Organic Gas Speciation Profiles for Off-Highway Recreational Vehicles Running Exhaust (OG2309 and OG2310)

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April 19, 2018

1 Introduction

Off-highway recreational vehicle (OHRV) engines are defined as 4-stroke or 2-stroke, gasoline, diesel, or alternate-fuel powered engines or electric motors that are designed for powering off-road recreational vehicles. OHRVs primarily include off-highway motorcycles (OHMCs), all-terrain vehicles (ATVs), minibikes, golf carts and specialty vehicle carts. OHRVs are frequently used in occupational disciplines that include, but are not limited to, agricultural, building and trades, landscape maintenance, and law enforcement.

Due to the lack of off-road profiles, the emissions of OHRV categories are assigned with on-road motor vehicle speciation profiles in CARB's current inventory. For example, OG665 (Non-catalyzed on-road stabilized exhaust – 1996 SSD 2.0%O ethanol) is used to describe all running exhaust emissions for gasoline-powered OHRVs for 2004 and later years [1]. However, the profiles that were made for on-road motor vehicles, such as OG665, may not be applicable to off-road engines and vehicles. Therefore, it is necessary to develop profiles specifically for off-highway vehicles to better understand their emission composition.

CARB's inventory indicates that most of the OHRVs in the state are equipped with spark ignition (SI) engines running on gasoline fuel rather than compression ignition (CI) engines running on diesel fuel, thus developing speciation profiles for gasoline-powered OHRV is the focus of this work. Reichle et al. discovered significant differences in the compositions of emissions from 4-stroke engines and 2-stroke engines [2]. According to a recent CARB research project on OHRV emissions and referring to EPA's speciation profiles for OHRV, two organic gas (OG) speciation profiles were generated to replace the current-in-use OG665. The new profiles include:

- *OG2309: 4-stroke off-highway recreational vehicle running exhaust (E10)*
- *OG2310: 2-stroke off-highway recreational vehicle running exhaust (E10)*

2 Methodology

2.1 OG2309: 4-stroke OHRV running exhaust (E10)

In 2014, Project 2R1404 was performed at CARB's Haagen-Smit Laboratory (HSL) in El Monte, CA. The primary objective of this project was to conduct exhaust and evaporative emissions testing for OHRVs. The specific focus of this test plan was OHMC. The test vehicles were obtained through a combination of CARB fleet vehicles, CARB standard procurement

contracts through rental agencies and private owners, and vehicle purchasing. Four MCs were selected for the running exhaust speciation tests (Table 1).

Table 1. Four test motorcycles in Project 2R1404.

Vehicle Make/Model	*Vehicle Model Year*	*Engine Type*	*Fuel Delivery System*	*Engine Displacement*
YAMAHA/WR450FF	2015	4-Stroke	EFI*	490 cc
KTM/250XC-FW	2013	4-Stroke	EFI*	249 cc
KAWASAKI/KX250Y	2012	4-Stroke	EFI*	250 cc
HONDA/CRF150R	2013	4-Stroke	Carbureted	150 cc

Note: *EFI: Electronic Fuel Injection

All vehicles were filled with California Phase III certification gasoline fuel containing 10% ethanol by volume (E10). They were tested on a chassis dynamometer using the three-phase Federal Test Procedure (FTP) cycle, which consists of a cold start Urban Dynamometer Driving Schedule (UDDS), a transient phase and a hot start UDDS. The tailpipe exhaust samples were diluted in a constant volume sampler (CVS) system which maintains a constant total flow rate of exhaust plus dilution air. Tedlar bags were used to collect organic gas samples from each phase for GC speciation analysis (MLD SOP#102/103) [3]. Aldehyde and ketone compounds in the exhaust were collected by 2,4-dinitrophenylhydrazine (DNPH) impregnated cartridges and analyzed by using HPLC (MLD SOP#104) [4]. The methanol and ethanol in the exhaust were obtained by flowing exhaust through deionized water contained in glass impingers and analyzed by using GC (MLD SOP#101) [5].

Over two hundred organic compounds were measured in the exhaust samples. For each test vehicle, the emissions of all three phases were collected and analyzed. The weighted emissions of the three phases were calculated by weighing these emissions for the overall FTP cycle. The speciation profile for each test vehicle was calculated by dividing the emission of each species by the total emissions of all the species generated from the same vehicle. Each profile consists of the weight percent of total organic gas (TOG) for every compound for the overall FTP cycle. Four individual speciation profiles were obtained for the test MCs.

Among the four test vehicles, the 2015 YAMAHA, 2013 KTM and 2012 KAWASAKI were equipped with an Electronic Fuel Injection (EFI) system, and the 2013 HONDA was equipped with a carburetor. Comparisons of the four profiles indicate that their compositions of broad chemical classes were qualitatively similar even though their fuel delivery systems were different (Figure 1). Therefore, to increase the robustness of the FTP profiles, a composite profile OG2309 was made by averaging all four individual weighted profiles. The details of OG2309 are provided in the Appendix (Table 1).

