MOBILE6.2 Air Toxic Emission Factor Modeling: A Trend and Sensitivity Analysis

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ABSTRACT

On January 29, 2002, the US Environmental Protection Agency (EPA) officially released MOBILE6 - motor vehicle emission factor program for modeling oxides of nitrogen (NOx), carbon monoxide (CO) and volatile organic compounds (VOC). Since then, an updated version known as MOBILE6.2 has been released with air toxic and particulate matter emission factor modeling capabilities. Since the release, various entities have started using MOBILE6.2's air toxic modeling function. A series of test runs were performed in the study presented here to gain a better understanding of the air toxic modeling function and overall model behavior. These test runs/scenarios evaluated the changes in emission factors for the six compounds built into the air toxic module of MOBILE6.2 that resulted from changes in relevant input variables. These included parameters related to vehicle activities such as vehicle speed and vehicle miles traveled (VMT) on different roadway facilities; fuel physical properties such as Reid Vapor Pressure (RVP); sulfur content; percent evaporated at 200 and 300 degree Fahrenheit (E200 and E300 contents, respectively); fuel chemical compositions such as contents of benzene, aromatic compounds, olefin, chemical compounds used in blending oxygenated fuel, and environmental factors including both min/max temperature and humidity. To better understand the model behavior, exhaust and evaporative emission factors were analyzed separately due to their production mechanism differences. Based on testing results obtained, it is clear that the emission factors for acrolein, acetaldehyde, benzene, 1,3 butadiene, formaldehyde, methyl tertiary butyl ether (MTBE) (both exhaust and evaporative) are inversely proportional to both freeway and arterial vehicle speeds. This phenomenon follows the trend of total organic gas (TOG) emission factors. Effects from roadway facility differences indicated that the higher the vehicle miles traveled on a freeway, the lower the air toxic emission factors on a per vehicle mile traveled basis. When VMT is compared between a local road and an arterial facility, air toxic emission factors from local roads are significantly higher than those from the arterial facility. This facility difference is apparently directly related to the vehicle speed rather than the more complicated facility driving cycle (accelerating and decelerating pattern) differences. Both exhaust and evaporative air toxic emission factors increase with fuel RVP value and sulfur content. It is interesting to note that diesel sulfur content has no effect on all air toxic compound emission factors. Effects from fuel chemical compositions on all emission factors are varied. However, chemical compositions do have significant effects on all air toxic compound emission factors. On the same note, both min/max temperatures and humidity affects all air toxic emissions significantly. Time series

evaluation shows that all six tested air toxic compound emissions decrease linearly from year 2002 to 2020.

INTRODUCTION

Since the official release of the MOBILE6.0-motor vehicle emission factor modeling program by the US EPA on January 29, 2002, an updated software version known as MOBILE6.2 has been released. MOBILE6.2 has functions of estimating both air toxic and particulate emission factors in addition to all functions contained in MOBILE6.0. (update to reflect the recent release of M6.2) According to EPA's technical guidance, MOBILE6.2's air toxic function is a consolidation of an earlier hazardous air pollutant estimation model known as MOBTOX. With the robust capability of the MOBILE6 model, it appears that this new function can evaluate effects of more specific vehicle activities, environmental conditions, fuel properties, and other parameters on air toxic emissions. The objective of this analysis is to explore the effects of various parameters and conditions on emission factors of compounds built into the air toxics module of MOBILE6.2 model, which includes of acrolein, acetaldehyde, benzene, 1,3 butadiene, formaldehyde, and MTBE. Evaluation of diesel particulate matter (DPM) emission behavior as affected by various vehicle and environmental conditions through MOBILE6.2 is reported separately from this study.

METHODOLOGY

The MOBILE6.2 software utilized in this trend/sensitivity analysis was the officially released model. The software was downloaded from EPA's website http://www.epa.gov/otaq/m6.htm#m60 on January 22, 2003. All modeling runs were conducted on a Dell Latitude C640 laptop with an x86 Family 15 Model 2 Stepping 7 Genuine Intel microprocessor (1994 Mhz) under Windows 2000 Professional operating system.

For all modeling runs, non-required data (not associated with required MOBILE6 Commands) other than those being tested were based on MOBILE6 national defaults. For all scenarios, the modeling year (calendar year) was 2005. Fuel Reid Vapor Pressure (RVP) used for all runs except in RVP testing was 8.5 pounds per square inch (psi). Min/Max temperatures were 88.0 degrees Fahrenheit and 100.0 degrees Fahrenheit except in the case of min/max temperature testing.

Emission factors for all air toxic compounds are reported in two categories: 1) exhaust emission factors for acrolein, acetaldehyde, benzene, 1,3 butadiene, formaldehyde, and MTBE, and 2) evaporative emission factors including both benzene and MTBE. The separation of exhaust emissions from evaporative emissions is due to the fact that different production mechanisms are involved. Air toxic compounds contained in the exhaust emission are due to combustion and the catalytic oxidation/reduction that are chemical processes. Compounds reported in the evaporative emission are from the physical evaporation process where no chemical reactions occurred.

Emission for all six air toxic compounds and TOG were plotted on the same graph for a given tested parameter. Raw data for one or more emission factors on the graph were either scaled up or scaled down. For example, benzene data in a given graph were scaled up by multiplying all data points by three. In this case, the legend for benzene in the graph would be benzene*3. The true emission factor for benzene in this graph is equal to the graph value divided by three. By conducting the above scale up or down operations, trend deviation and pattern development are more decipherable. Units for all air toxic compounds are milligram per vehicle miles traveled (mg/mile). The unit for TOG emissions is gram per mile (g/mile).

Tested parameters are categorized into the following groups: 1) vehicle activities such as vehicle speed and VMT ratio, 2) fuel physical properties such as Reid vapor pressure, 3) fuel chemical compositions such as benzene content, aromatic content, olefin content, sulfur content, E200, and E300 contents, 4) other chemical additives used in oxygenated fuel, 5) environmental factors such as min/max temperatures and humidity, and 6) time series data for calendar years between 2002 and 2020.

