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Inventory of conventional air pollutants emissions from road transportation for the state of Rio de Janeiro

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HIGHLIGHTS

- ► We estimate road transportation emissions for Rio de Janeiro from 1980 to 2010.
- ► *C* gasoline was most responsible for CO (74%) and diesel for PM (91%).
- ► Emissions/vehicle for Rio de Janeiro are (12% to 59%) smaller than Brazilian.
- ► 1,760,370 t of emissions was avoided using non-petroleum-based fuels.
- ► Strategies to reduce the emissions of these air pollutants were proposed.

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ABSTRACT

Road transportation has contributed to increased emissions of conventional air pollutants and, consequently, to the increase in problems associated with the environment and human health, depending on the type of pollutant and the concentration of it. To support the development of public policies aimed to decrease total tonnes of emissions, we used a bottom-up approach to estimate the amount of air pollutants, such as carbon monoxide (CO), total hydrocarbons (THC), nitrogen oxides (NO_x), particulate matter (PM), and aldehydes (RCHO), that are emitted by road transportation in the state of Rio de Janeiro (RJ) from 1980 to 2010. The results from 2010 show that cars are responsible for 55% of CO emissions, 61% of THC emissions, and 93% of RCHO emissions. Due to the use of hydrated ethanol and compressed natural gas (CNG) instead of petroleum based fuels during the period analyzed, 1,760,370 t of air pollutant emissions were avoided. Compared to Brazil, in 2010, RJ had a quantity of emissions per vehicle from 12% (CO) to 59% (PM) smaller than the national average. As strategies to reduce air pollutant emissions, we consider reducing the intensity of use, with a proportional reduction in emissions, and increased the use of biodiesel.

1. Introduction

Due to an energy dependency on petroleum products such as gasoline and diesel fuel, road transportation has contributed decisively to the emission of atmospheric pollutants, with consequent problems for the environment and human health (Faiz, 1993; Colvile et al., 2001; Saija and Romano, 2002; Öner and Altun, 2009; Uherek et al., 2010; and Progiou and Ziomas, 2011).

According to the Brazilian Ministry of Mines and Energy (MME), Ministério de Minas e Energia [Ministry of Mines and Energy], 2011, in 2010, the transportation sector consumed 53.1% of petroleum derivatives, of which 90% was used in road transportation. By analyzing the Brazilian states, we see that the state of Rio de Janeiro follows the national trend and stands out with the second highest Gross Domestic Product (GDP) in the country (11.3%) (IPEA, 2011). During the next five years (2012 to 2016), it will host international events such as the World Cup in 2014, and the Olympic Games in 2016.

Because of Rio de Janeiro's contribution to the Brazilian economy and its global exposure, it is important to identify the state's contribution to atmospheric pollutant emissions from road transportation in order to highlight upcoming opportunities to show the rest of the world how a country can successfully make the transition to cleaner transportation.

In the last two decades, the automobile industry has invested in technologies to reduce the emissions of air pollutants from

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road motor vehicles, prompted by stricter legislations. To support the development of public policies aimed to decrease total tonnes of emissions, it is essential to preparing an inventory of air pollutants emitted by the transportation sector in the state of Rio de Janeiro, specifically road transportation by its importance.

In this context, this study aimed to (1) estimate the quantity of conventional air pollutants such as carbon monoxide (CO), total hydrocarbons (THC), nitrogen oxides (NO_x), particulate matter (PM), and aldehydes (RCHO) emitted by road transportation in the state of Rio de Janeiro from 1980 to 2010; (2) compare the fleet size of road motor vehicles, fuel consumption, and emission of these pollutants in the state of Rio de Janeiro with those of Brazil; (3) verify the avoided emissions by using non-petroleum based fuels, such as hydrated ethanol and CNG, and (4) propose strategies to reduce the emissions of those air pollutants.

Therefore, a bottom-up approach was applied, which allowed for the identification of the main conventional air pollutants emitted in the studied region, as well as the contribution of each category of road motor vehicles in emitting these pollutants.

This study is divided into 7 sections. In Section 2, the conventional air pollutants that are emitted by road motor vehicles are identified. Section 3 describes a general view of policies for reducing air pollutant emissions from road motor vehicles. The methodology used to estimate the emissions of air pollutants is described in Section 4. Section 5 introduces and discusses the results from the inventory of air pollutant emissions from road transportation in the state of Rio de Janeiro. In Section 6, the strategies used to reduce air pollutant emissions from road motor vehicles are listed. Finally, in Section 7 we show final considerations, limitations, and suggestions for further studies.