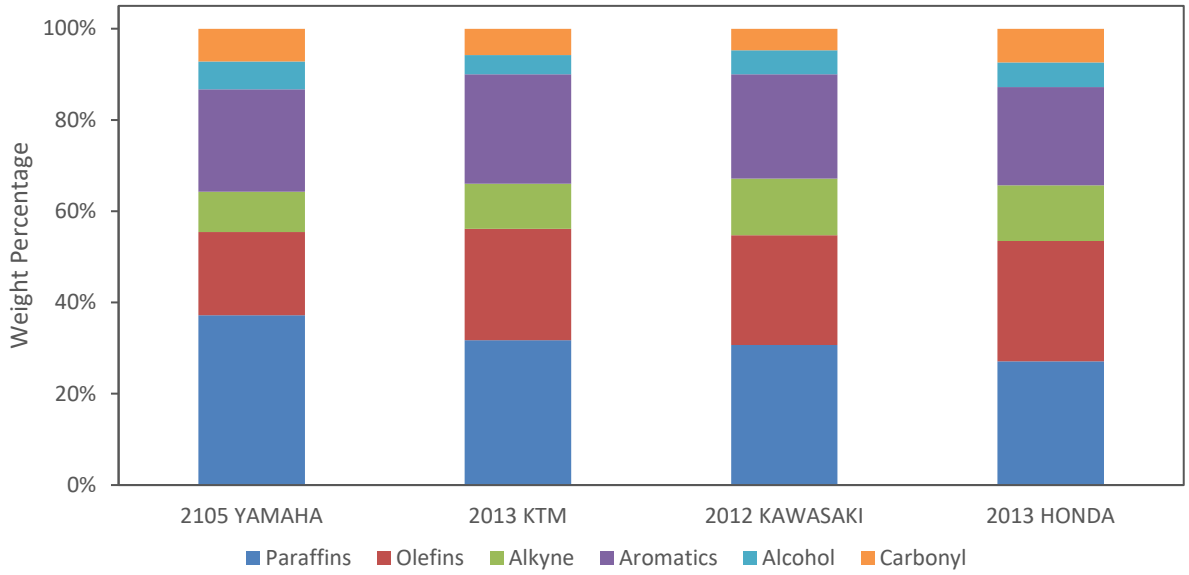

Figure 1. Comparison of weighted FTP profiles (4-stroke) by compound class.

2.2 OG2310: 2-stroke OHRV running exhaust (E10)

Unlike 4-stroke engines, 2-stroke engines do not rely on a bath of motor oil to lubricate the piston and rings from below. Instead, they use a fuel-oil mixture for lubricity. Although the CARB 2R1404 project had emission tests on 2-stroke engines, none of the tests included speciation. Hence, testing data from other research studies were reviewed and used in order to make the speciation profile for 2-stroke engines running exhaust.

Organic gas speciation profile 95328 in USEPA's speciation profile database SPECIATE 4.5 [6] is a profile for SI exhaust emissions from 2-stroke off-road engines using E10 ethanol gasoline. This profile was created based on a source test conducted by Southwest Research Institute (SwRI), under contract to USEPA [2]. Four recreational equipment vehicles including two ATVs and two MCs (without catalyst) were selected for the test and E10 was used as one of the test fuels. Each vehicle was tested on a chassis dynamometer using the UDDS transient driving cycle. During the test, exhaust samples were collected in bags and analyzed for the presence of more than two hundred different species, including C1-C12 hydrocarbons, aldehydes and ketones, and alcohols. C1-C12 species were analyzed using gas chromatography with a flame ionization detector (GC-FID) procedures. Aldehydes and ketones were collected from the bag samples on cartridges packed with silica gel impregnated with 2,4-dinitrophenylhydrazine and a high-performance liquid chromatography procedure was used to analyze the collected aldehydes and ketones.

The test data used for to make EPA profile 95328 was reviewed, the chemical species were assigned with CARB-SAROAD codes, and the profile was adopted as CARB's new profile OG2310 for 2-stroke OHRV running exhaust (E10). The details of OG2310 are provided in the Appendix (Table 1).

3 Results and Discussion

Figure 2 compares the two new profiles by broad chemical class. The differences between OG2309 (4-stroke) and OG2310 (2-stroke) are significant. The emissions from 4-stroke engines (OG2309) have a higher percentage of olefins (mostly due to higher propylene, ethylene, and acetylene), alkynes and carbonyls; while the 2-stroke engine exhaust (OG2310) contains a higher percentage of paraffins (mostly due to 2,2,4-trimethylpentane, isopentane, and 2-methylhexane).

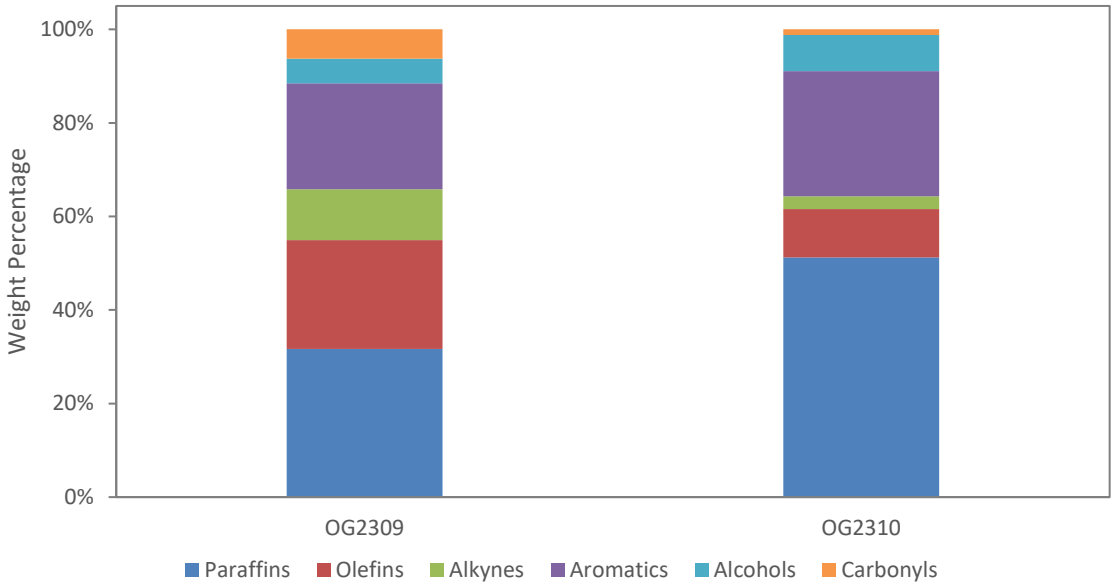

Figure 2. Comparison of OG2309 (4-stroke) and OG2310 (2-stroke) by compound class.