RESULTS AND DISCUSSION

1. Vehicle Activity Effects

In order to evaluate vehicle activity effects on air toxic emission factors, parameters other than the tested vehicle activity must remain constant. For all tested scenarios, gas aromatic, olefin, and benzene contents based on units of volume per unit of volume (v/v) were 15.0% (v/v), 15.0% (v/v), and 1.5% (v/v), respectively; E200 was 50.0% (v/v) while E300 was100.0% (v/v). Oxygenated fuel consisted of 8.0% (v/v) MTBE with a 1.0% market share, 10% (v/v) ethyl tertiary butyl ether (ETBE) with a 1.0% market share, 5.0% ethanol (ETOH) (v/v) with a 1.0% market share, and 1.0% tertiary amyl methyl ether (TAME) (v/v) with a 1.0% market share.

1a. Vehicle Speed

The AVERAGE SPEED command was used to evaluate both arterial and freeway mainline speed effects. Speeds ranging from 2.5 to 65.0 miles per hour (mph) with a 2.5 mph increment were tested.

Fig. 1 shows the relationship between exhaust emission factors and freeway mainline speeds. It is clear from Fig.1 that emission factors for all six air toxic compounds are following the trend of TOG emission. Between 2.5 and 22.5 mph, the relationship can be approximated by an exponential function. Emission factors decrease rapidly as vehicle speeds approach 22.5 mph. Between 22.5 and 65.0 mph, all exhaust air toxic emission factors decrease in a flat linear fashion. The higher the speed, the lower the exhaust emission factor.

Fig. 2 depicts the relationship between evaporative air toxic compound emission factors and freeway mainline speeds. Unlike the exhaust emission trend, the initial rapid

decrease of evaporative emission stops at 5.0 mph. The second rapid decrease occurs between 5.0 and 12.5 mph. Between 12.5 and 65.0 mph, the relationship between evaporative emission and vehicle speed can be described through a linear model. Again, the higher the speed becomes, the lower the emission factor.

Evaporation is a physical process where the amount of time is linearly related to the amount of material evaporated. The higher the vehicle speed, the less time it takes to travel a unit of distance and the less amount of material evaporates. However, this time-dependence theory can not fully explain the portion of non linear relationship.

Fig. 3 and 4 demonstrate relationships between emission factors and arterial facility speeds. Those relationships are essentially duplicates of the emission factor/freeway facility correlations. It clearly that roadway facility speeds are major factors leading to air toxic emission factor differences.

1b. VMT Ratio

Effects of vehicle miles traveled (VMT) ratios between different roadway facilities were evaluated by using the command of "VMT BY FACILITY" and appropriate external VMTvmt files. Tested VMT ratios between freeway mainline/arterial and arterial/local were from 0.0% to 100.0%. The objective of this test is to understand how critical it is to accurately allocate VMT among all roadway types during transportation demand modeling and forecasting.

Fig.5 depicts effects of VMT ratios between an arterial roadway and a local facility on emission factors of all exhaust air toxic compounds, and TOG. Clearly, relationships between VMT ratios and emission factors are linear for all exhaust emissions. The more VMT fraction on a local road, the higher the exhaust air toxic emission factors. Evaporative benzene and MTBE emission factors are also linearly related to VMT ratios (Fig. 6)

Effects of VMT ratios between a freeway mainline and an arterial facility on air toxic emissions (Fig 7. and Fig. 8) are similar to but less pronounced than the arterial/local VMT ratio effects. Vehicles traveling a freeway produce lower air toxic emission factors (both exhaust and evaporative) than vehicles traveling an arterial facility on a per mile traveled basis.

2. Fuel Physical Property Effects

Fuel Reid Vapor Pressure

Fuel Reid Vapor Pressure (RVP) is one of few required inputs to run MOBILE6. While it is known that a high RVP fuel produces high amounts of evaporative and exhaust VOC emissions, it is not clear how RVP affects air toxic emissions. The objective for the RVP test is to understand how air toxic emissions are influenced by fuel RVP changes.

All input data other than fuel RVP are the same as the basic input data for all VMT runs described in Section 1b. Effects from fuel RVP ranging from 6.5 to 15.5 psi were evaluated.

Fig. 9 outlines the RVP effects on the six air toxic compoundsE and TOG exhaust emissions. As fuel RVP increases, TOG emission factors increase with different factors depending on the range of RVP data. Unlike the TOG emission trend, the air toxic compound exhaust emissions exhibit three distinctively different trends. Between 6.5 and 8.5 psi, the air toxic compound emission factors decease in a linear fashion as fuel RVP increases. Between 8.5 and 12.5 psi, the air toxic compound emission factors increase with increasing fuel RVP value. Once the fuel RVP value exceeds 12.5 psi, benzene, formaldehyde, and 1,3 butadiene emission factors start to decrease again as fuel RVP increases. The acetaldehyde, acrolein, and MTBE emission factors remain unaffected while the TOG emission factor increases at a lower factor.

Fig.10 shows the evaporative benzene and MTBE emission trends. As fuel RVP increases, both benzene and MTBE emission factors increase although MTBE does not increase as rapidly as benzene.

3. Fuel Chemical Composition Effects

3a. Gasoline Sulfur Effects

All input data other than gasoline sulfur contents are identical to data used in testing fuel RVP. The MOBILE6 command “FUEL PROGRAM” was used. Effects of gasoline sulfur content ranging from 32 to 92 ppm for calendar year 2005 were evaluated.

