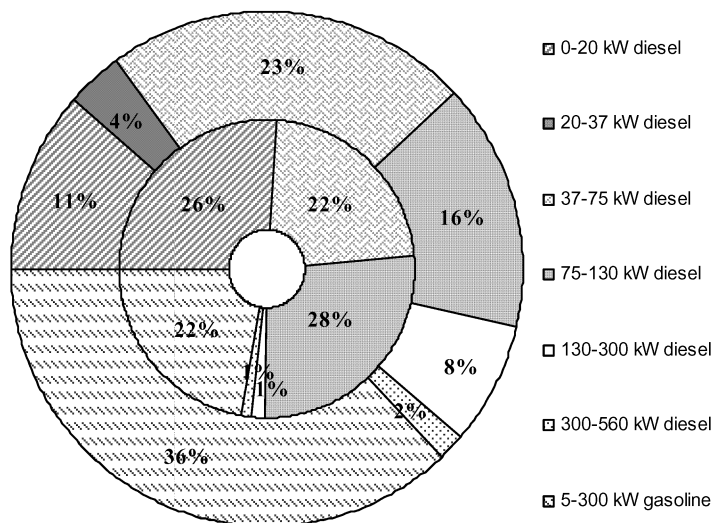


Figure 2. Percentage distribution of ground support equipments into the seven power ranges (kW) considered, in Linate e Malpensa airports, reference year 2005.

3. Results And Discussion

The emissions of the three airports in Lombardy, Malpensa (MXP), Linate (LIN) and Orio al Serio (BGY) for SO₂, NO_x, VOC, CO, CO₂, PM_{2.5} and PM₁₀, as compared with overall regional emissions, are shown in Table 1.

Aircraft main contributors to regional emission are NO_x (1.2% of total NO_x emissions in Lombardy in 2005), CO (0.8%), CO₂ and SO₂ (0.7%), whereas for PM (0.2%) and VOC (0.4%) the contribution is lower.

Figure 3 shows emissions of the three airports for 2001, 2003 and 2005 inventories; the growing emission trend is due to the increase in the number of flights (+10% compared to 2001), as well as the aircraft average size that influences fuel consumption and consequently emission factors.

Table 1. Annual flights number and emissions from Malpensa, Linate and Orio al Serio airports in comparison with regional emissions, reference year 2005 (t y⁻¹).

Year 2005	Flights	SO ₂	NO _x	VOC	CO	CO ₂	PM _{2.5}	PM ₁₀
	n°	t y ⁻¹	t y ⁻¹	t y ⁻¹	t y ⁻¹	kt y ⁻¹	t y ⁻¹	t y ⁻¹
Malpensa	224,598	107	1,419	840	2,065	327	19	20
Linate	119,007	88	604	424	1,001	159	10	11
Orio al Serio	47,831	25	282	87	351	67	4	4
Total airport activities	391,436	220	2,305	1,351	3,417	553	33	35
Lombardy Region		29,813	193,226	352,628	442,301	78,699	19,553	23,204
% of total emission in Lombardy		0.7	1.2	0.4	0.8	0.7	0.2	0.2

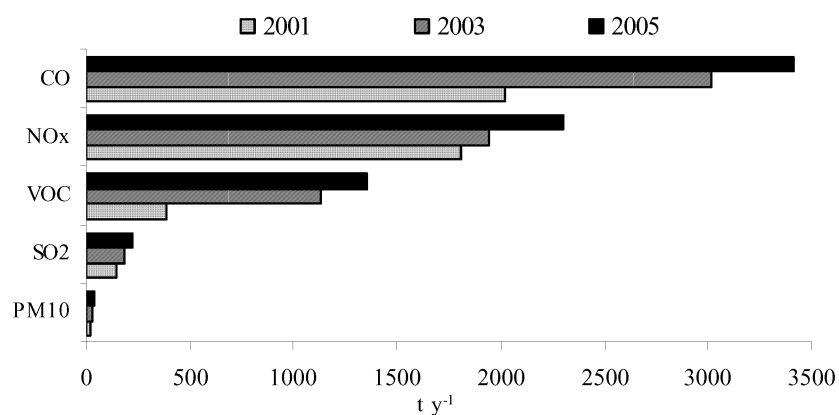


Figure 3. Annual emissions from Malpensa, Linate and Orio al Serio airport in 2001, 2003 and 2005 (t y⁻¹).