The major species of the two profiles are displayed in Figure 3. The contributions of these compounds to TOG vary greatly between 2-stroke and 4-stroke engines. In the tailpipe exhaust from 4-stroke engines (OG2309), ethylene (12%) and acetylene (10%) are the largest contributors. Methane (8%) is also a major species in the exhaust and it is likely due to incomplete combustion. In the 2-stroke running exhaust, 2,2,4-trimethylpentane (13%), toluene (8%) and ethanol (8%) are the top three contributors.

The variations in the profiles of 4-stroke and 2-stroke engines are likely due to the technology differences between the two engine types. In 2-stroke engines, lubricating oil is mixed with the gasoline, some of the fresh oil-gas mixture passes directly to the exhaust without being combusted, which contributes to high organic emissions from 2-stroke engines and impacts the composition of the exhaust. It has to be noted that OG2309 and OG2310 were developed based on tests using the FTP cycle and the UDDS cycle, respectively. As stated previously, a FTP cycle consists of a cold start UDDS cycle, a transient phase and a hot start UDDS cycle.

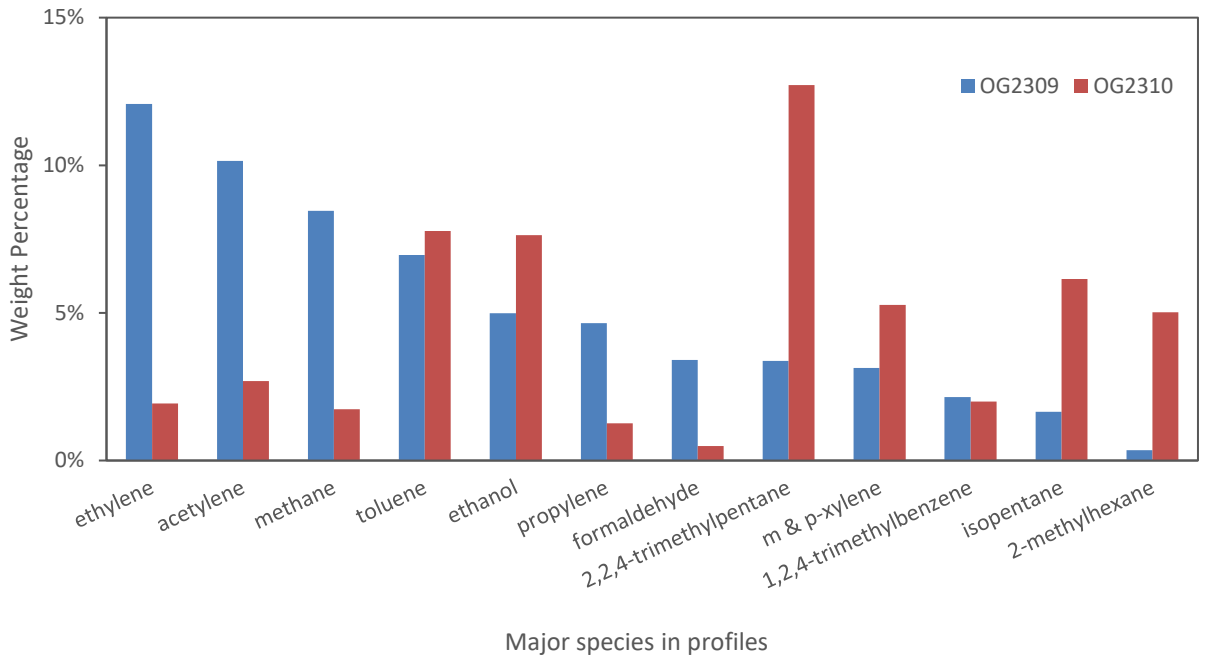

Figure 3. Major species in OG2309 vs. OG2310.

4 Estimated Impacts of the Profile Update on the Emission Inventory

Due to the lack of test data for off-road vehicles, the on-road non-catalyzed profile OG665 has been used for OHRV running exhausts in CARB's inventory. Compared to OG665, the new profile OG2309 has less paraffins and more alkynes, but new OG2310 has more paraffins and less alkynes.

The ROG/TOG (reactive organic gas/total organic gas) ratios of OG2309 and OG2310 are 0.90 and 0.98, respectively. They are comparable to the ROG/TOG of OG665 (0.92). The ozone forming potential (OFP) of the new profiles is estimated based on SAPRC07. They are 4.37 and 3.36 g O_3/g Organics for OG2309 and OG2310, respectively, both lower than the OFP of OG665 (4.55 g O_3/g Organics).

Table 2. ROG/TOG and OFP of OG2309 and OG2310.

Profile Number	*OG2309*	*OG2310*
ROG/TOG	0.90	0.98
Ozone forming potential (g O_3/g Organics)	4.37	3.36

The newly-developed profiles OG2309 will replace OG665 for the categories relevant to 4-stroke running exhaust; and OG2310 will replace OG665 for the categories relevant to 2-stroke running exhaust. The affected EIC/SCC categories and the assignment of the new profiles are summarized in the Appendix (Table 2).

Implementation of the new profiles for the related categories will impact the estimation of ROG and toxic emissions. The OFP contributed by these categories will also be affected.

