

The Effect of Switching Mobile Sources to different Biodiesel Blends on the Benzo[a]pyrene and main Emissions at Urban Areas using MOVES; the Case of Temuco, Chile.



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 13th Annual CMAS Conference October 27-29, 2014, Chapel Hill, NC

ABSTRACT

Temuco is one of the most highly wood-smoke polluted cities in Chile; however, the diesel mobile sources are growing very fast in the last 10 years and so far scarce studies have been done. The main goal of this research was to develop a 2013 emission inventory of criteria pollutants and Benzo[a]pyrene (BaP) and to evaluate the use of six biodiesel blends of 0%, 1%, 4%, 8%, 12%, and 20% by volume of fuel in diesel motors from the vehicle fleet within the mentioned areas using the Motor Vehicle Emission Simulator (MOVES). Input parameters were established to implement and adapt the model to Chile for the base year 2005, whose results of NO_x, PM₁₀, PM_{2.5}, NH₃, CO₂ equivalent and SO₂ were compared with the Chilean Emission Inventory estimated by the model "Methodology for the Calculation of Vehicle Emissions" (MODEM). The 2013 emissions diminished with respect to 2005, in the majority of the contaminants analyzed, despite of the 47% increase in the annual miles traveled. Using biodiesel blends, an emissions reduction was estimated at up to 15% in particulate matter, BaP, and CO for the year 2013, as well as an increment of 2% in NO_x emissions, attributed to low sulfur content (50 ppm) in the diesel for this year and the antiquity of the vehicle fleet. The results obtained gave evidence of the influence of the biodiesel use in the pollutant emissions to improve the Chilean air quality, as well as providing a tool in Chile for decision making on air quality and air pollution control from mobile sources.

Acknowledgment Acknowledgments of FONDECYT 1120791 and FONDEF PD0911070 Projects.

INTRODUCTION

Diverse studies on emissions and modelling of air quality have been done in this urban zone, with the objective of stimulating the decision making process in policy. In the city of Temuco, the software MODEM II has been used to obtain results from mobile sources. The results have indicated that the particulate matter (PM) emissions came fundamentally from vehicles that use diesel fuel, such as buses and trucks. However, the reach of this software is limited so far, given that it can only analyze some pollutants, such as PM, carbon monoxide (CO), total hydrocarbons (TH), nitrogen oxides (NO_x), nitrous oxides (NO), sulfur dioxides (SO₂), methane (CH₄), ammonia (NH₃), and carbon dioxide (CO₂), leaving out the toxic contaminants in the analysis.

One of the best simulation programs with the largest state-of-the-art for doing mobile sources inventory is the software MOVES, implemented by the Office of Transportation and Air Quality in the United States, pertaining to the U.S. Environmental Protection Agency (EPA). The program in its version named 2010b, presents improvements in the database and error correction, permitting the emission estimations for metals, polycyclic aromatic hydrocarbons (PAHs), dioxins, furans, and hydrocarbon gases, among others. This software can also obtain results for areas outside of the United States, and this requires an advanced compilation of data. It is for this reason it is recommended to employ the database that the program possesses that contains information about emission in the United States, as well as driving patterns, vehicle classes, and road types, among others.

One of the advantages that MOVES offers is that it can simulate the emission of Benzo(a)pyrene (BaP), categorized as carcinogenic for the population. This substance has not been studied in mobile sources in Chile. It is necessary to implement MOVES's model to estimate and design control strategies for these and other emission sources. One of the strategies studied to reduce emissions by the exhaust pipe is the use of biodiesel in diesel motors. Chilean legislation allows up to 5% by-volume mix in diesel motors. However, the composition of biodiesel can be greater.

This study had the objective of evaluating the use of biodiesel in different blends in diesel motors for the vehicle fleet of the Temuco and Padre Las Casas counties, using MOVES. This work was done to analyze the impact on emissions caused by mobile sources, especially focused on BaP, PM, NO_x, and CO. Additionally, input parameters were established for this software in order to implement its inventory models in Chile, and in this way to provide an air quality management tool, useful in this country and as a model for other developing countries facing the same pollution issues.

The counties under study are considered in conjunction, dividing themselves in five zones, as is demonstrated in Figure 1. This was done with the goal of assigning distribution factors to the freeways and of vehicle use that is closer to the current reality. The required parameters from each one of these zones was fixed by estimations according to the geographical characteristics as well as the economic conditions of the area, given that there did not exist prior information on the topic.