Emissions for every airport were divided among municipalities crossed by aircraft routes during LTO cycle, taking into account the frequency of covering the routes (by landing/take-off aircrafts) and the extent of the same routes in each municipality. The portion of route to be considered has been defined basing on the average slope of LTO cycle, which leads to distance of about 5 km from the runway.

An hourly, daily and monthly emission pattern is available for every airport, as well as average emission factors. The percentage distribution of hourly NO_x and CO_2 emissions due to flight operations is shown in Figure 4, where is clear the traffic flow during the day with hour peaks well-rendered for Malpensa.

Daily emissions in Figure 5 are comparable around the whole month.

In terms of monthly emissions, Figure 6 shows an opposite trend in the two airports: Malpensa highlights bottom values during winter time, in February and November, and a peak in July, linked to charter flights, while Linate, where business traffic overbears, shows decreasing emissions during holiday's periods, in August and January.

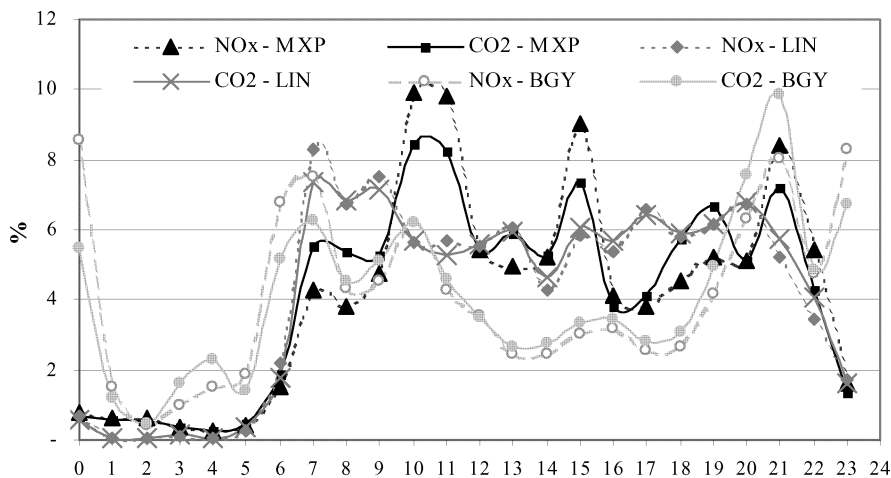


Figure 4. Percentage distribution of NO_x and CO_2 hourly emissions in Linate (LIN), Malpensa (MXP) and Orio al Serio (BGY) airports, reference year 2005.

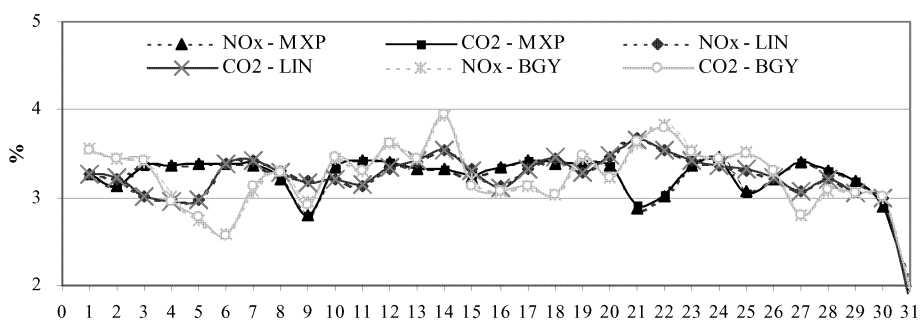


Figure 5. Percentage distribution of NO_x and CO_2 daily emissions in Linate (LIN), Malpensa (MXP) and Orio al Serio (BGY) airports, reference year 2005.