Using 2016 emissions as an example, the statewide annual average TOG emissions of OHRV running exhaust are about 8.90 tons/day based on CEPAM (version 1.05): 2016 SIP Baseline Emission Projection for year 2016 [7]. Using the new profiles OG2309 and OG2310, the corresponding ROG of these OHRV running exhaust emissions will be 8.56 tons/day, which is 4.5% higher than the ROG emissions estimated based on the current profile OG665. If the new profiles are applied, the calculated OFP of these categories will be 21.2% lower than the estimation using the current profile OG665. For toxic species, the emissions of benzene, formaldehyde, 1,3-butadiene, and acetaldehyde will decrease with the application of the new profiles; while the emissions of toluene will increase compared to the values calculated based on OG665 (Table 3).

Table 3. Changes on emissions of organic gas species for OHRV running exhaust categories (2016).

Statewide Annual Ave. Emissions		*Current OG665 (tons/day)*	*New OG2309 & OG2310 (tons/day)*	*Change*	
				Emissions (tons/day)	*Percentage*
ROG		8.19	8.56	+0.37	+4.5%
Ozone forming potential		40.50	31.93	-8.57	-21.2%
Toxics	Benzene	0.30	0.15	-0.15	-50.0%
	Formaldehyde	0.27	0.10	-0.17	-63.0%
	1,3-butadiene	0.07	0.03	-0.04	-57.1%
	Acetaldehyde	0.09	0.05	-0.04	-44.4%
	Toluene	0.62	0.68	+0.06	+9.7%

References:

1. *California Air Resources Board Main Speciation Profiles,* 2017, California Air Resources Board, *Accessed*: July 31, 2017.
2. Reichle, L.J., et al., *Development of organic gas exhaust speciation profiles for nonroad spark-ignition and compression-ignition engines and equipment.* Journal of the Air & Waste Management Association, 2015. **65**(10): p. 1185-1193.
3. CARB, *Standard Operating Procedure No. MLD 102 / 103 (Version 2.2): Procedure for the Determination of C2 to C12 Hydrocarbons in Automotive Exhaust Samples by Gas Chromatography*, 2007: El Monte, CA.
4. CARB, *Standard Operating Procedure No. MLD 104 (Revision 3.0): Procedure for the Determination of Aldehyde and Ketone Compound in Automotive Source Samples by High Performace Liquid Chromatography*, 2006: El Monte, CA.

5. CARB, *Standard Operating Procedure No. MLD 101 (Revision 2.2): Procedure for the Analysis of Automotive Exhaust for Methanol and Ethanol*, 2005: El Monte, CA.
6. *SPECIATE 4.5,* 2016, USEPA, *Accessed*: March, 2018.
7. *CEPAM,* 2018, California Air Resources Board, *Accessed*: Feb 2, 2018.

Appendix

Table 1. OG speciation profiles for OHRV running exhaust (OG2309 & 2310).

Species Name	*SAROAD*	*Weight Percentage, %*	
		OG2309 OHRV 4-Stroke Running Exhaust (E10)	*OG2310 OHRV 2-Stroke Running Exhaust (E10)*
(1-methylpropyl)benzene	45234		0.003234
(2-methylbutyl)benzene	98162		0.154475
(2-methylpropyl)benzene	45235	0.147515	0.055285
1,1-dimethylcyclopentane	99098		0.002921
1,2,3,4-tetramethylbenzene	91109	0.004864	0.069670
1,2,3,5-tetramethylbenzene	91104	0.023807	0.011575
1,2,3-trimethylbenzene	45225	0.423068	0.063915
1,2,4,5-tetramethylbenzene	91103	0.020437	0.140935
1,2,4-triethylbenzene	91119		0.020233
1,2,4-trimethylbenzene	45208	2.152985	2.000133
1,2,4-trimethylcyclopentane	43400	0.024570	0.068998
1,2-butadiene	43221	0.021748	
1,2-diethylbenzene	98154	0.008996	0.076126
1,2-dimethyl-3-ethylbenzene	45254	0.015983	0.004091
1,2-dimethyl-4-ethylbenzene	45252	0.087936	0.027472
1,2-propadiene	43208	0.411707	
1,3,5-triethylbenzene	91117		0.018357
1,3,5-trimethylbenzene	45207	0.592024	0.720569
1,3,5-trimethylcyclohexane	98061	0.023902	
1,3-butadiene	43218	0.725573	0.264567
1,3-butadiyne	43222	0.037860	
1,3-cyclopentadiene	90026		0.120872
1,3-diethylbenzene	45113	0.042655	0.168608
1,3-dimethyl-2-ethylbenzene	45253	0.064301	0.013818
1,3-dimethyl-4-ethylbenzene	45251	0.074336	0.007719
1,3-dimethyl-5-ethylbenzene	45257	0.159445	
1,3-n-dipropylbenzene	91116	0.000695	
1,4-diethylbenzene	45114	0.037469	0.391385
1,4-dimethyl-2-ethylbenzene	45250	0.132345	0.239756
1-butene	43213	0.511262	0.127422
1-butyne	98131	0.041752	
1-decene	43268		0.013574
1-ethyl-1-methylcyclopentane	91046		0.018951
1-ethyl-2-n-propylbenzene	98179	0.001631	
1-heptene	98005	0.001328	
1-hexene	43245	1.044985	0.108483
1-methyl-2-ethylbenzene	99915	0.480924	0.493496
1-methyl-2-isopropylbenzene	91096	0.088300	0.050826
1-methyl-2-n-butylbenzene	45243	0.005725	
1-methyl-2-n-propylbenzene	98178	0.061221	0.028181
1-methyl-3-ethylbenzene	99912	1.102210	1.532336
1-methyl-3-isopropylbenzene	98153	0.054671	0.026544

