Airport Contributions to Local Air Pollution Case Study: Rio de Janeiro International Airport

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Abstract

This paper outlines a procedure for estimating the relative contributions by airports to local air pollution, taking into account the operations of aircraft, as well as support vehicles and equipment, in addition to any other items required for routine airport activities. A selected set of air pollution sources is taken as a comparative reference, drawn from the airport surroundings. The results of this procedure help identify each source of emission by relative importance, indicating the principal actions required to lower these emissions. A case study is presented based on specific information for the Rio de Janeiro International Airport – RJIA.

1 Introduction

Air pollution is an environmental issue causing much concern, which must be taken under consideration in areas with large airports handling heavy air traffic, such as those found in several Brazilian State capitals. Local air quality and in the surrounding area is directly influenced by the profile of the pollutant emissions caused not only by aircraft operations but also by all the support vehicles and equipment that meet the technical, logistics and operating requirements of the aircraft when on the ground [1][2], representing a complex set of sources of air pollutant emissions that require constant monitoring.

The purpose of this paper is to suggest the procedure for estimating the relative contribution of air pollutant emissions caused by airport operations, caused not only by aircraft but also the support vehicles and equipment for other activities that are vital to the functioning of the Airport. As a comparative reference, the potential sources of air pollutant emissions are taken under consideration for the region surrounding the Airport. The results of this procedure will help identify the relative importance of each source of emission and guide high-priority actions for reducing these emissions. This paper was prepared on the basis of the initial section of a study of air quality in airports commissioned by the Brazilian Airport Infrastructure Authority (INFRAERO). The case study presented is based on information that is specific to the Rio de Janeiro International Airport – RJIA [3].

2 Brief description of the procedure

Three aspects guided the preparation of the procedure for estimating the emissions. (1) the influence of the Airport Authority over the sources of the emission; (2) the possibility of using the results in an air pollution dispersal study, and (3) the possibility of reconciling the data available with the results desired. The selected approach was adapted from the detailed emissions estimation method prepared by the Intergovernmental Panel on Climate Change – IPCC[4]. For the first aspect, the sources of air pollutant emissions were classified as internal, noted in the area under the direct influence of the Airport Authorities, and external, noted in areas outside the influence of the Airport Authorities, usually the neighborhoods surrounding the Airport. For both cases, the sources can be classified as mobile, when their positions vary over time or fixed. This is an important aspect for characterizing the emissions profile of each source during the day, producing results that can be used later in a pollutants dispersal study [3].

Assuming that each of the fixed sources under analysis consists of a set of contributing elements with an Emission Factor (EF) for a specific Pollutant (POL), the Fixed Source Emission Volume (FSEV) for this pollutant may be calculated through Equation 1.

$$\mathrm{FSEV}_{\mathrm{POL}} = \sum_{i=1}^{n} \mathrm{P}_i . \mathrm{EF}_{\mathrm{POL},i} \qquad (1)$$

Where: $\mathrm{FSEV}_{\mathrm{POL}}$ and $\mathrm{EF}_{\mathrm{POL},i}$ are given by mass units per time unit; i, varying from 1 to n, are all the contributing elements in the fixed source emitting the pollutant under study (POL). P is the relative share held by the contributing factor i in the set of emissions from the fixed source

In order to calculate the Mobile Sources Emissions Volume (MSEV) it is necessary to know the volume (V) contribution from each of these sources, expressed by the quantity of mobile sources in the region under study, by time unit. The MSEV may be calculated through Equation 2.

$$\text{MSEV}_{\text{POL}} = \text{V}.\sum_{i=1}^{n} \text{P}_i.\text{EF}_{\text{POL},i} \qquad (2)$$

Where: MSEV_{POL} is given by mass units per time unit; $\text{EF}_{\text{POL},i}$ is given by mass unit per time volume unit contribution from the source; P is the relative share held by the source i in the set of e missions.

It is possible to propose a procedure divided in 5 Stages. Stage 1 identifies the area under study. Stage 2 then determines the sources of emission within the area and identifies the air pollutant to be analyzed. Having determined the sources of emission, they are then classified as fixed or mobile in Stage 3, in order to apply the relevant equations. In order to determine the Emission Factor (EF) it is recommended that a survey of the emissions be carried out, or if not possible, the theoretical limits of the emission should be identified. Through Stage 3, the terms of Equations 1 and 2 (P, EF and V) are obtained, with its application in Stage 4. A critical operation situation is rated as being that with the highest pollutant emissions volumes per time unit. The successive application of Stage 4 throughout a specific period of time provides the emission profile. Stage 5 outlines these profiles and undertakes the comparisons.