MODELING DOMAINS

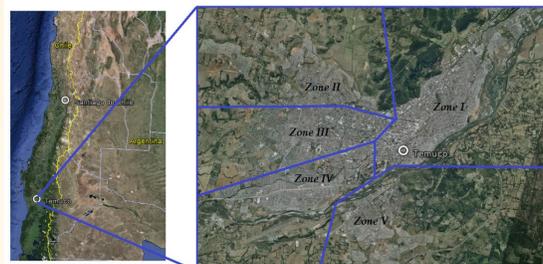
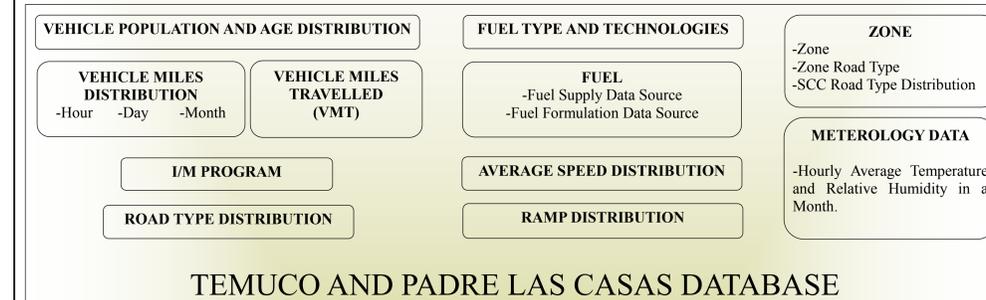


Figure 1 Modeling Domain of Simulation.

METHODOLOGY

In order to carry out an inventory outside of the United States, MOVES requires 11 input variables. Simulations were carried out in time frames of one month, creating 12 work scenarios that were later added to obtain the basis annual inventory from the year 2005. Once the input variables were accepted comparing the MOVES results with the Chilean emission inventory for 2005, the mobile sources inventory was then developed for the year 2013, replacing fuels with blends of biodiesel and diesel in vehicles that used diesel.



TEMUCO AND PADRE LAS CASAS DATABASE

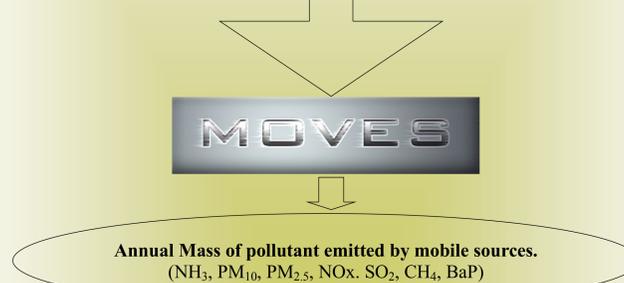


Figure 2. Input to MOVES to create Temuco's inventory

As an information source, the National Institute of Statistics (INE) of the Araucania Region was utilized, the National Petroleum Company (ENAP in Spanish), as well as studies from the DICTUC. The vehicle classes present in MOVES were organized according to the patterns of vehicle activity. It was done a comparison with the Chilean vehicle classes, establishing a consensus of the types of vehicles to use for the simulation. This classification is shown in Table 1 with their respective codes.

Table 1 Classification of vehicle classes in MOVES and Chile, and Vehicle Miles Travelled for 2005 and 2013.

ID	MOVES Vehicular Class	Chile vehicular class	2005 VMT	2013 VMT
11	Motorcycle	Motorcycle	1 316 326	6 226 222
21	Passenger Car	Personal vehicles (sedan, stationwagon)	137 733 523	212 109 625
31	Passenger Truck	Hired cars (basic and shared "colectivo" taxis)	35 531 738	50 419 536
32	Light Commercial Truck	Commercial vehicles, (jeeps, pick-ups, vans)	74 456 559	105 653 857
42	Transit Bus	Buses	24 910 803	28 896 531
52	Single Unit Short-haul Truck	Light trucks	4 288 883	6 175 991
53	Single Unit Long-haul Truck	Medium trucks	4 369 613	6 292 243
62	Combination Long-haul Truck	Heavy trucks	74 104	1 068 054

One of the input variables that insides in the expected results is the factor supplied by the age of vehicle fleet population. MOVES allows the introduction of age distributions up to 30 years, but due to the lack of real data, vehicles with a maximum age of 20 years were used for the year 2005 and 28 years for 2013.

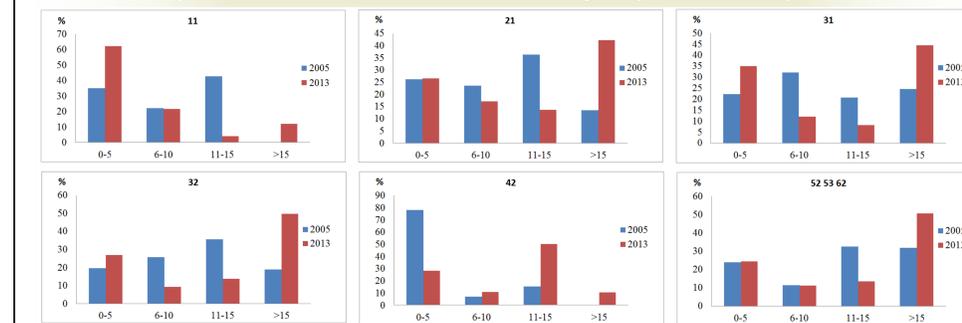


Figure 3 Distribution of age vehicle in different range of antiquity.