Species Name	*SAROAD*	*Weight Percentage, %*	
		OG2309 OHRV 4-Stroke Running Exhaust (E10)	*OG2310 OHRV 2-Stroke Running Exhaust (E10)*
1-methyl-3-n-propylbenzene	98152	0.288821	0.183775
1-methyl-4-ethylbenzene	99914	0.501767	0.636575
1-methyl-4-isopropylbenzene	91094	0.028958	
1-methyl-4-n-propylbenzene	98182	0.043959	0.023332
1-methylcyclopentene	92000	0.014283	0.166454
1-nonene	43267	0.009577	0.068877
1-octene	43265	0.014098	
1-pentene	43224	0.065941	0.222829
1-propyne	43209	0.586147	0.018800
1-tert-butyl-2-methylbenzene	45244	0.001146	0.157026
1-tert-Butyl-3,5-dimethylbenzene	45256	0.000326	0.135783
1-tert-butyl-4-ethylbenzene	91118		0.060491
2,2,3-trimethylbutane	43160	0.011847	0.068420
2,2,3-trimethylpentane	43296		1.050445
2,2,4-trimethylheptane	98174	0.009888	
2,2,4-trimethylhexane	45222		0.019305
2,2,4-trimethylpentane	43276	3.370061	12.719220
2,2,5-trimethylheptane	43252	0.082506	
2,2,5-trimethylhexane	98033	0.441196	0.040862
2,2-dimethylbutane	43291	0.682288	0.069752
2,2-dimethylhexane	98138	0.017648	0.088338
2,2-dimethyloctane	98175	0.023327	0.055500
2,2-dimethylpentane	90042	0.040433	0.611259
2,2-dimethylpropane	98130	0.013713	0.070406
2,3,3-trimethylpentane	43280	0.354039	0.208432
2,3,4-trimethylhexane	91053		0.020413
2,3,4-trimethylpentane	43279	1.201433	0.665256
2,3,5-trimethylhexane	98141	0.067475	0.037403
2,3-dimethyl-1-butene	43234	0.047280	
2,3-dimethyl-2-pentene	90061	0.208300	
2,3-dimethylbutane	98001	0.419061	0.540096
2,3-dimethylheptane	98145	0.000684	0.024464
2,3-dimethylhexane	98139	0.040371	0.129052
2,3-dimethyloctane	98183	0.100175	
2,3-dimethylpentane	43274	0.315231	0.001468
2,4,4-trimethyl-1-pentene	98054	0.003361	0.106997
2,4,4-trimethyl-2-pentene	98055	0.000401	0.018429
2,4,4-trimethylhexane	45223	0.011328	
2,4-dimethyl-1-pentene	90063	0.011873	
2,4-dimethylheptane	98142	0.030800	0.059934
2,4-dimethylhexane	43277	0.551154	1.144790
2,4-dimethyloctane	98149	0.074151	0.066979
2,4-dimethylpentane	43271	0.417011	0.946955
2,5-dimethylbenzaldehyde	47029		0.023721
2,5-dimethylheptane	98143		0.067571

Species Name	*SAROAD*	*Weight Percentage, %*	
		OG2309 OHRV 4-Stroke Running Exhaust (E10)	*OG2310 OHRV 2-Stroke Running Exhaust (E10)*
2,5-dimethylhexane	43278	0.432125	
2,5-dimethyloctane	98176	0.047877	
2,6-dimethylheptane	98157	0.056680	0.006707
2,6-dimethyloctane	98177	0.078584	
2-butanone	43552	0.058396	0.009949
2-methyl-1-butene	43225	0.147376	0.441633
2-methyl-1-pentene	98040		0.128281
2-methyl-2-butene	43228	0.198736	0.756446
2-methyl-2-hexene	90028		0.132216
2-methyl-2-pentene	98004	0.017703	0.18405
2-methyl-2-propenal	43506	0.146593	
2-methylheptane	98140	0.194085	0.549163
2-methylhexane	43275	0.354255	5.021903
2-methylindan	91108	0.004486	
2-methylnonane	90047	0.920979	
2-methyloctane	98146		0.469795
2-methylpentane	43229	0.604506	2.322823
2-methylpropanal	98036		0.009949
2-methyl-trans-3-hexene	91006	0.017720	
3,3-dimethyl-1-butene	98169	0.025496	0.009949
3,3-dimethylheptane	91063		0.037398
3,3-dimethylhexane	98171	0.005671	0.080883
3,3-dimethyloctane	98184	0.025173	
3,3-dimethylpentane	90040	0.070990	0.040802
3,4-dimethyl-1-pentene	90075	0.031561	0.02128
3,4-dimethylheptane	91069		0.02899
3,4-dimethylhexane	98150	0.081867	0.07152
3,5-dimethylheptane	98144	0.06564	0.067571
3-ethyl-2-pentene	98007	0.001727	0.012107
3-ethyl-3-methylpentane	91036		0.071518
3-ethylpentane	43300	0.019515	0.327152
3-methyl-1-butene	43223	0.061485	0.127382
3-methyl-1-hexene	90030	0.058881	0.019791
3-methyl-1-pentene	43211	0.008045	0.088217
3-methyl-cis-2-hexene	90029	0.004425	
3-methyl-cis-2-pentene	98163	0.008738	0.235147
3-methylcyclopentene	43272	0.003671	0.003328
3-methylheptane	43298	0.163601	0.724876
3-methylhexane	43295	0.292794	1.352597
3-methyloctane	98172	0.083383	0.310738
3-methylpentane	43230	0.433244	1.546411
3-methyl-trans-2-pentene	43270	0.010932	0.273636
4,4-dimethylheptane	91060		0.071989
4-methyl-1-pentene	98135	0.017914	0.01954
4-methylheptane	43297	0.060273	0.176009