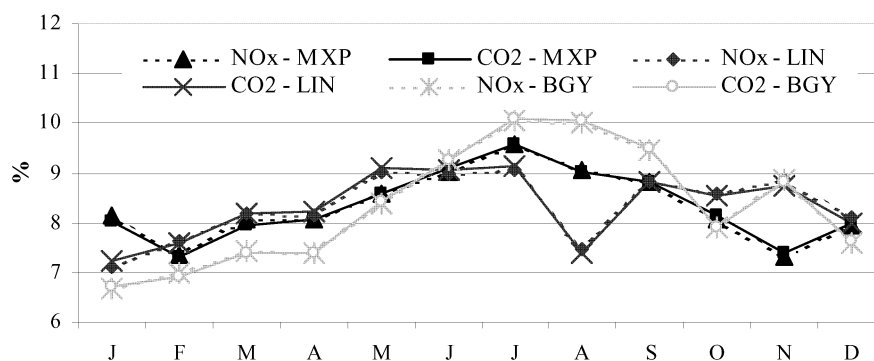


Figure 6. Percentage distribution of NO_x and CO_2 monthly emissions in in Liniate (LIN), Malpensa (MXP) and Orio al Serio (BGY) airports, reference year 2005.

Table 2 shows a comparison between aircraft traffic emissions and ground support equipment (GSE) ones in Malpensa, Liniate and Orio in 2005; LTO emissions are far higher than emissions from diesel vehicles used in land activities.

NO_x e PM_{10} emission density for airport areas (Table 3), calculated by the ratio between total airport emission (Table 2) and the overall area of the airport, are comparable to emission density in urban areas; the latter has been calculated by the ratio, in every municipalities, between emissions assessed by the regional emission inventory (Regione Lombardia, 2007) for the year 2005 and the extension of urbanized area in the vector Lombardy cartography (Regione Lombardia, 2008). Figure 7 shows that more than one hundred of the 1546 municipalities of Lombardy Region have NO_x emission density above 100 t km^{-2} . If emissions density from airports is assessed considering all the area interested by the LTO cycles (a 5 km radius centered on the airport), results are comparable with central values of the distribution of road transport emission density in Lombardy (Figure7).

Table 4 shows a comparison between average emission factors for LTO cycle of main aircrafts in Malpensa, Liniate and Orio in 2005; greater CO emission factors are interrelated with greater VOC ones, although NO_x emission factors are not high.

Table 2. Annual emissions from aircraft traffic in comparison with GSE (ground support equipment) ones in Malpensa, Liniate and Orio, reference year 2005 (t y^{-1}).

Year 2005	SO_2	NO_x	VOC	CO	CO_2	PM_{10}
	t y^{-1}	t y^{-1}	t y^{-1}	t y^{-1}	kt y^{-1}	t y^{-1}
Aircraft traffic	218	2,129	1,318	2,929	544	21
GSE	2.2	176	33	488	9.6	14
% GSE/Aircraft traffic	1.0	8.3	2.5	17	1.8	68

Table 3. Annual NO_x and PM₁₀ emission density ($t\ km^{-2}$) for airport areas and LTO areas of Malpensa, Linate and Orio al Serio, reference year 2005.

	Area	NO _x	PM ₁₀	LTO Area	NO _x	PM ₁₀
	km ²	t km ⁻²	t km ⁻²	km ²	t km ⁻²	t km ⁻²
Malpensa	12	116	1.7	79	18	0.30
Linate	4.0	153	2.7	79	8.0	0.10
Orio al Serio	3.5	81	1.2	79	4.0	0.10

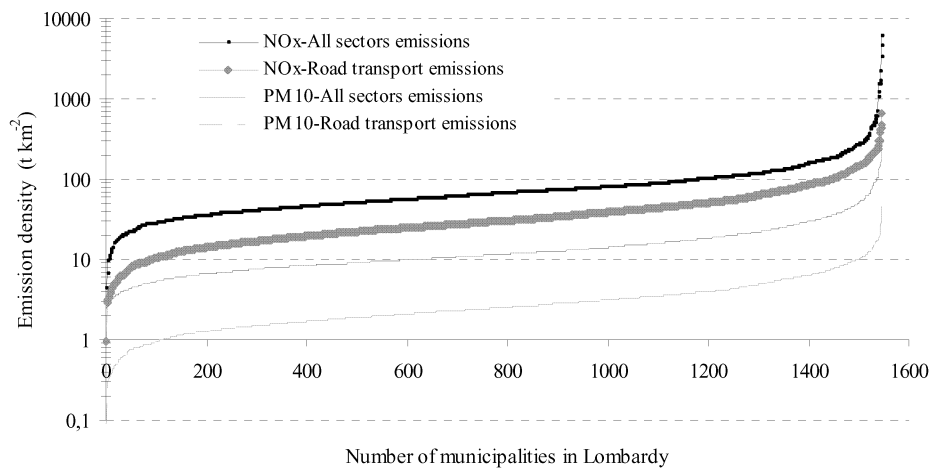


Figure 7. NO_x and PM₁₀ emission density ($t\ km^{-2}$) for all inventory sectors and for road transport in urban areas of Lombardy municipalities.