Based on results contained in Fig. 11, all exhaust toxic air compound emission factors increase as gasoline sulfur increases. It appears that all air toxic compound emissions follow the TOG emissions trend. It is known that TOG emissions increases are due to gasoline sulfur content increases. These increases are mainly due to fouling effects of sulfur compounds on the catalyst. A catalyst is normally highly selective in oxidizing different chemical compounds. Based on the sulfur data here, it appears that all chemical compounds are treated equally regarding their potential of being oxidized.

Gasoline sulfur content has no effect on evaporative air toxic compound emissions (Fig 12).

3b. Diesel Sulfur Effects

Diesel sulfur content has no effect on emissions of all six air toxic compound emissions tested here.

3c. E200 Effects

E200 is a gasoline volatility measurement. It is the volume percentage of a given amount of gasoline that evaporates at 200 degrees Fahrenheit under one atmospheric pressure. The range of E200 tested was between 30.0% and 70.0%

According to Fig. 13, exhaust TOG, MTBE and acrolein emissions are not affected by E200 contents. Exhaust benzene emissions increase slightly when E200 increases from 35.0% to 45.0%. Between 45.0% and 70.0% E200 contents, exhaust benzene emissions decrease rapidly as E200 content increases. Emission factors for both formaldehyde and acetaldehyde increase as the E200 content increases.

One of the most dramatic phenomena is the decreasing of 1, 3 butadiene emission as the content of E200 increases. As E200 content increases (the content of lower molecular weight distillates increase), more of the relatively large 1,3 butadiene is produced.

E200 content has no effects on evaporative benzene and MTBE emissions (Fig. 14). As discussed in the fuel RVP evaluation section, the volatility of fuel should impact both benzene and MTBE evaporative emission factors.

3d. E300 Effects

E300 is another measurement of gasoline volatility. It is the volume percentage of a given amount of gasoline evaporated at 300 degrees Fahrenheit under one atmospheric pressure. The range of E300 tested was from 70.0% to 100.0%.

Exhaust benzene emission (Fig. 15) increase rapidly with increasing E300 content. This observation is just the opposite of the E200 result. Given the fact that both fuel benzene and aromatic contents are constant in all tested runs, it is not difficult to conclude that more refined field data are required to further define and evaluate the observed results.

Formaldehyde, acetaldehyde and 1,3 butadiene exhaust emissions increase as E300 increases from 70.0% to 80.0%. Between 80.0% and 100.0%, the emission factors for these three compounds decrease as E300 increases.

Acrolein, MTBE and TOG emission factors are not affected by E300 contents. This observation is consistent with the E200 data.

Evaporative emission factors for both MTBE and benzene are not affected by E300 changes (Fig. 16). This result is the same as the E200 results.

3e. Aromatic Effects

Aromatic compounds are any compound that possess the six-carbon ring (benzene) structure. These compounds in gasoline are produced during the petroleum distillation and subsequent refining processes. Effects of aromatic content on air toxic

compound production were evaluated by using the command of “Gas Aromatic%.” Aromatic contents ranging from 10.0% to 55.0% were evaluated while benzene content was fixed at 1.5%.

Exhaust emission factors for TOG, acrolein, and MTBE are also not affected by the contents of aromatic compounds (Fig. 17). However, exhaust benzene emission factors increase rapidly in a virtually linear mode as the aromatic content increases. This phenomenon may be partially explained by the breaking down of aromatic compounds and producing benzene during the combustion process. However, it is very difficult to conclude that such phenomena would follow a linear relationship. It will be more satisfying to further explore this trend with more field data.

While exhaust benzene emission factors increase with increasing aromatic contents, butadiene, formaldehyde, and acetaldehyde emissions decrease in a linear fashion.

According to Fig. 18, evaporative emission factors for both benzene and MTBE are not affected by the amounts of aromatic compounds in fuel.

3f. Benzene Effects

While benzene is one of many compounds referred to as aromatic, it is the only reported air toxic chemical among all aromatic compounds. Effects of benzene ranging from 0.0% to 5.0% were analyzed.

As benzene content increases from 0.0% to 5.0%, exhaust benzene emissions increase linearly (Fig. 19). This same linear response is also observed with the evaporative benzene emission factors (Fig. 20). When fuel contains zero amount of benzene, it produces over 0.5 mg/mile of exhaust benzene. However the evaporative benzene emission factor is zero.

No other air toxic compound emission factors are affected by benzene content.

3g: Olefin Effects

Olefin refers to a class of compounds containing either double or triple bonds (unsaturated) between carbon atoms. Although all aromatic compounds are also unsaturated, olefins are non-aromatic unsaturated organic compounds. Due to its double or triple carbon bonds, olefins are much more reactive than saturated compounds. The effects of olefin ranging from 0.0% to 30.0% on the production of air toxic compounds were analyzed.

Exhaust air toxic emissions as affected by olefin contents are very complex (Fig. 21). While both 1,3 butadiene and acetaldehyde emission factors increase with increasing olefin content, formaldehyde emission factor decreases. As shown in Fig. 22, both MTBE and benzene evaporative emissions are not affected by olefin content.

4. Oxygenated Fuel Effects

To evaluate effects from fuel additives used in oxygenated fuel blending, the MOBILE6 command "OXYGENATE" was used. For each additive, a 70.0% market share was used.

4a. EOTH Effects

The blending volume percentages for ethanol ranging from 0.0% to 10.0% were used in evaluating ethanol effects on air toxic emissions.

Exhaust emission factors for all air toxic compounds except acetaldehyde decrease as ethanol content increases (Fig. 23). This decreasing trend is also true with TOG emissions. Acetaldehyde emission increase rapidly as ethanol content increases. This phenomenon may be contributed to the direct oxidation of ethanol to acetaldehyde during the combustion process.

According to Fig. 24, as more ethanol is blended in the fuel, evaporative emissions of both benzene and MTBE decrease. This phenomenon is especially true for evaporative benzene emissions.