2. Conventional air pollutants from road motor vehicles

Road motor vehicle technology (power supply and fuel systems, motor, and after treatment systems for exhaust gases), the type and quality of fuel used, maintenance and driving conditions, planning and land use, and meteorological factors (atmospheric pressure and ambient temperature) determine the type of air pollutants emitted (Thambiran and Diab, 2011).

Faiz (1993) classifies air pollutants into two categories: conventional pollutants, which mostly have a local impact, and greenhouse gases, which have a global impact. The local impact is related to problems such as urban air quality and human health. These are mostly responsible for air pollution in large cities, justifying the selection of the city of Rio de Janeiro for this study.

According to Faiz et al. (1996), air pollutant emissions could originate either from burning engine fuel (exhaust emissions) or fuel evaporation from power systems or engine crankcases (evaporative emissions), which may occur during vehicle use or when vehicles are at rest. Evaporative emissions can also occur in fuel distribution system, specially from CNG, ethanol and C gasoline, that are light fuels. However this study considered only end use emissions.

Exhaust emissions are composed of various substances such as carbon monoxide (CO), total hydrocarbons (THC), aldehydes (RCHO), nitrogen oxides (NO_x), and particulate matter (PM). In turn, evaporative emissions are composed of non-methane hydrocarbons ($NMHC_{evaporative}$) (Faiz et al., 1996).

United States Environmental Protection Agency (EPA) (2012), describes the six more common air pollutants as ozone (O_3), particulate matter (PM), carbon monoxides (CO), nitrogen oxides (NO_x), sulfur oxides (SO_x) and lead.

However, we opted to consider CO, NO_x, PM, Aldehydes (RCHO) and total hydrocarbons (THC), the latter forming part of evaporative and exhaust emissions, because these pollutants are stated as air pollutants in Brazil for automotive emissions. Besides, those are the pollutants measured and considered in the Brazilian inventory (MMA, 2011), which allows a comparison between our inventory and the Brazilian one.

SO_x and O_3 were not considered because the emission factors for these pollutants are not available in the level of details that are necessary to apply the methodology. Lead was also not considered because it is not used in Brazil as ethanol is as an ant-knocking additive in gasoline. Except for flexible-fuel vehicles, which in 2010, represented 30% of the fleet, vehicles equipped with Otto Cycle engines mostly use gasoline as fuel and have emissions factors of CO, THC, and $NMHC_{evaporative}$ higher than vehicles equipped with Diesel cycle engines. Emissions of aldehydes (RCHO) are more closely related to the use of ethanol (hydrated ethanol, C gasoline and CNG, in this case when the vehicle is using the original fuel that can be C gasoline or ethanol). Vehicles equipped with Diesel cycle engines have emissions factors of NO_x and PM higher than vehicles equipped with Otto cycle engines (Heywood, 1988; Faiz et al., 1996).

Table 1
Emission limits established by PROCONVE and PROMOT in Brazil.
Source: MMA (1993, 2002a, 2002b, 2003 and 2008).

Phases [a, b]	PROCONVE–Vehicles with Otto engines						PROMOT–Motorcycles				
	L1	L2	L3	L4	L5	L6	M1	M2		M3	
								< 150 cc	≥ 150 cc	< 150 cc	≥ 150 cc
Emission Limits											
Date of implementation	1989	1992	1997	2007	2009	2014	2003	2005		2009	
CO (g/km)[c]	4.00	12.00	2.00	2.00	2.00	1.30	13	5.5		2	
HC (g/km)[d]	2.10	1.20	0.30	0.16	0.05	0.05	3	1.2	1	0.8	0.2
NO_x (g/km)[e]	2.00	1.40	0.60	0.25	0.12	0.08	0.3	0.3		0.15	
PM (g/km)[f]	–	–	–	–	–	–	–	–	–	–	–
RCHO (g/km)[g]	–	0.15	0.03	0.03	0.02	0.02	–	–	–	–	–

Notes:

[a] Li-Phase *i* of PROCONVE for light vehicles, where i: 1 to 6;
[b] Mj-Phase *j* of PROMOT for motorcycles, where *j*: 1 to 3.
[c] Carbon monoxide;
[d] Hydrocarbons;
[e] Nitrogen oxides;
[f] Particulate matter—this pollutant is stated only for vehicle with Diesel engines;
[g] Aldehydes.