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Air quality impacts and health-benefit valuation of a low-emission technology for rail yard locomotives in Atlanta Georgia

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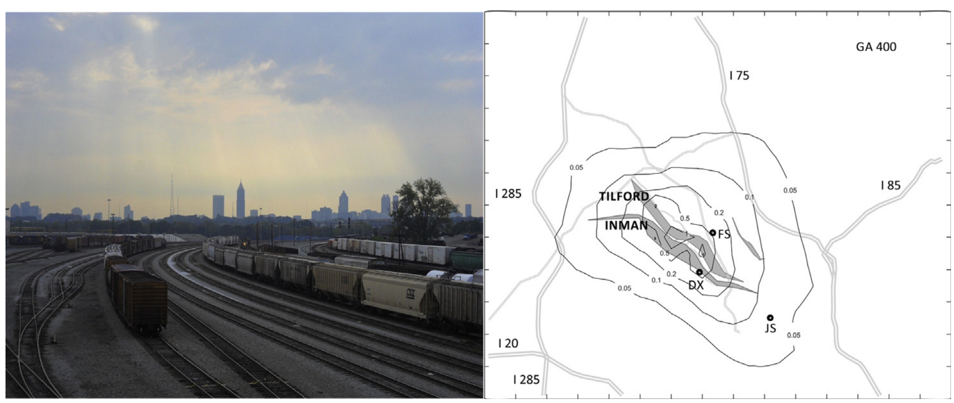
HIGHLIGHTS

- We quantify the impact on local air quality from two rail yards in Atlanta before and after conversion to a low emission technology.
- We calculate the avoided incidence in health impacts and the economic value saved by the reduction of fine particulate coming from the rail yards
- We evaluate the cost benefit of the conversion.

GRAPHICAL ABSTRACT



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ABSTRACT

One of the largest rail yard facilities in the Southeastern US, the Inman and Tilford yards, is located in the northwestern section of Atlanta, Georgia alongside other industries, schools, businesses, and dwellings. It is a significant source of fine particulate ($PM_{2.5}$) and black carbon (BC) (Galvis, Bergin, & Russell, 2013). We calculate 2011 $PM_{2.5}$ and BC emissions from the rail yards and primary industrial and on-road mobile sources in the area and determine their impact on local air quality using Gaussian dispersion modeling. We determine the change in $PM_{2.5}$ and BC concentrations that could be accomplished by upgrading traditional switcher locomotives used in these rail yards to a lower emitting technology and evaluate the health benefits for comparison with upgrade costs.

Emissions from the rail yards were estimated using reported fuel consumption data (GAEPD, 2012b) and emission factors previously measured in the rail yards (Galvis et al., 2013). Model evaluation against 2011 monitoring data found agreement between measured and simulated concentrations. Model outputs indicate that the line-haul and switcher activities are responsible for increments in annual average concentrations of approximately 0.5 ± 0.03 μg/m^3 (39%) and 0.7 ± 0.04 μg/m^3 (56%) of BC, and for 1.0 ± 0.1 μg/m^3 (7%) and 1.6 ± 0.2 μg/m^3 (14%) of $PM_{2.5}$ at two monitoring sites located north and south of the rail yards respectively. Upgrading the switcher locomotives at the yards with a lower emitting technology in this case “mother slug” units could

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decrease $PM_{2.5}$ and BC emissions by about 9 and 3 t/year respectively. This will lower annual average $PM_{2.5}$ concentrations between 0.3 ± 0.1 µg/m^3 and 0.6 ± 0.1 µg/m^3 and BC concentrations between 0.1 ± 0.02 µg/m^3 and 0.2 ± 0.03 µg/m^3 at monitoring sites north and south of the rail yards respectively, and would facilitate $PM_{2.5}$ NAAQS attainment in the area. We estimate that health benefits of approximately 20 million dollars per year could be gained.

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1. Introduction

Ambient particulate matter affects public health. Worldwide, it is responsible for approximately 3 million deaths a year (Lim et al., 2012). It causes lung cancer (Hystad et al., 2012; Loomis et al., 2013; López-Cima et al., 2011; Nafstad et al., 2003; Pope et al., 2011; Raaschou-Nielsen et al., 2013; Raaschou-Nielsen et al., 2011; Sax et al., 2013) and cardiovascular and respiratory diseases (Laden et al., 2006; Nachman and Parker, 2012; Pope et al., 2002). It is among the 10 main risk factors that impact human health globally, having a greater impact than other factors such as high body-mass index, a diet high in sodium or unimproved sanitation (Lim et al., 2012). Emissions from on-road and nonroad diesel engines (e.g., locomotives, marine vessels, heavy-duty equipment, etc.) are among the main sources of ambient particulate matter in many urban areas. Diesel emissions measured as diesel particulate matter (DPM) represent around 6% of the nationwide emissions inventory of particles with an aerodynamic diameter of 2.5 µm or less ($PM_{2.5}$) in the U.S., ranging from 10% to 40% in urban areas (EPA, 2002; Simon et al., 2008).