4b. MTBE Effects

The blending volume percentages for MTBE ranging from 0.0% to 14.5% were used in analyzing MTBE effects on air toxic emission. Exhaust emission factors for acrolein, 1,3 butadiene, acetaldehyde, benzene and TOG decrease linearly as MTBE content increases (Fig 25). Exhaust formaldehyde emission increases in a linear fashion as MTBE content increases (Fig. 25a). The exhaust MTBE emission factor increases as fuel MTBE increases. The exhaust MTBE emission is most sensitive to fuel MTBE contents ranging from 5 to 13 % (v/v). Evaporative benzene emission factors decrease as MTBE content increases (Fig. 26).

4c. ETBE Effects

The blending volume percentages for ETBE ranging from 0.0% to 16.0% were used to evaluate ETBE effects on air toxic emission. For both evaporative and exhaust emissions, similar patterns as EOTH affecting air toxic emissions are observed (Fig. 27 and 28). As ETBE content increases, all air toxic emissions except acetaldehyde decrease. This is a very interesting discovery since ETBE is more related to ether than alcohol.

4d. TAME Effects

The blending volume percentages for TAME ranging from 0.0% to 18.0% were analyzed for their impacts on air toxic emissions. While effects from ETBE resemble the

EOTH effect, effects from TAME on all air toxic emissions resemble the MTBE impact. Formaldehyde emission factors increase in a linear fashion as TAME content increases while all other air toxic emission factors decrease (Fig. 29 and 30).

5. Environmental Factors

Effects from environmental factors including both minimum/maximum daily temperatures and humidity were evaluated for their impacts on air toxic emissions. While testing minimum temperature effects, maximum daily temperature was held at 70 degrees Fahrenheit. The minimum daily temperature was held at 80 degrees Fahrenheit, while daily maximum temperature effects were evaluated.

As indicated in Fig. 31, all exhaust air toxic compounds and TOG emissions increase as daily minimum temperature decreases. All emission factors are virtually parallel to each other. On the other hand, evaporative emissions of both benzene and MTBE decrease as daily minimum temperature decreases (Fig 32).

Fig. 33 demonstrates that as the daily maximum temperature increase, all exhaust emissions increase. However, all air toxic compound emissions are at a much lower factor than the TOG emission factor. Evaporative emissions of both benzene and MTBE increase as daily maximum temperature increases (Fig. 34).

Humidity impacts on air toxic emissions are shown in Fig. 35 and 36. As humidity increases, all exhaust emissions including all air toxic compounds, MTBE and TOG increase at a similar factor. Humidity has no effect on evaporative emissions.

6: Time Series Analysis

By using default MOBILE6 data and other required data as specified in section 1, a trend evaluation was carried out for the calendar years between 2002 and 2020.

According to Fig. 37, exhaust emissions for all air toxic compounds and TOG are declining as time moves forward. This declining trend is essentially parallel to the TOG trend. Evaporative emission trends for both benzene and MTBE are also declining as time moves forward (Fig. 38). However, evaporative benzene emission factors decline at a much faster factor than MTBE.

SUMMARY

Effects of various parameters including vehicle, roadway facility, environment, and time on six different air toxic compound emissions and TOG were evaluated. While some parameters affected certain air toxic compounds significantly, others appeared to have no impacts. All impacts are grouped into six different categories, which are listed in the summary table below.

Table 1: Emission Factor Sensitivity Classification Table

TESTED	EXHAUST EMISSION FACTOR (EF)							EVAPORATIVE EF	
PARAMETER	ACETALDEHYDE	ACROLEIN	BENZENE	1,3 BUTADIENE	FORMALDEHYDE	MTBE	TOG	BENZENE	MTBE
AROMATIC	◔	○	◓	◔	◔	○	○	○	○
A-SPEED(2.5-10.0)	●	●	●	●	●	☀	☀	☀	☀
A-SPEED(10.0-22.5)	◓	◓	◓	◓	◓	◓	◓	◓	◓
A-SPEED(22.5-65.0)	◔	◔	◔	◔	◔	◔	◔	◔	◔
BENZENE	○	○	☀	○	○	○	○	☀	○
E200	◔	○	○	◔	○	○	○	○	○
E300	◔	○	◔	◔	○	○	○	○	○
ETBE	◓	◔	◔	◔	○	◔	○	◔	○
ETHANOL	◓	◔	◔	◓	○	◔	◔	◔	◔
F-SPEED(2.5-10.0)	●	●	●	●	●	●	☀	☀	☀
F-SPEED(10.0-22.5)	◓	◓	◓	◓	◓	◓	◓	◓	◓
F-SPEED(22.5-65.0)	◔	◓	◔	◔	◔	◔	◓	◓	◔
GAS-S	○	○	○	○	○	○	○	○	○
HUMIDITY	○	○	○	○	○	○	○	○	○
MAX.TEMPERATURE	○	○	○	○	○	○	◓	◓	◓
MIN.TEMPERATURE	◔	◔	◔	◔	◔	◔	○	◔	◔
MTBE	◔	◔	◔	◔	◔	●	◔	◔	●
OLEFIN	○	○	◔	◕	◔	○	○	○	○
RVP(6.5-8.5)	◓	○	◓	◓	◓	◔	☀	●	◔
RVP(8.5-12.5)	☀	☀	☀	☀	●	☀	☀	☀	☀
RVP(12.5-15.0)	◔	◔	☀	☀	◔	◓	◓	◕	●
TAME	○	◔	◔	◔	◔	◔	◔	◔	○
VMT RATIO(A vs.L)	◔	◔	◔	◔	◔	◔	◔	◔	◔
VMT RATIO(F vs. A)	○	○	○	○	○	○	○	○	○
YEAR(2002-2006)	☀	☀	●	☀	☀	☀	●	◕	◕
YEAR(2006-2011)	●	●	◕	●	●	☀	●	●	●
YEAR(2011-2020)	◕	◕	◕	◕	◕	◕	◕	●	●

○ :Percentage of an emission factor change as a result of one unit increase of tested parameter is ≤ 0.2%.