DISCUSSIONS AND RESULTS

Figure 4 shows the 2005 emissions inventory results estimated by MOVES for the Temuco and Padre Las Casas counties, and a comparison is presented with respect to the values obtained by MODEM. The most similar emission value between these two models was NO_x, with 8% in difference. On the other hand, SO₂ registered the highest value of difference, rising 31% over the 2005 Chilean Emission Inventory for Temuco and PLCs. This could be due to the age of the vehicle fleet in the study areas. This generates emission factors that are higher than the new vehicles, given the advanced deterioration of the motors, and the resulting unfavorable combustion for the emission of toxic substances. In addition, the results obtained regarding particulate matter were found between 7-11% lower than MODEM model.

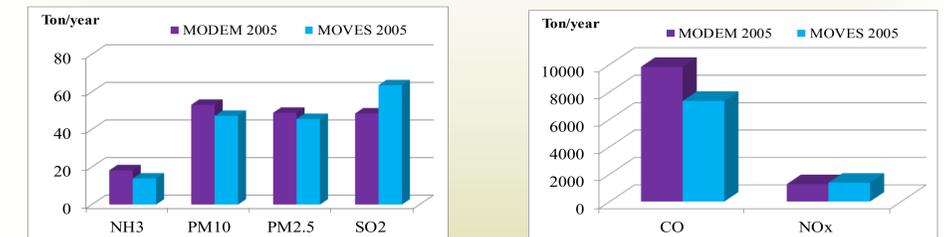


Figure 4 Emissions from MOVES and MODEM for the year 2005.

Figure 5 shows the results of the emissions inventory of mobile sources for 2013 using gasoline and diesel as fuel using MOVES. The vehicles that use gasoline are those responsible for the majority of the emission of NH₃ and CO. In contrast, PM and SO₂ are emitted in largely by those that use diesel fuel. The results of NO_x and BaP were similar in agreement with the type of fuel used, resulting in 54 and 61% the diesel contribution, respectively. The values obtained of SO₂ are significantly lower than the 2005 results, due mainly to the reduction of the sulfur content in the fuels being a positive measure for the improvement of the air quality for these areas. On the other hand, the emission of PM₁₀ and PM_{2.5} decreased in 15 and 16%, respectively, despite the fact that the number of miles travelled annually increased by 47% from one period to the next. An improvement in the age of the vehicle fleet and lower sulfur content influenced the obtained results.

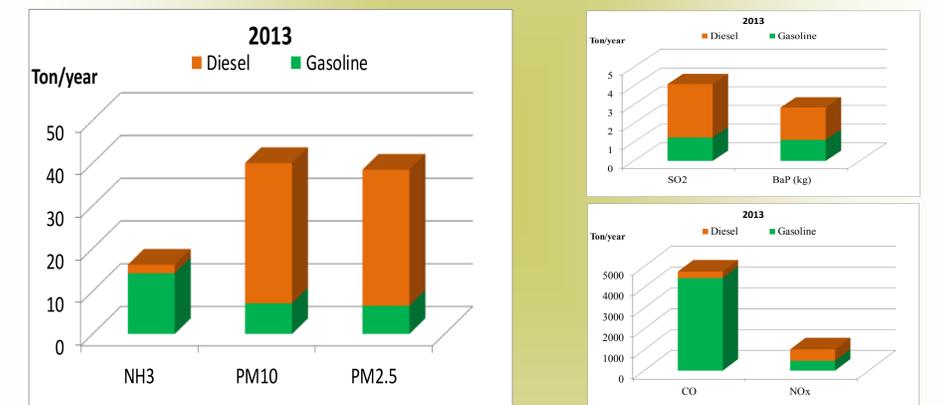


Figure 5 Total Emissions for 2013 using gasoline and diesel in Temuco and Padre Las Casas counties

Figure 6 shows the difference in the percentage of the emission of NO_x, CO, PM₁₀, PM_{2.5} and BaP, using biodiesel mixes in vehicles that used diesel during 2013. The behavior obtained corresponds to that expressed in diverse studies of literature. The maximum value of the emission reductions of PM_{2.5}, CO, and BaP was around 15%, and the increase in NO_x emissions was approximately 2%. The results showed that MOVES is designed to vary diesel emissions with respect to a given value when biodiesel is used.

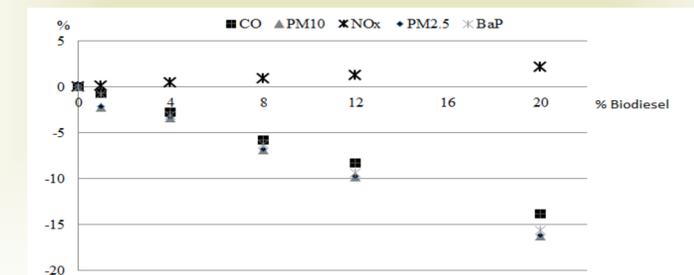


Figure 6 Differences in the emissions using biodiesel blends in 2013 at Temuco and Padre Las Casas counties.

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