3. Application of the procedures to the Rio de Janeiro International Airport

An application of this procedure is presented based on information specific to the Rio de Janeiro International Airport. Within this context, the area of the study to be identified in Stage 1 is limited to the premises of the Rio de Janeiro International Airport and its immediate neighborhood [3]. As this is a study on the contribution made by regulated local air-pollutant emissions [5], Stage 2 merely identified the emissions of nitrogen oxides (NO_x), particulate matter (PM), carbon monoxide (CO) and volatile organic compounds except methane (HC). The sulfur oxides (SO_x) were not taken under consideration, as there are no Brazilian regulations imposing constraints on these gases emitted by road vehicles. For Stages 2 and 3, in terms of the sources of emissions, the air pollutions were analyzed coming from the internal mobile sources, consisting of the functioning of operations support equipment and vehicles, and the aircraft themselves, during the many different activities involved in landing and takeoff procedures. The mobile external sources come from vehicle traffic on the roads near the Airport, identified as Avenida 20 de Janeiro, providing access to the Airport, Estrada do Galeão and the Linha Vermelha expressway, running alongside the Airport premises. The main fixed internal source is the solid waste incinerator. No external fixed sources were noted nearby in the neighborhood. As it was impossible to obtain the survey of the emissions, the aircraft emission factors used for Stage 4 were those established by the IPCC [6].

For Stage 3, and based on the fleet and equipment registration data presented by [7], it was noted that 84% of the fleet was manufactured before 1996, and 65% of the fleet is more than ten years old. Lacking more specific surveys, this indicates the selection of the emission limits determined by Phase II of the Automotive Vehicles Air Pollution Control Program (PROCONVE – *Programa de Controle da Poluição do Ar por Veículos Automotores*) for emissions of CO, NOx and HC, and Phase III for the particulates matter [8]. Through cross-referencing manufacturing information (brand), as well as model and tank capacity (fuel), taken from the equipment and fleet records [7] in addition to the manufacturers handbooks and an understanding of the operations obtained through the field survey of the premises of the Rio de Janeiro International Airport [3], it was possible to classify the support vehicles by horsepower and rpm, characterizing their operating system. It was assumed that most of the tractors are fitted with 86 HP engines (capacity below 85 kW) with the engines running at 2,500 rpm, with fur cylinders. The aircraft tow-tractors/push-backs have an average capacity of 190 HP and six-cylinder engines, being classified as vehicles with a capacity of over 110 kW [9].

For auxiliary power generation equipment (APU), as well as air conditioning and low-pressure supply units, the calculations take the emission limits as being similar to those for diesel-powered generators, with factors of 0.032 g/kWh for emissions of particulate matter, 4.68 g/kWh for emissions of NO_x [10]. For the HC and CO emissions, the same factor was adopted as used for diesel vehicles, as a conservative hypothesis, as diesel engines for vehicles post emission levels that are higher than those for stationary engines, due to their non-uniform operating system [11]. Furthermore, the auxiliary power generation units were assumed to have an average capacity of 300 kW [9].

In order to calculate the emissions for the external mobile sources, it was assumed that the vehicles traveling on the roads outside the Rio de Janeiro International Airport are similar to the composition of the fleet in Rio de Janeiro State in terms of age and type of fuel used [12]. For these mobile sources, the vehicle emission factors (EF) were used, obtained from [13] for the Rio de Janeiro Metropolitan Region fleet.

The internal fixed-source emission factors were based on the studies carried out by WS Engenharia Ambiental, [3]. Although the incinerator has two burners that can operate simultaneously, under normal operations at the Rio de Janeiro International Airport, only one burner is in operation, from 8:00 to 17:00.

In order to characterize the critical selection as part of Stage 4, a day with heavy aircraft traffic was selected [7]. Table 1 lists the main aircraft involved for LTO on the day in question. LTO is taken as being a complete Landing + Take-Off operation for an aircraft. The specific characteristics of the aircraft were taken under consideration for each type of operation, complying with the classification under domestic flights (D) and international flights (I), with the percentage contribution by each aircraft to the total of these LTOs (P), the distribution of the flight times throughout the day, and the number of LTOs for each hour in operation. For the support vehicle traffic, it was assumed that 11% of the LTOs on a typical day use a larger number of support vehicles, as required by older aircraft and/or those halted in more remote parts of the airfield, and not using extendable walkways (fingers) for boarding and departing passengers [3]. The remaining LTOs require fewer vehicles and less support equipment The calculations are based on the average functioning time of each support vehicle per LTO taken as being approximately thirty minutes, other than the aircraft tow-tractors/push backs, whose operating time per LTO was estimated at 6 minutes [3].