◕ :Percentage of an emission factor changes as a result of one unit increase of tested parameter is greater than 0.2% but ≤ 1.0%.

◐ :Percentage of an emission factor change as a result of one unit increase of tested parameter is greater than 1% but ≤ 4.0%.

◕ :Percentage of an emission factor change as a result of one unit increase of tested parameter is greater than 4% but ≤ 6%.

● :Percentage of an emission factor change as a result of one unit increase of tested parameter is greater than 6.0% but ≤ 10.0%.

☀ :Percentage of an emission factor change as a result of one unit increase of tested parameter is greater than 10.0%.

Figure 1 Freeway Facility Speed Effects on Exhaust Toxic Emissions

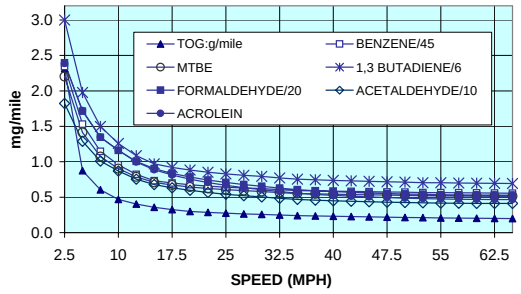


Figure 2 Freeway Facility Speed Effects on Evaporative Toxic Emissions

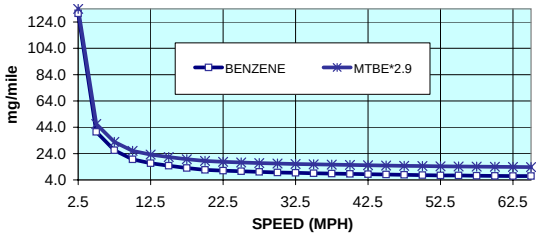


Figure 3 Arterial Facility Speed Effects on Exhaust Toxic Emissions

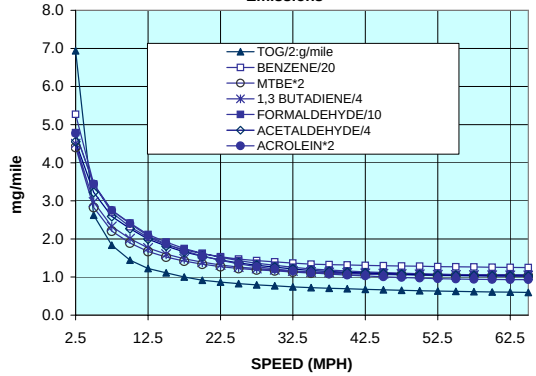


Figure 4 Arterial Facility Speed Effects on Evaporative Toxic Emissions

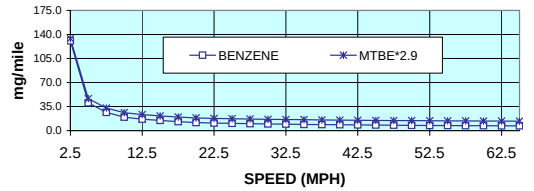


Figure 5 VMT Ratio (ARTERIAL/LOCAL) Effects on Exhaust Toxic Emissions

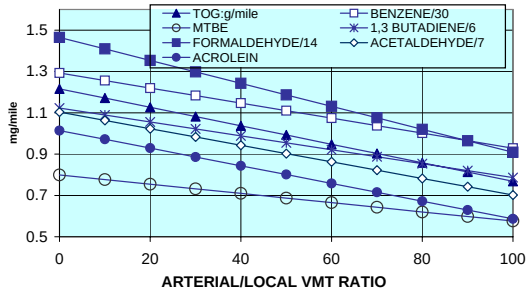