Species Name	*SAROAD*	*Weight Percentage, %*	
		OG2309 OHRV 4-Stroke Running Exhaust (E10)	*OG2310 OHRV 2-Stroke Running Exhaust (E10)*
4-methylindan	91107	0.006402	
4-methyloctane	98173	0.130529	
4-methyl-trans-2-hexene	90031	0.002214	
4-methyl-trans-2-pentene	43293	0.017928	0.081597
5-methylindan	91106	0.012590	
acetaldehyde	43503	1.496552	0.327677
acetone	43551	0.193790	0.048577
acetylene	43206	10.150172	2.687888
acrolein	43505	0.199525	0.043282
benzaldehyde	45501	0.389938	0.065098
benzene	45201	3.094518	1.230739
butyraldehyde	43510	0.056153	
c5 olefins	43143		0.008737
c6 olefins	43289		0.069928
c9-c12 isoalkanes	99275		3.560145
cis-1,2-dimethylcyclohexane	91055	0.007378	0.099531
cis-1,3-dimethylcyclohexane	98180	0.080760	
cis-1,3-dimethylcyclopentane	91018	0.041962	0.019127
cis-1,4-dimethylcyclohexane	91051		0.027113
cis-1,trans-2,3-trimethylcyclopentane	91038	0.031686	0.234399
cis-1-ethyl-2-methylcyclopentane	99093		0.065621
cis-1-methyl-3-ethylcyclopentane	90080	0.007675	0.058254
cis-2-butene	43217	0.158078	0.103688
cis-2-heptene	91028	0.017283	0.056943
cis-2-hexene	98035	0.003603	0.095327
cis-2-octene	43266	0.002363	0.012619
cis-2-pentene	43227	0.027602	0.280742
cis-3-hexene	98003		0.115803
cis-3-nonene	91084		0.006227
crotonaldehyde	98156	0.046974	0.023537
cyclohexane	43248	0.733837	0.075760
cyclohexene	43273	0.047069	0.037119
cyclopentane	43242	1.659773	0.104055
cyclopentene	43292	0.094535	0.127186
ethane	43202	1.356727	0.285807
ethanol	43302	4.991258	7.632697
ethylbenzene	45203	0.951863	2.184315
ethylcyclohexane	43288	0.048534	0.106714
ethylcyclopentane	98057	0.077586	
ethylene	43203	12.073293	1.936947
formaldehyde	43502	3.404960	0.486141
hexaldehyde	98159	0.011622	0.001910
indan	98044	0.076515	
isobutane	43214	0.040405	0.015751
isobutylene	43215	2.064727	1.020314

Species Name	*SAROAD*	*Weight Percentage, %*	
		OG2309 OHRV 4-Stroke Running Exhaust (E10)	*OG2310 OHRV 2-Stroke Running Exhaust (E10)*
isopentane	98132	1.646384	6.143946
isoprene	43243	0.117232	0.143279
isopropylbenzene	98043	0.095836	0.062163
isopropylcyclopentane	43178		0.033730
isovaleraldehyde	98056		0.018537
m & p-xylene	99024		5.269483
methane	43201	8.454469	1.737374
methanol	43301	0.269910	0.129132
methylcyclohexane	43261	0.357148	0.630032
methylcyclopentane	43262	0.325605	0.598933
methylhexenes	99353		0.029704
m-tolualdehyde	45502	0.177814	0.075666
m-xylene	45205	2.094182	
naphthalene	98046	0.026932	0.045786
n-butane	43212	0.541510	1.170298
n-butylbenzene	91098		0.023332
n-decane	43238	0.176048	0.058607
n-dodecane	43255	0.000286	0.052210
n-heptane	43232	0.408854	0.617514
n-hexane	43231	0.952477	0.699382
n-hexylbenzene	91121		0.028412
n-nonane	43235	0.245827	0.155650
n-octane	43233	0.285613	0.301356
n-pentane	43220	0.800679	0.866959
n-pentylbenzene	45255	0.007099	0.089885
n-propylbenzene	45209	0.349827	0.474777
n-undecane	43241	0.029506	0.108081
n-valeraldehyde	98200	0.001528	0.004735
other c7	99030		0.270316
other c8	99031		0.116767
o-tolualdehyde	45504		0.017748
o-xylene	45204	1.010405	1.818510
propanal	43504	0.077028	0.051050
propane	43204	0.775846	0.030452
propylcyclopentane	90116		0.006706
propylene	43205	4.648107	1.263677
p-xylene	45206	1.045276	
styrene	45220	0.304712	0.172517
t-butylbenzene	45215		0.031423

Species Name	*SAROAD*	*Weight Percentage, %*	
		OG2309 OHRV 4-Stroke Running Exhaust (E10)	*OG2310 OHRV 2-Stroke Running Exhaust (E10)*
toluene	45202	6.958331	7.773328
trans-1,2-dimethylcyclohexane	91047		0.173187
trans-1,2-dimethylcyclopentane	91021	0.029169	0.099129
trans-1,3-dimethylcyclohexane	98059	0.029394	0.030269
trans-1,3-dimethylcyclopentane	91019	0.037842	0.351627
trans-1,3-pentadiene	90100	0.013552	
trans-1,4-dimethylcyclohexane	98181	0.048398	0.023927
trans-1-ethyl-2-methylcyclopentane	43182		0.111685
trans-1-methyl-3-ethylcyclopentane	91044	0.020809	0.136887
trans-2-butene	43216	0.200240	0.228361
trans-2-heptene	91026	0.003587	0.067332
trans-2-hexene	98034	0.015973	0.177560
trans-2-nonene	91075		0.007993
trans-2-octene	43263	0.002925	0.111207
trans-2-pentene	43226	0.044618	0.490529
trans-3-heptene	98006	0.002865	0.109035
trans-3-hexene	98136	0.004661	
trans-3-nonene	91080		0.051270
trans-4-octene	43250		0.045548
vinylacetylene	98134	0.007702	
Total		*100.000000*	*100.000000*

Table 2. Gasoline powered-OHRV running exhaust related categories and profile assignment.