The hourly vehicle volumes were noted on the Linha Vermelha expressway [14] on the stretch running alongside the Rio de Janeiro International Airport Cargo Terminal. The composition of this fleet follows the same profile as the fleet in Rio de Janeiro State [12] in terms of type of vehicle. This estimate was ratified by fifteen minutes of classified volumetric counting. The day selected was a peak period, allowing this calculation to include the most critical situation, meaning a day of heavy traffic, together with much activity at the airport. The stretch of road running alongside the Airport was taken as covering 4.5 kilometers. For the Estrada do Galeão highway, the same considerations prevail, although noting that the traffic volumes differ by area [15]. Along the stretch between the exit from the Linha Vermelha expressway and the access road leading to Avenida 20 de Janeiro (leg 1) the traffic volume was more intense, partially affected by traffic going to the Rio de Janeiro International Airport. Along the leg between the access road leading to Avenida 20 de Janeiro and the end of the area under study (leg 2), the traffic volume was less intense, consisting only of vehicles going to Ilha de Governador. Legs 1 and 2 run 1.6 and 5 kilometers respectively. A classified traffic volumetric count was taken at Avenida 20 de Janeiro over 24 hours, and the survey of this thoroughfare gave a length of 3.95 kilometers for this stretch [16].

For the conclusion in Stage 4, Equations 1 and 2 were applied to the fixed and mobile sources respectively. An example of this application is given in Equation 3, for calculating the profile of the aircraft emissions ($VEA_{H,POL}$). In this case, the variable V in Equation 2 takes the following values: LTO_D and LTO_I (Table 7 – Columns 2 and 3) and Index H indicates that the calculation is carried out on an hourly basis throughout the day, representing the critical situation.

$$VEA_{H,POL} = \frac{1}{3.6}.[LTO_{H,D}.(\sum_{i=1}^{8} P_{D,i}.FE_{POL,i}) + LTO_{H,I}.(\sum_{j=1}^{3} P_{I,j}.FE_{POL,j})] \qquad (3)$$

Where: 3.6 = Conversion factor from [kg/h] to [g/s]; POL: CO, NOx, HC and PM; H: Varies from 00:00 to 01:00 up to 23:00 to 24:00, i: Types of aircraft used for Domestic flights, j: Types of aircraft used for International flights.

As an initial part of Stage 5, a similar application was used for the support vehicles and equipment, as well as for all external traffic, giving the emissions profiles for the internal and external mobile sources over the 24 hours of the day rated as a critical situation.

4.Comparative analysis of contributions

Supplementing Stage 5, in order to analyze the contributions from each source, in terms of the current pollutant emissions in the area under study, three comparisons were carried out. To do so, the total mass of pollutants emitted was analyzed over 24 hours for each contributing element individually, following the respective operating systems. It is important to stress that this initial analysis was intended to identify the relative contribution to air pollution by the emissions from each sector, rather than qualifying their effects on air quality. Initially, the contributions to air pollution were compared for the two scenarios, considering the existence and non-existence of the Rio de Janeiro International Airport in the area where it is currently established.

Table 1. Selected comparison scenarios

Scenario	Status	Emissions [kg/day]			
		CO	HC	NOx	PM
A	Without Airport	14,850	2,300	1,831	116
B	With Airport	21,308	3,961	4,603	277
	Airport contribution	30.3%	41.9%	60.22%	58.12%
	Additional Airport contribution	43.39%	72.21%	151.39%	138.79%

Scenario A covers only the emissions produced by traffic on the Linha Vermelha expressway and the Estrada do Galeão highway (lower volume – leg 2) as, if the Rio de Janeiro International Airport did not exist, neither would Avenida 20 de Janeiro, and consequently the road traffic around the airport facilities would drop. Scenario B covers the internal emissions by the Rio de Janeiro International Airport, as well as those from Avenida 20 de Janeiro and others caused by increased road traffic on the Estrada do Galeão highway. As indicated by the results shown in Table 1, it is estimated that under its current operating conditions, the Rio de Janeiro International Airport causes an additional 43.49% increase in emissions of CO, 72.21% for HC, 151.39% for NOx and 138.79% for PM in the area under analysis, compared to the emissions for the scenarios covering the existence (B) and non-existence (A) of the Rio de Janeiro International Airport.