Figure 6 VMT Ratio (ARTERIAL/LOCAL) Effects on Evaporative Toxic Emissions

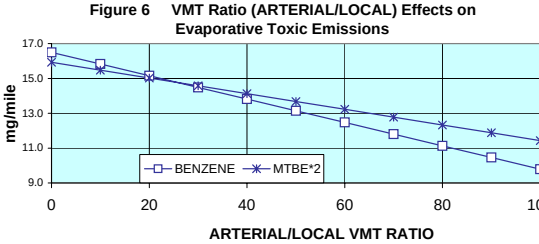


Figure 7 VMT Ratio (Freeway/Arterial) Effect on Exhaust Toxic Emissions

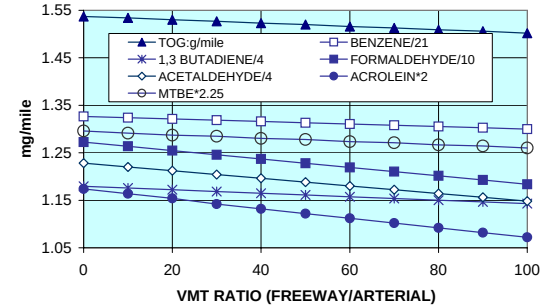


Figure 8 VMT Ratio (Freeway/Arterial) Effects on Evaporative Toxic Emissions

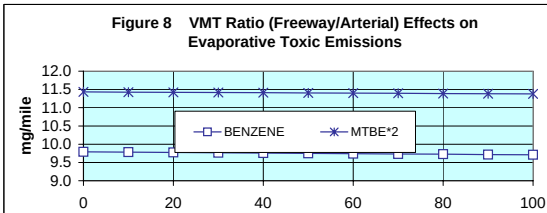


Figure 9 Fuel RVP Effects on Exhaust Air Toxic Emissions

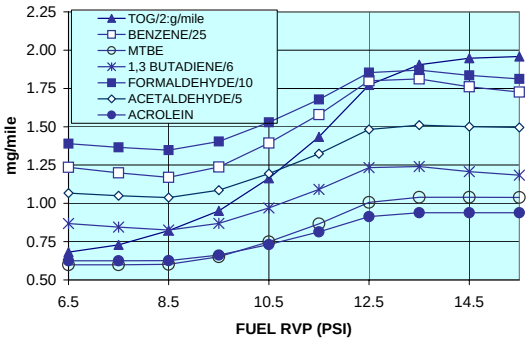


Figure 10 Fuel RVP Effects on Evaporative Air Toxic Emissions

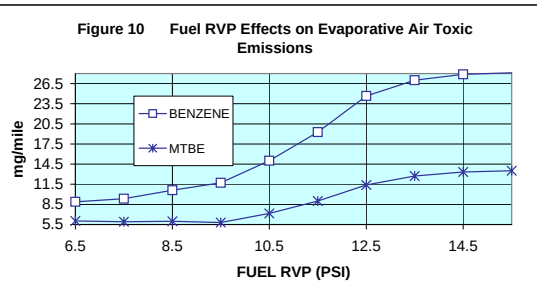


Figure 11 Gasoline Sulfur Effects on Exhaust Toxic Emissions

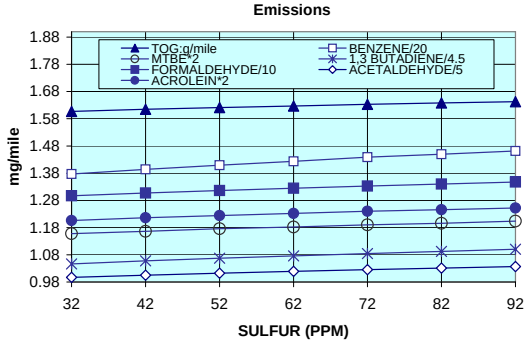


Figure 12 Gasoline Sulfur Effects on Evaporative Toxic Emissions

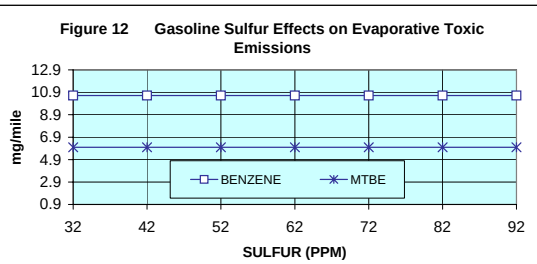


Figure 13 E200 Effects on Exhaust Air Toxic Emissions

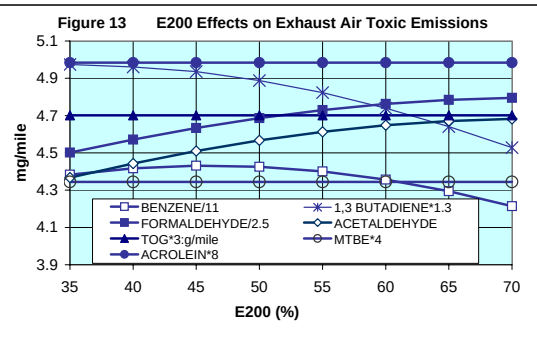


Figure 14 E200 Effects on Evaporative Air Toxic Emissions

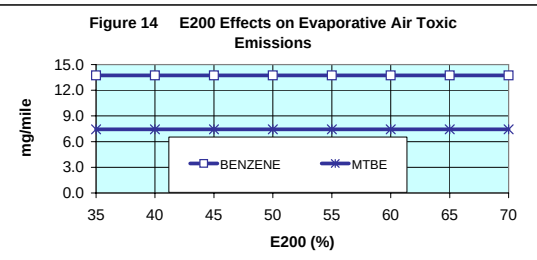


Figure 15 E300 Effects on Exhaust Air Toxic Emissions

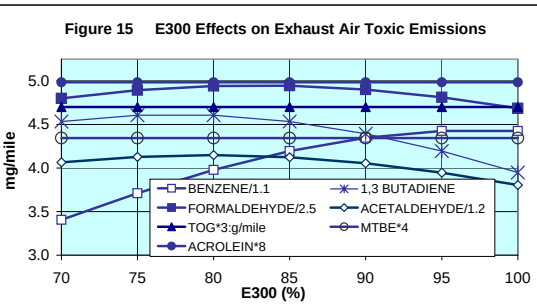


Figure 16 E300 Effects on Evaporative Air Toxic Emissions

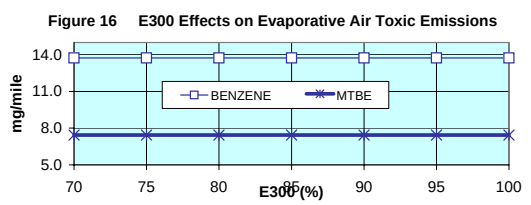


