Evaluation of the USEPA MOVES Model Sensitivity to Ethanol Fuel Blends in Cook County, Illinois

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Introduction

The Energy Resources Center (ERC) at the University of Illinois at Chicago (UIC) performed evaluations of the U.S. Environmental Protection Agency's (USEPA) Motor Vehicle Emission Simulator (MOVES) model under a variety of scenarios for Cook County, Illinois. The intention of the analyses was to examine the MOVES model sensitivity to changes in modeling parameters for Cook County, particularly focusing on the model's response to ethanol fuel formulation changes. Cook County encompasses all of the City of Chicago and many adjacent suburbs (Figure 1), and has historically been the predominant area of evaluation and State Implementation Plan (SIP) development for the Chicago ozone non-attainment area. Understanding the response of the MOVES model to changes in ethanol fuel formulations and the potential impact of such formulation shifts on the regional emissions inventory of criteria pollutants is important in the evaluation of potential improvements to regional air quality and progress towards ozone attainment.

Figure 1. Municipalities in Cook County, Illinois

Background on MOVES Model

The current version of the MOVES model was published for use by the USEPA in October 2014. This version was approved by the USEPA for SIP development and transportation conformity analyses everywhere in the U.S. except California (Federal Register/Vol. 79, No. 194, p 60343). In order to perform the MOVES analyses for Cook County, the MOVES County Data Manager was populated with input parameters and data consistent with that used by the Illinois EPA in the most recent regional MOVES modeling (i.e., 2013). MOVES default data were used for parameters for which the Illinois EPA did not have specific Cook County data. Fuel formulation data and other fuel parameters were generated as default values by the MOVES model, inputted from analyses of Chicago-area fuel samples, or otherwise modified as variables in the analyses as described in this paper.

MOVES Response to Default Fuel Formulation Adjustments

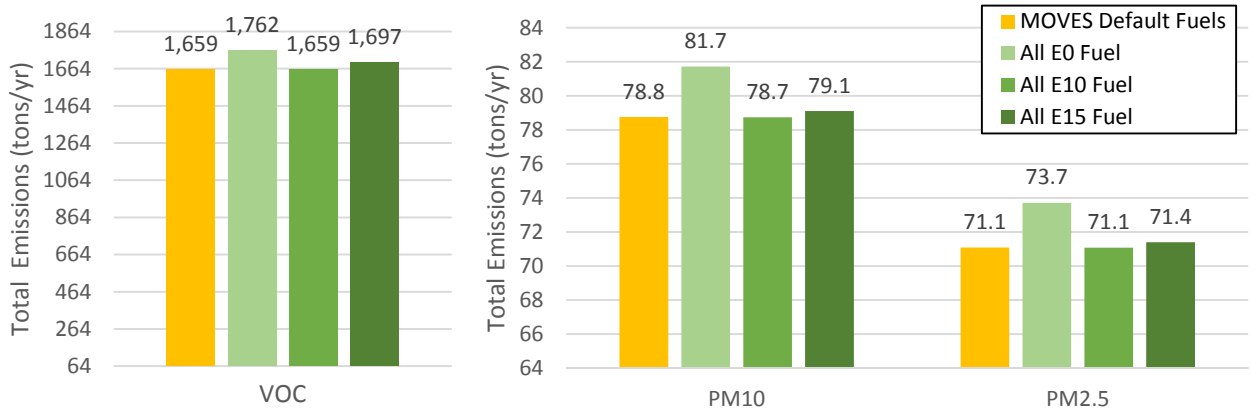
The sensitivity of the MOVES model to shifts in ethanol concentration was examined by modifying the default fuel input files provided in the MOVES County Data Manager for Cook County in 2014. This was done in two ways. First, the fuel formulation file, which contains default data on fuel properties for several E10 and E15 blends, was adjusted so that the E15 blends matched all E10 fuel properties, and then vice versa. No other adjustments to the fuel formulation were made; therefore, this effectively made all gasoline equivalent to E10 in the first run and E15 in the second run. The second method of modifying the default fuel input files consisted of adjusting the fuel supply data. The market shares were changed to 100 percent E0 gasoline in the first run, 100 percent E10 gasoline in the second run, and 100 percent E15 gasoline in third run.

As one might expect, the results from adjusting the fuel formulation input file and the results from adjusting the market shares in the fuel supply input file were nearly identical for the E10 and E15 runs.

Each method effectively reduced the gasoline fuel category to a single ethanol blend. In both cases, volatile organic compounds (VOC) emissions increased approximately 2.3 percent and particulate matter (PM) emissions increased approximately 0.5 percent from all E10 to all E15 (Figure 2). Although not shown in Figure 2, emissions of carbon monoxide (CO) and nitrogen oxides (NOx) were also calculated; the model indicated no change by shifting from E10 to E15 blends.