A second comparison carried out on the basis of the current operating system at the Rio de Janeiro International Airport estimated that the internal activities on its premises account for the emissions presented in Table 2, also indicating the individual contribution made by each activity to local air pollution.

Table 2. Emissions from internal sources – Rio de Janeiro International Airport

Emissions [kg/day] / Individual Contribution [%]								
Source	CO	%	HC	%	NOx	%	P. M.	%
Air Traffic	2,519	76.10	999	85.24	1,588	65.97	89	64.40
Support Vehicles and Equipment	791	23.90	173	14.76	805	33.44	29	20.86
Incinerators	na	-	na	-	14	0.59	21	14.74
Total	3,310	100	1,172	100	2,407	100	139	100

Note: na = not available

The participation of the support vehicles in causing air pollution is particularly noteworthy, largely with regard to the NOx emissions whose values are comparatively high. The emission of pollutants by the incinerators is negligible, compared to levels for other sources, particularly for the substances analyzed (CO, NOx, HC and PM). Burning solid wastes causes emissions of other types of toxic substances that are not assessed in this Paper.

Finally, a third comparison is given in Table 3, summarizing the contributions to air pollution caused by activities related to the current operating system at the Rio de Janeiro International Airport. This draws a comparison between the external sources of pollutant emissions caused by outside road traffic and the internal sources of pollutant emissions caused by the activities of the Airport itself.

Table 3. Relative contributions to air pollution

Emissions (kg/day) / Individual contribution (%)								
Contributing factors	CO	%	HC	%	NOx	%	P.M.	%
External traffic	17,998	84.46	2,788	70.38	2,196	47.,70	139	50.18
Rio de Janeiro International Airport	3,320	15.54	1,173	29.62	2,407	52.30	138	49.82
Total	21,308		3,961		4,603		277	

Within this context, it is noted that the Rio de Janeiro International Airport is a heavy emitter of NOx and PM, at 52.30% and 49.82% respectively. On the other hand, external traffic is the main factor responsible for emissions of CO and HC.

Figure 1 presents the emissions profile (g/s) for air traffic and the operations of support vehicles and equipment during the day under study. The curves indicate that the pollutant emissions vary in the course of the day, peaking in the morning between 05:00 and 12:00, as well as in the evening and first part of the night between 17:00 and 23:00. These periods with higher emission volumes account for 77.07% of the total emissions for the day under analysis, with 38.76% produced by the morning peak and 38.31% by the evening peak.

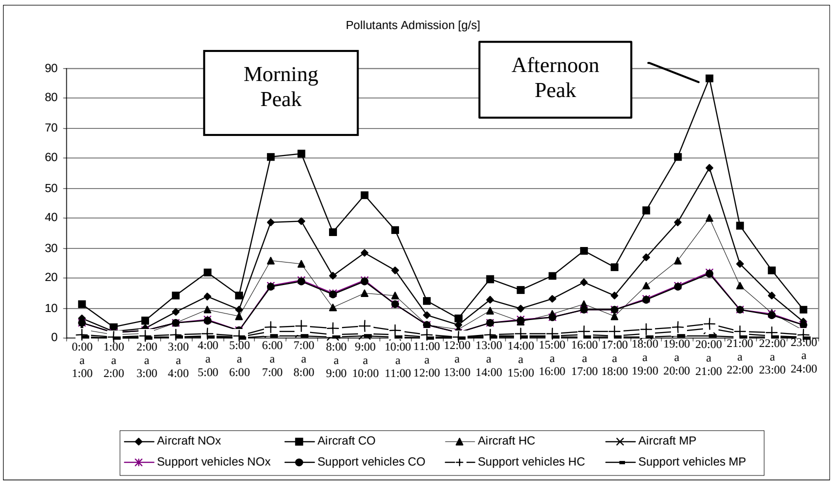

Figure 1. Emissions profile – internal sources, Rio de Janeiro International Airport.