SCC/EIC	*Category Name*				*New OG Profile*
85087011000000	OFF-ROAD RECREATIONAL VEHICLES	SNOWMOBILES	GASOLINE (UNSPECIFIED)	SUB-CATEGORY UNSPECIFIED	OG2309
85087011006252	OFF-ROAD RECREATIONAL VEHICLES	SNOWMOBILES	GASOLINE (UNSPECIFIED)	Snowmobiles -G2-25-Exhaust	OG2310
85087011006254	OFF-ROAD RECREATIONAL VEHICLES	SNOWMOBILES	GASOLINE (UNSPECIFIED)	Snowmobiles -G4-25-Exhaust	OG2309
85087011006552	OFF-ROAD RECREATIONAL VEHICLES	SNOWMOBILES	GASOLINE (UNSPECIFIED)	Snowmobiles -G2-50-Exhaust	OG2310
85087011006554	OFF-ROAD RECREATIONAL VEHICLES	SNOWMOBILES	GASOLINE (UNSPECIFIED)	Snowmobiles -G4-50-Exhaust	OG2309
85087011006652	OFF-ROAD RECREATIONAL VEHICLES	SNOWMOBILES	GASOLINE (UNSPECIFIED)	Snowmobiles -G2-120-Exhaust	OG2310
85087011006654	OFF-ROAD RECREATIONAL VEHICLES	SNOWMOBILES	GASOLINE (UNSPECIFIED)	Snowmobiles -G4-120-Exhaust	OG2309
85087111000020	OFF-ROAD RECREATIONAL VEHICLES	RECREATIONAL EQUIPMENT	GASOLINE (UNSPECIFIED)	TWO-STROKE EXHAUST	OG2310
85087111000040	OFF-ROAD RECREATIONAL VEHICLES	RECREATIONAL EQUIPMENT	GASOLINE (UNSPECIFIED)	FOUR-STROKE EXHAUST	OG2309
85087211000000	OFF-ROAD RECREATIONAL VEHICLES	OFF-ROAD MOTORCYCLES	GASOLINE (UNSPECIFIED)	SUB-CATEGORY UNSPECIFIED	OG2309
85087211004052	OFF-ROAD RECREATIONAL VEHICLES	OFF-ROAD MOTORCYCLES	GASOLINE (UNSPECIFIED)	Off-Road Motorcycles -G2-5-Exhaust	OG2310
85087211004054	OFF-ROAD RECREATIONAL VEHICLES	OFF-ROAD MOTORCYCLES	GASOLINE (UNSPECIFIED)	Off-Road Motorcycles -G4-5-Exhaust	OG2309
85087211004152	OFF-ROAD RECREATIONAL VEHICLES	OFF-ROAD MOTORCYCLES	GASOLINE (UNSPECIFIED)	Off-Road Motorcycles -G2-15-Exhaust	OG2310
85087211004154	OFF-ROAD RECREATIONAL VEHICLES	OFF-ROAD MOTORCYCLES	GASOLINE (UNSPECIFIED)	Off-Road Motorcycles -G4-15-Exhaust	OG2309
85087211004252	OFF-ROAD RECREATIONAL VEHICLES	OFF-ROAD MOTORCYCLES	GASOLINE (UNSPECIFIED)	Off-Road Motorcycles -G2-25-Exhaust	OG2310