4. Conclusions

A detailed airports emission inventory has been made in Lombardy, basing on the reference methodology proposed by the EMEP-CORINAIR and accurate flights data available at the local level.

Possibilities of improvements are associated with the incomplete availability of emission factors for all aircraft categories operating in the three Lombardy airports; further work and measurements are needed in order to better grouping aircraft models into representative categories with emission factors available. Another weak point of the assessment is linked to GSE (ground support equipment) emission; although their contribution is far lower than LTO cycles, emission valuation depends on the power of the engine, the load factor and the operational time, thus they are not directly comparable with data used for road transport emission assessment.

NO_x and PM₁₀ emission density from airport activities is comparable with emission density in urban area.

Table 4. Average emission factors (kg LTO⁻¹) for LTO cycle of main aircrafts in Malpensa, Linate and Orio, reference year 2005 (t y⁻¹).

Icao code	Flights n°	NO _x	SO ₂	CO	CO ₂	PM10	VOC
		kg LTO ⁻¹	kg LTO ⁻¹	kg LTO ⁻¹	t LTO ⁻¹	kg LTO ⁻¹	kg LTO ⁻¹
B744	2,479	28.9	1.7	11.0	5.4	0.1	1.0
B742	773	28.8	1.7	11.0	5.4	0.1	1.0
B772	4,027	27.3	1.3	31.9	4.1	0.1	11.5
MD11	2,827	21.3	1.2	32.1	3.8	0.1	11.5
A332	3,078	18.5	1.1	12.0	3.5	0.1	1.1
B763	10,789	13.5	0.8	4.3	2.6	0.1	0.5
A30B	4,011	13.5	0.8	4.3	2.6	0.1	0.5
B762	1,447	13.4	0.8	4.3	2.6	0.1	0.5
A310	1,510	12.0	0.8	14.2	2.4	0.1	2.9
B752	7,082	10.3	0.6	7.5	2.0	0.1	0.7
B733	10,427	6.6	0.5	4.5	1.6	0.1	1.0
MD82	71,204	6.6	0.5	4.5	1.6	0.1	1.0
B735	5,193	6.6	0.5	4.5	1.6	0.1	1.0
B737	2,803	6.6	0.5	4.5	1.6	0.1	1.0
A321	25,845	5.9	0.4	10.0	1.3	0.1	1.0
A320	43,879	5.8	0.4	10.1	1.3	0.1	1.0
B734	26,283	4.6	0.4	7.2	1.3	0.1	0.4
A319	22,313	4.6	0.4	7.2	1.3	0.1	0.4
B738	20,464	4.6	0.4	7.2	1.3	0.1	0.4
E170	6,501	3.3	0.4	8.1	1.2	0.1	0.8
F100	3,340	3.3	0.4	8.1	1.2	0.1	0.8
CRJ2	7,367	3.0	0.3	17.6	1.1	0.1	16.5
E145	26,982	3.0	0.3	17.6	1.1	0.1	16.5
RJ1H	4,534	2.5	0.3	6.1	0.9	0.1	0.6
AT72	12,855	1.2	0.1	1.6	0.3	0.1	0.1

5. References

- EEA, 2007, Atmospheric Emission Inventory Guidebook 3rd edition, European Environment Agency, EMEP - CORINAIR, Copenhagen, <http://reports.eea.eu.int/EMEP-CORINAIR/en>.
- Regione Lombardia, 2007, INEMAR Emission Inventory, <http://www.ambiente.regione.lombardia.it/inemar/inemarhome.htm>.
- Regione Lombardia, 2008, Base dati geografica di sintesi - vettoriale. <http://www.cartografia.regione.lombardia.it/portale>
- US-EPA, 2004, Air CHIEF ver. 11. Emission Factor and Inventory Group, Inventories and emission Factor (CHIEF), EPA454/C-04-001, www.epa.gov/ttn/chief.