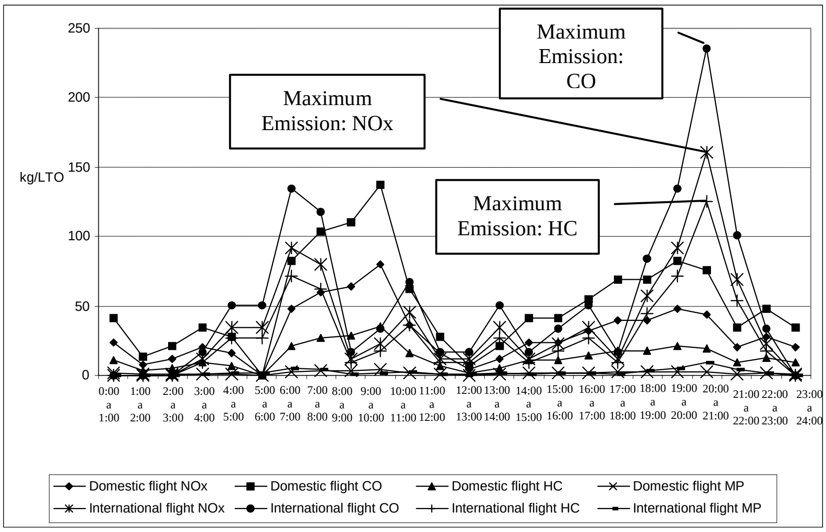

Figure 2. Air Traffic Emissions Profile, Rio de Janeiro International Airport

Another significant aspect related to internal sources of emission is shown in Figure 2. As international flights operate with larger aircraft, they make a decisive contribution to pollutant emissions, as shown during the period running from 17:00 to 23:00, when the LTOs of these flights are most frequent. The three highest: CO, NOx and HC emission volumes during the critical day were observed from 20:00 to 21:00. The domestic LTOs are more evenly distributed throughout the day, evening out their contribution to air pollutant emissions. It should also be recalled that although representing 26.03% of the LTOs at the Rio de Janeiro International Airport, international flights contribute to over one half of the emissions of NOx (54.84%), CO (50.84%), HC (68.11%) and PM (54.32%).

5.FINAL COMMENTS AND RECOMMENDATIONS

The procedure presented proved adequate for estimating the contributions by internal and external sources of pollution at airports and the emissions profile for these sources, in a critical situation. This latter result is particularly important, as it provides the input data needed to assess air pollution dispersal as well as the relative contribution by airports for local air quality. The concept of this procedure includes some refinements, as it involves parameters related to the vehicle operating system and the characteristics of their fuels and engines. These characteristics make its application flexible, allowing it to be used in other similar situations, including for calculating global air pollutant emissions such as CO_2 and CH_4, for instance.

With regard to the case study, some conclusions have already been listed in Section 4. However, it is also appropriate to stress the relevance of the emissions caused by the operations of the support vehicles and equipment, which contributed significantly to NOx, CO and PM emissions, all at over 20%. Even if not explicitly stated, it was also noted that, despite the fact that the support vehicle traffic is far lower than traffic on the outside roads, these emissions are comparatively high [3]. As these are internal sources, under the direct influence of the Airport authority, they could be controlled by INFRAERO.

This situation justifies the suggestion that a set of measures should be introduced in order to reduce the participation of these sources in the total internal emissions. These measures could be implemented through programs run by the INFRAERO management, stressing: (1) Fuel Consumption Reduction and Control Program – implementing a set of measures in order to guide the operators on how to fine-tune the functioning of the engines running this equipment; (2) Vehicle Tuning and Inspection Program – Introduction of a regular inspection system for the emissions produced by support vehicles and equipment for the ground operations of the aircraft, particularly those whose operations are limited to the runways and are consequently not subject to regular inspection by the Municipal Traffic Departments, and (3) Alternative fuels program, designed to substitute traditional fuels by others with lower pollutions emission factors such as natural gas or renewable sources such as ethanol and biodiesel (Ribeiro *et al.*, 2001).

Another significant aspect consists of the emissions by international air traffic. This situation should be carefully analyzed when planning to step up traffic flows at the Rio de Janeiro International Airport – AIRJ, striving to schedule the flights more evenly whenever possible. It should also be recalled that increased air traffic will prompt a proportional rise in the operations of support vehicles and equipment.

The lack of information and the impossibility of carrying out field surveys for specific pollutant emissions factors based on the sources studied resulted in the adoption of theoretical limits, meaning that this case study requires fine-tuning. It is suggested that a survey be undertaken of the specific pollutant emission factors for each sources assessed: vehicles, support equipment and aircraft. This comment does not invalidate these results, as the intention was obtain an indicial estimate of airport contributions to local air pollution.

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