SCC/EIC	*Category Name*				*New OG Profile*
85087211004254	OFF-ROAD RECREATIONAL VEHICLES	OFF-ROAD MOTORCYCLES	GASOLINE (UNSPECIFIED)	Off-Road Motorcycles -G4-25-Exhaust	OG2309
85087211004552	OFF-ROAD RECREATIONAL VEHICLES	OFF-ROAD MOTORCYCLES	GASOLINE (UNSPECIFIED)	Off-Road Motorcycles -G2-50-Exhaust	OG2310
85087211004554	OFF-ROAD RECREATIONAL VEHICLES	OFF-ROAD MOTORCYCLES	GASOLINE (UNSPECIFIED)	Off-Road Motorcycles -G4-50-Exhaust	OG2309
85087211004652	OFF-ROAD RECREATIONAL VEHICLES	OFF-ROAD MOTORCYCLES	GASOLINE (UNSPECIFIED)	Off-Road Motorcycles -G2-120-Exhaust	OG2310
85087211004654	OFF-ROAD RECREATIONAL VEHICLES	OFF-ROAD MOTORCYCLES	GASOLINE (UNSPECIFIED)	Off-Road Motorcycles -G4-120-Exhaust	OG2309
85087311003052	OFF-ROAD RECREATIONAL VEHICLES	MINIBIKES	GASOLINE (UNSPECIFIED)	Minibikes -G2-5-Exhaust	OG2310
85087311003054	OFF-ROAD RECREATIONAL VEHICLES	MINIBIKES	GASOLINE (UNSPECIFIED)	Minibikes -G4-5-Exhaust	OG2309
85087311003252	OFF-ROAD RECREATIONAL VEHICLES	MINIBIKES	GASOLINE (UNSPECIFIED)	Minibikes -G2-15-Exhaust	OG2310
85087311003254	OFF-ROAD RECREATIONAL VEHICLES	MINIBIKES	GASOLINE (UNSPECIFIED)	Minibikes -G4-15-Exhaust	OG2309
85087311003452	OFF-ROAD RECREATIONAL VEHICLES	MINIBIKES	GASOLINE (UNSPECIFIED)	Minibikes -G2-25-Exhaust	OG2310
85087311003454	OFF-ROAD RECREATIONAL VEHICLES	MINIBIKES	GASOLINE (UNSPECIFIED)	Minibikes -G4-25-Exhaust	OG2309
85087411000000	OFF-ROAD RECREATIONAL VEHICLES	ALL-TERRAIN VEHICLES (ATV'S)	GASOLINE (UNSPECIFIED)	SUB-CATEGORY UNSPECIFIED	OG2309
85087411000952	OFF-ROAD RECREATIONAL VEHICLES	ALL-TERRAIN VEHICLES (ATV'S)	GASOLINE (UNSPECIFIED)	All-Terrain Vehicles (ATVs)-G2-5-Exhaust	OG2310
85087411000954	OFF-ROAD RECREATIONAL VEHICLES	ALL-TERRAIN VEHICLES (ATV'S)	GASOLINE (UNSPECIFIED)	All-Terrain Vehicles (ATVs)-G4-5-Exhaust	OG2309
85087411001052	OFF-ROAD RECREATIONAL VEHICLES	ALL-TERRAIN VEHICLES (ATV'S)	GASOLINE (UNSPECIFIED)	All-Terrain Vehicles (ATVs)-G2-15-Exhaust	OG2310
85087411001054	OFF-ROAD RECREATIONAL VEHICLES	ALL-TERRAIN VEHICLES (ATV'S)	GASOLINE (UNSPECIFIED)	All-Terrain Vehicles (ATVs)-G4-15-Exhaust	OG2309

SCC/EIC	*Category Name*				*New OG Profile*
85087411001252	OFF-ROAD RECREATIONAL VEHICLES	ALL-TERRAIN VEHICLES (ATV'S)	GASOLINE (UNSPECIFIED)	All-Terrain Vehicles (ATVs)-G2-25-Exhaust	OG2310
85087411001254	OFF-ROAD RECREATIONAL VEHICLES	ALL-TERRAIN VEHICLES (ATV'S)	GASOLINE (UNSPECIFIED)	All-Terrain Vehicles (ATVs)-G4-25-Exhaust	OG2309
85087411001552	OFF-ROAD RECREATIONAL VEHICLES	ALL-TERRAIN VEHICLES (ATV'S)	GASOLINE (UNSPECIFIED)	All-Terrain Vehicles (ATVs)-G2-50-Exhaust	OG2310
85087411001554	OFF-ROAD RECREATIONAL VEHICLES	ALL-TERRAIN VEHICLES (ATV'S)	GASOLINE (UNSPECIFIED)	All-Terrain Vehicles (ATVs)-G4-50-Exhaust	OG2309
85087411001652	OFF-ROAD RECREATIONAL VEHICLES	ALL-TERRAIN VEHICLES (ATV'S)	GASOLINE (UNSPECIFIED)	All-Terrain Vehicles (ATVs)-G2-120-Exhaust	OG2310
85087411001654	OFF-ROAD RECREATIONAL VEHICLES	ALL-TERRAIN VEHICLES (ATV'S)	GASOLINE (UNSPECIFIED)	All-Terrain Vehicles (ATVs)-G4-120-Exhaust	OG2309
85087511002152	OFF-ROAD RECREATIONAL VEHICLES	GOLF CARTS	GASOLINE (UNSPECIFIED)	Golf Carts -G2-15-Exhaust	OG2310
85087511002154	OFF-ROAD RECREATIONAL VEHICLES	GOLF CARTS	GASOLINE (UNSPECIFIED)	Golf Carts -G4-15-Exhaust	OG2309
85087611000000	OFF-ROAD RECREATIONAL VEHICLES	FOUR-WHEEL DRIVE VEHICLES	GASOLINE (UNSPECIFIED)	SUB-CATEGORY UNSPECIFIED	OG2309
85087711005152	OFF-ROAD RECREATIONAL VEHICLES	SPECIALTY VEHICLES CARTS	GASOLINE (UNSPECIFIED)	Specialty Vehicles Carts -G2-5-Exhaust	OG2310
85087711005154	OFF-ROAD RECREATIONAL VEHICLES	SPECIALTY VEHICLES CARTS	GASOLINE (UNSPECIFIED)	Specialty Vehicles Carts -G4-5-Exhaust	OG2309
85087711005252	OFF-ROAD RECREATIONAL VEHICLES	SPECIALTY VEHICLES CARTS	GASOLINE (UNSPECIFIED)	Specialty Vehicles Carts -G2-15-Exhaust	OG2310
85087711005254	OFF-ROAD RECREATIONAL VEHICLES	SPECIALTY VEHICLES CARTS	GASOLINE (UNSPECIFIED)	Specialty Vehicles Carts -G4-15-Exhaust	OG2309
85087711005352	OFF-ROAD RECREATIONAL VEHICLES	SPECIALTY VEHICLES CARTS	GASOLINE (UNSPECIFIED)	Specialty Vehicles Carts -G2-25-Exhaust	OG2310
85087711005354	OFF-ROAD RECREATIONAL VEHICLES	SPECIALTY VEHICLES CARTS	GASOLINE (UNSPECIFIED)	Specialty Vehicles Carts -G4-25-Exhaust	OG2309