Figure 2 also provides the results from modeling a 100 percent market share scenario for E0 gasoline (per the second method above). For comparison purposes, the results using MOVES default fuel supply and fuel formulation data are also graphed. The highest VOC and PM emissions were found with the E0 scenario, followed by E15. The E0 scenario also resulted in the highest CO emissions and the lowest NOx emissions (the other fuel scenarios were identically lower and higher, respectively).

Figure 2. MOVES Emissions Results for Cook County, IL for Default Fuel Blends in 2014



Additionally, there was interest in comparing the results from the MOVES default fuel inputs for 2014 and a future year. The year 2024 was selected for comparison. Initially, the MOVES model was run with the "National" domain selection so that all MOVES default values could be used without Illinois EPA's modeling inputs. The selected geographic boundary was the State of Illinois (the most granular option available with this type of run). The results indicated that the MOVES model predicts substantial reductions in VOC, PM, NOx, and CO emissions from 2014 to 2024.

A comparison specific to Cook County was also performed. This was done by manually adjusting the market share of the E15 blend to 20 percent in each year. For reference, the default MOVES market shares for E15 and E10 in Cook County are 3.14 percent and 96.86 percent, respectively, for modeling year 2014 and 14.22 percent and 85.78 percent, respectively, for modeling year 2024. The results again show a substantial reduction in emissions of the targeted pollutants from 2014 and 2024.

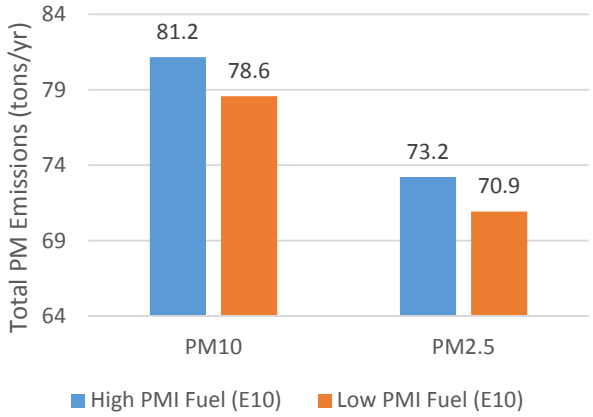
Evaluation of High PMI and Low PMI Fuels

The influence of certain fuel properties on the generation of PM emissions during gasoline combustion has been studied by the Honda R&D Company. The PM Index (PMI) was developed for fuels based on the observed direct correlation between the double bond equivalent (DBE) of gasoline fuel components and the production of PM emissions. In order to evaluate the sensitivity of the MOVES model's predicted PM emissions based on PMI, total hydrocarbon analyses were performed on five E10 fuel samples obtained from retail stations in the Chicago area, allowing the calculation of DBEs for those fuels. The MOVES

default E10 fuel formulation for 2014 was replaced in the fuel input file with the properties of the lowest DBE fuel from the samples, and then the highest DBE fuel from the samples.

The results, shown in Figure 3, indicate that the MOVES model predicts lower PM emissions (PM_{10} and $PM_{2.5}$) for low-PMI fuels compared to high-PMI fuels. The direction of change in PM emissions is consistent with the PMI research. VOC emissions were not specifically evaluated in the Honda R&D Company's research; however, the MOVES model predicted VOC emissions to be lower with the low PMI fuels.

Figure 3. MOVES PM Emissions Results for Cook County, IL for High and Low PMI Fuels in 2014



Conclusions

The MOVES model was evaluated for Cook County, Illinois using a number of scenarios designed to test the model's response to changes in ethanol fuel blends. More detail on the specific run scenarios and results is provided in Table 1 on the next page. In summary, the key findings are as follows:

- When comparing the all-E10 and all-E15 gasoline blend scenarios that relied on MOVES default data, the MOVES model predicted a slight increase in PM emissions with the addition of ethanol. Similarly, a positive correlation between ethanol content and PM emissions was reported by the USEPA in the EPAct/V2/E-89 study in 2013. Several researchers have questioned USEPA's conclusion in that study, pointing to the limitations of match blending to produce fuels for combustion analysis (Anderson and Wallington et al., 2014). In fact, numerous other studies have shown the opposite—PM emissions decrease with increasing ethanol content (Stein et al., 2013).
- The same model runs that compared the default E10 and E15 blends in MOVES also predicted an increase in VOC emissions from E10 to E15. This result is again supported by the EPAct/V2/E-89 study from 2013. Conversely, Stein et al. noted a neutral or decreasing change in VOC emissions with the addition of ethanol based on a 2011 study conducted by the Coordinating Research Council (Stein et al., 2013).
- The MOVES model predicted substantial reductions in all criteria pollutant emissions from 2014 to 2024. A review of the MOVES input data files indicates that this difference is likely due to the shift in the fleet compositions and related vehicle emissions over that time period. The default vehicle fleet in 2014 is comprised of 1984-2014 model year vehicles. By 2024 the vehicle fleet shifts to be comprised of 1994-2024 model year vehicles.
- When MOVES default fuel formulations were entirely replaced with analyses from high PMI and low PMI fuels sampled from the Chicago area, the model predicted a decrease in PM emissions. This is directionally consistent with the expected results based on published research from Honda R&D Company, which suggests that because ethanol molecules are not double-bonded, the addition of ethanol to gasoline via splash blending does not increase the PMI of the fuel (Aikawa and Jetter, 2014).