Figure 17 Aromatic Effects on Exhaust Air Toxic Emissions

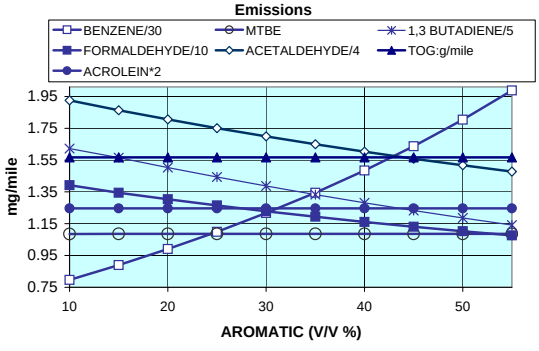


Figure 18 Aromatic Effects on Evaporative Air Toxic Emissions

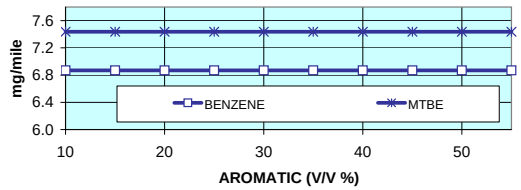


Figure 19 Benzene Effects on Exhaust Air Toxic Emissions

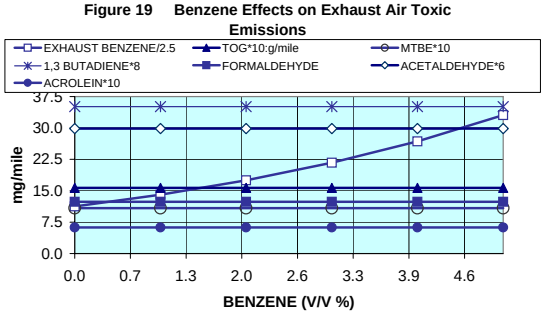


Figure 20. Benzene Effects on Evaporative Air Toxic Emissions

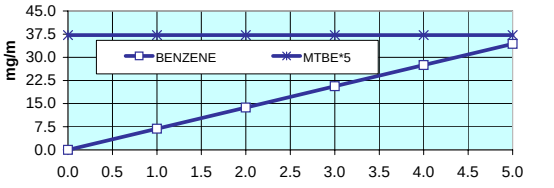


Figure 21 Olefin Effects on Exhaust Air Toxic Emissions

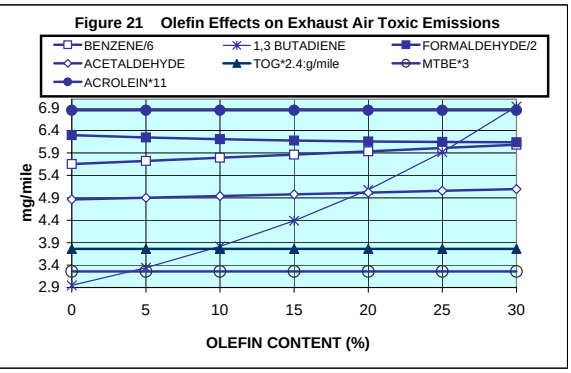


Figure 22 Olefin Effects on Evaporative Air Toxic Emissions

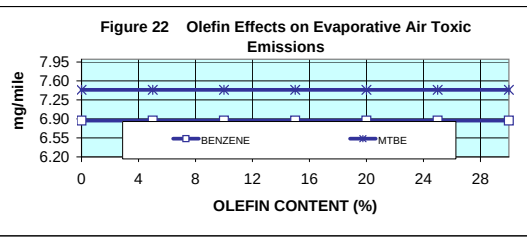


Figure 23 ETHANOL Effects on Exhaust Air Toxic Emissions

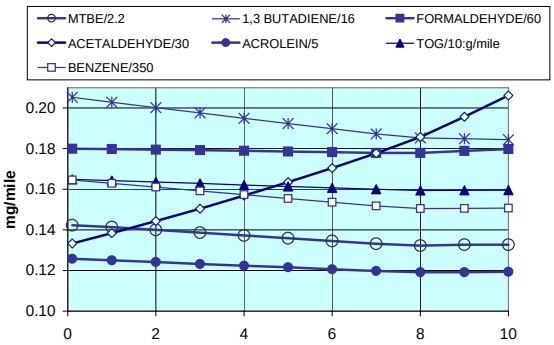


Figure 24 ETHANOL Effects on Evaporative Air Toxic Emissions

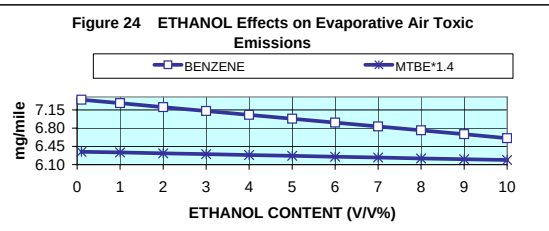


Figure 25 MTBE Effects on Exhaust Air Toxic Emissions

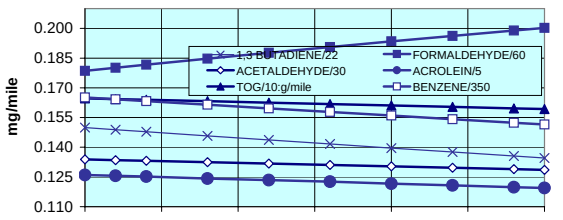


Figure 25a MTBE Effects on Exhaust Air Toxic Emissions

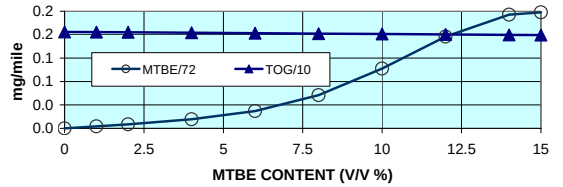


Figure 26 MTBE Effects on Evaporative Air Toxic Emissions

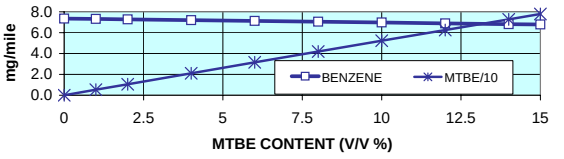


Figure 27 ETBE Effects on Exhaust Air Toxic Emissions

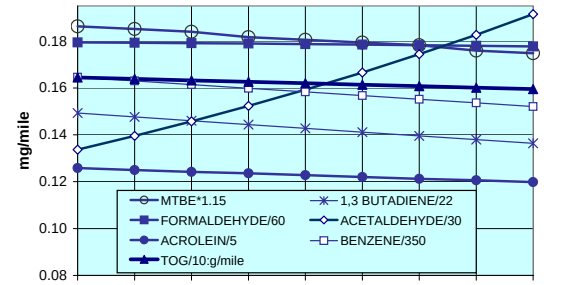