Many actions have been taken to lower diesel emissions in the last 30 years. Improved fuel quality, stringent emission regulations, new exhaust treatments, and more efficient engine technologies have significantly decreased nitrogen oxides and particulate emissions from onroad diesels (Hricko et al., 2014; McDonald et al., 2013; Parris, 2003). However, inventory trends in the U.S. show that non-road diesel emissions have increased during the same period (Simon et al., 2008). Rail yard emissions are expected to have increased due to the use of switcher locomotives to reassemble freight cars. Switchers are typically older models operating at low-power duty cycles (EPA, 2008, 2011, 2011-09-21; Miller et al., 2006) along with the fast growing economic activity of the rail industry (Chester and Ryerson, 2014; Hricko et al., 2014; Laurits and Christensen Associates, 2009; Leachman and Jula, 2012; Rowangould, 2013; Spychalski and Swan, 2004). Currently, the industry is reducing emissions from yards across the nation, with the support of the US Department of transportation's Congestion Mitigation and Air Quality Improvement Program (CMAQ) and other federal, state and private funds. Measures taken to reduce emissions involve upgrading switcher locomotives used in rail yards with cleaner alternatives for low-speed applications. One approach is replacing the traditional switchers for "mother-slug" locomotives. In a "mother-slug" switcher, a conventional diesel locomotive called "mother" sends the excess power generated by its diesel electric engine at low speeds to a "slug" which is a locomotive with only traction motors but no engine nor electric generator. The slug contains a large block of ballast to provide sufficient weight for traction. A mother-slug switcher replaces two conventional switchers and can save approximately 33% of the fuel consumed, meeting EPA tier II/III emission standards (NS, 2011). However, the fuel consumption reduction has not been widely documented. The Georgia Environmental Protection Division (GAEPD) along with the Georgia rail industry is currently pressing forward with a project to replace older switcher locomotives operating in the 'urban core' of Atlanta. This area is currently in non-attainment of the $PM_{2.5}$ National Ambient Air Quality Standard (NAAQS). Funding has been awarded by the Georgia Department of Transportation to the GAEPD through the CMAQ (2009) program to employ lower emission technologies at the Inman and Tilford yards.

Changes in air quality resulting from the implementation of emission reduction measures at rail yards have seldom been quantified (Jaffe et al., 2014). The same is true for their associated health benefits. These tasks have been hindered by significant uncertainties of rail yard emissions and insufficient air quality monitoring data near these sources. Estimates of emissions from rail yards are typically highly uncertain due to inadequacies in available emission factors and activity indicators (Kean et al., 2000). Generic emission factors normally used may fail to effectively represent operating conditions, technologies, and yard fleet mix (Galvis et al., 2013), and often activity indicators may not describe the characteristics of a given rail yard (Gould and Niemeier, 2009). Previous work carried out by Sierra Research (2011) compared modeled diesel particulate matter (DPM) and nitrogen oxides (NOx) ground-level concentrations to measured upwind–downwind concentration differences of BC, elemental carbon (EC), organic carbon (OC), $PM_{2.5}$, and NOx measured at four monitoring stations operated during the Roseville Rail yard Air Monitoring Project (RRAMP) in California. Gaussian dispersion models were used to assess the impact of rail yard emissions on local air quality. Models were run with rural and urban dispersion coefficients and two different meteorological data sets. In all cases, both measurements and models, found reductions in DPM and NOx impacts over the four-year period of the RRAMP study. Reductions observed were mostly attributed to the decrease of emissions at the rail yard over that period. Comparisons of the measured $PM_{2.5}$ and NOx concentrations with simulated DPM and NOx concentrations predicted by the models were not in good agreement (Campbell and Fujita, 2009). Feinberg et al. (2011), estimated impacts of the CSXT Rougemere rail yard in Dearborn, Michigan on local air quality using a Gaussian atmospheric dispersion model without evaluation of modeling results. They developed a bottom-up temporally and spatially allocated $PM_{2.5}$ emissions inventory before and after a retrofit of the switchers in the yard. Results of the inventory estimated a reduction in $PM_{2.5}$ emissions from 2007 to 2008, attributed to the retrofits and reductions in the sulfur content of the diesel fuel.

Health risk assessments for several rail yards have been carried out by the California Air Resources Board (CARB, 2011). They used emission inventories and air quality modeling results previously prepared for the rail yards, to characterize potential cancer and non-cancer risks associated with exposure to DPM. They estimated impacted areas and exposed population associated with different cancer risk levels for different exposure durations. They also reported near-source cancer risks. GAEPD (2006) assessed benefits of avoided mortality and morbidity of several emissions control strategies including reducing 10% of emissions of ground level anthropogenic primary carbon $PM_{2.5}$ (EC and OC) throughout the state of Georgia. EC is one of the main emissions from rail yard areas. They used the Community Multiscale Air Quality Model to estimate changes in ambient air pollution levels and the Environmental Benefits Mapping and Analysis Program (BenMAP) (ABT, A, 2012) to assess the health benefits and concluded that ground level controls of primary carbon significantly reduced exposure and have the highest health benefits of all the strategies evaluated, saving 223 million dollars annually.

The objectives of this research are to estimate the impact on local air quality of $PM_{2.5}$ and BC emissions from Tilford and Inman rail yards in Atlanta, GA, and to assess the reduction on the $PM_{2.5}$ and BC concentrations that could be accomplished by converting the switcher locomotives at the rail yards to mother-slugs. Emissions from the rail yards are estimated using available fuel consumption data and emission factors measured for the rail yards (Galvis et al., 2013). First, a 2011 base case is simulated, and results are compared to measurements of BC

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