Table 1. Summary of MOVES 2014 Modeling Comparisons and Results in Emissions Inventory Totals for Cook County

Modeling Scenario	Sum of VOC (tons)	Sum of Total PM10 (tons)	Sum of Total PM2.5 (tons)	Sum of Total NOx (tons)	Sum of Total CO (tons)	% Change in VOC	% Change in PM10	% Change in PM2.5	% Change in NOx	% Change in CO
Modeling for 2014 Using IEPA Data and MOVES Fuels Changing All E10 to High PMI Illinois Fuel[1]	1,757	81.2	73.2	N/A	N/A	-	-	-	-	-
Modeling for 2014 Using IEPA Data and MOVES Fuels Changing All E10 to Low PMI Illinois Fuel[1]	1,740	78.6	70.9	N/A	N/A	**-1.0**	**-3.2**	**-3.1**	**N/A**	**N/A**
Modeling for 2014 Using Only MOVES Default E10 Blends for Ethanol Fuels[2]	1,658	78.7	71.1	2,717	15,814	-	-	-	-	-
Modeling for 2014 Using Only MOVES Default E15 Blends for Ethanol Fuels[3]	1,697	79.1	71.4	2,717	15,814	**2.3**	**0.5**	**0.5**	**0.0**	**0.0**
Modeling for 2014 Using all MOVES Default Inputs and Fuels on a National Basis, Illinois Totals[4]	23,301	4486.3	4087.9	128,209	448,134	-	-	-	-	-
Modeling for 2024 Using all MOVES Default Inputs and Fuels on a National Basis, Illinois Totals[4]	3,098	879.1	798.4	22,573	121,539	**-86.705**	**-80.4**	**-80.5**	**-82.39**	**-72.879**
Modeling for 2014 Using IEPA Data and MOVES Default Fuels	1,659	78.8	71.1	2,717	15,814	-	-	-	-	-
Modeling for 2024 Using IEPA data and MOVES Default Fuels	681	28.1	25.2	191	8,631	**-58.981**	**-64.4**	**-64.6**	**-92.95**	**-45.424**
Modeling for 2014 Using IEPA Data and MOVES Default Fuels	1,659	78.8	71.1	2,717	15,814	-	-	-	-	-
Modeling for 2014 Using IEPA Data and MOVES Default Fuels w E15 Market Share Increased to 20%[5]	1,666	78.8	71.1	2,732	15,630	**0.404**	**0.078**	**0.076**	**0.54**	**-1.161**
Modeling for 2024 Using IEPA data and MOVES Default Fuels	681	28.1	25.2	191	8,631	-	-	-	-	-
Modeling for 2024 Using IEPA Data and MOVES Default Fuels w E15 Market Share Increased to 20%[5]	681	27.2	24.4	192	8,531	**0.099**	**-3.2**	**-3.3**	**0.54**	**-1.161**
Modeling for 2014 Using IEPA Data and MOVES Default Fuels	1,659	78.8	71.1	2,717	15,814	-	-	-	-	-
Modeling Using IEPA Data and all E0 for Chicago Area[6]	1,762	81.7	73.7	2,665	16,231	**6.20**	**3.77**	**3.69**	**-1.90**	**2.64**
Modeling Using IEPA Data and All E10 for Chicago Area	1,659	78.7	71.1	2,717	15,814	**-0.04**	**-0.01**	**-0.01**	**-0.01**	**0.00**
Modeling Using IEPA Data and All E15 for Chicago Area	1,697	79.1	71.4	2,717	15,814	**2.27**	**0.45**	**0.44**	**-0.01**	**0.00**

1. NOx and CO were not run with high and low PMI fuels as the objective of the analysis was to determine the impact on PM and VOC.
2. Fuels were changed in the fuel formulation MOVES input files such that all E15 ethanol fuels were changed to E10 specifications.
3. Fuels were changed in the fuel formulation MOVES input files such that all E10 ethanol fuels were changed to E15 specifications.
4. The objective of this analysis was to determine the approximate range of expected 2014/22024 Using all MOVES default parameters. This can only be done on a national-level run, from which you can select a state. County-level runs require user input data.
5. Default 2014 %market share for E15/E10 is 3.14333%/96.8567%. The ratio was adjusted to 20%/80% for purposes of this analysis.
6. Analysis performed by changing the market share of Cook County fuels to 100% E0.

References

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