Figure 28 ETBE Effects on Evaporative Air Toxic Emissions

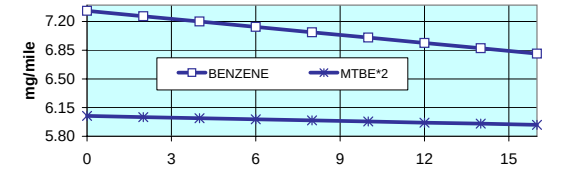


Figure 29 TAME Effects on Exhaust Air Toxic Emissions

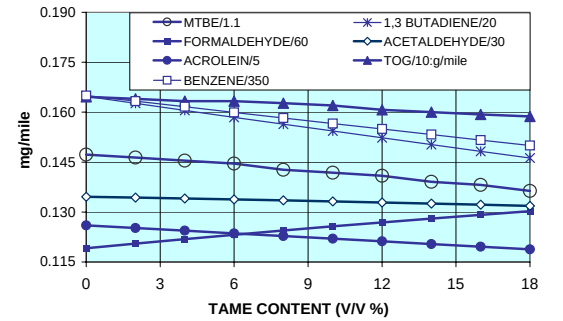


Figure 30 TAME Effects on Evaporative Air Toxic Emissions

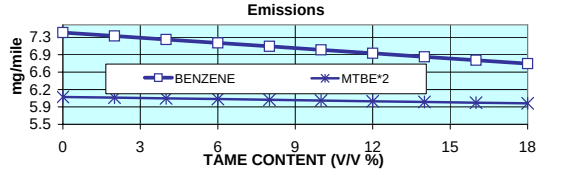


Figure 31 Minimum Temperature Effects on Exhaust Toxic Emissions

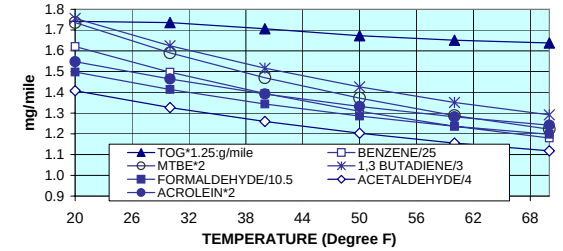


Figure 32 Minimum Temperature Effect on Evaporative Toxic Emissions

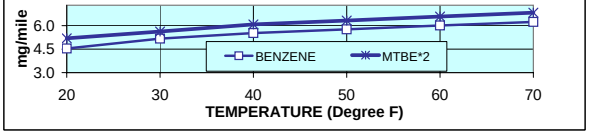


Figure 33 Maximum Temperature Effects on Exhaust Toxic Emissions

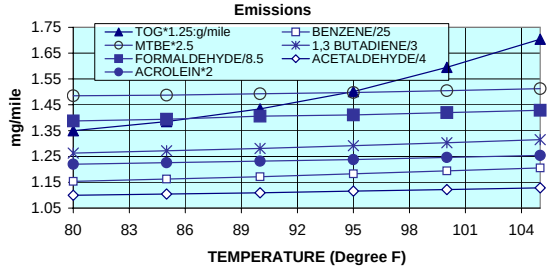


Figure 34 Maximum Temperature Effects on Evaporative Toxic Emissions

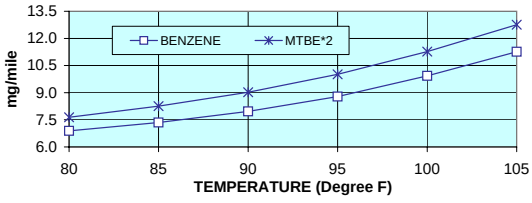


Figure 35 Humidity Effects on Exhaust Toxic Emissions

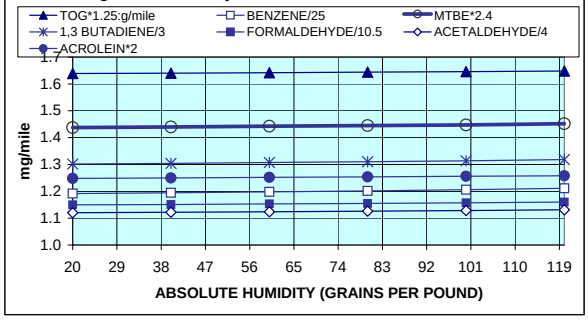


Figure 36 Humidity Effects on Evaporative Toxic Emissions

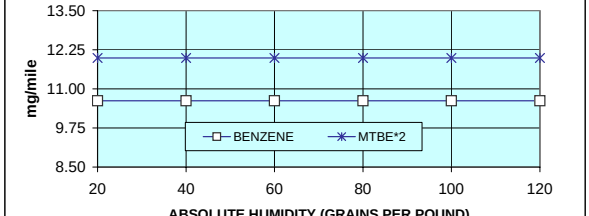


Figure 37 Time Series Evaluation on Exhaust Toxic Emissions

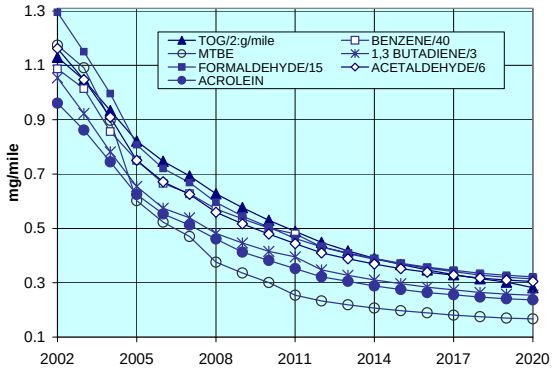
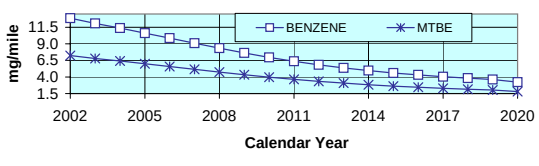


Figure 38 Time Series Evaluation on Evaporative Toxic Emissions



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