White Paper
Highly Reactive Volatile Organic Compound (HRVOC) Emissions from CAFOs

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Abstract

Concentrated animal feeding operations (CAFOs) are facing serious challenges of responding to new regulations soon to be implemented in California limiting emissions of reactive organic gases (ROGs). The justifications for these new regulations are the federal and state (SB700) requirements to bring areas classified as ozone non-attainment into attainment and the time-lines set by EPA. Ozone is formed by reaction of ROGs and NO_x in the presence of sunlight. ROGs comprise a fraction of volatile organic compounds (VOCs) being emitted from CAFOs. The research results and published findings quantifying ROG emissions from CAFOs are limited and confounded by the fact that not all VOCs are ROGs. In addition, the reactivities of ROGs vary. Some ROGs referred to as highly reactive volatile organic compounds (HRVOC) can create10 times more ozone per unit of ROG than those less reactive. Study results indicate that VOCs emitted from agricultural facilities are different from those emitted from petrochemical and industrial facilities in the urban areas. Because of the urgency of the EPA timeline, the California Air Resource Board (CARB) has been forced to use the only emission factor they could find for CAFOs. For dairy animals, VOC emissions are approximated using 12.8 pounds per animal per year (lb/head/year). This emission factor is based upon a 1938 publication specifying the methane emissions per animal and a study indicating that a fraction of the methane emissions are VOC. The resulting emission factor is based upon questionable science. The purpose of this paper is to present and discuss wide range of issues involving VOC emissions from CAFOs. Issues include the following: an acceptable definition of VOC, ROG or HRVOC; the current basis of the emission factor for ROG; the appropriate concentration measurement protocol; the chemical nature of ROG/VOC compounds; and the appropriate abatement procedures or BMPs. The premise of this white paper is that the regulation of VOC emissions from CAFOs based upon questionable science will create far reaching negative impacts on agricultural facilities in the near future. The justification of these negative impacts must be significant improvements in the environment such as bringing ozone non-attainment areas into attainment. It is possible and likely that expensive BMPs will be imposed on CAFOs that have no resulting change in ambient concentrations of ozone. The basis for appropriate regulation of ROG emissions from CAFOs must be sound science!

1.0 Issues

1.1 Acceptable Definition of VOC/ROG/HRVOC

A volatile organic compound is any low molecular weight compound of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate, that participates in atmospheric photochemical reactions. There are VOCs that are reactive in the atmosphere. An example is ethylene. Others, e.g. methane, are relatively inert. Many VOCs are hydrocarbons (contain only carbon and hydrogen), but there are also VOCs that are oxygen-containing such as aldehydes and ketones, or have halogens such as chlorinated solvents and so on (Cooper and Alley, 2002).

The NRC (2003) describes volatile organic compounds as readily vaporizing at room temperature and includes certain fatty acids, nitrogen heterocycles (nitrogen element spaced around the cyclic rings of compounds), sulfides, amines, alcohols, aliphatic aldehydes, ethers, *p*-cresol, mercaptans, hydrocarbons and halocarbons.

The EPA's definition of volatile organic compounds makes reference to the vapor pressure of the compounds (greater than 0.1 mm Hg) as a determinant of volatility (EPA, 1995). Hundreds of compounds fall under this definition. The EPA has a list of exempted compounds having "negligible photochemical reactivity". Recent final rulemaking from EPA listed exemptions such as ***acetone***, methyl acetate, perchloroethylene, chlorofluoromethane HFCs and 1-chloro-1-fluoroethane HCFCs , methane, ethane, dichloroethane, perchloroethylene, parachlorobenzotrifluoride, among others.

VOCs are known to be a component of odors associated with animal agriculture and over 200 compounds are listed (Shiffman, et. al., 2001). The major constituents of AFO VOC emissions that have been identified include organic sulfides, disulfides, C_4 to C_7 aldehydes, trimethylamine, C_4 amines, quinoline, dimethylpyrazine, and C_3 to C_6 organic acids, along with lesser amounts of aromatic compounds and C_4 to C_7 alcohols, ketones and aliphatic hydrocarbons (NRC, 2003). Many of these compounds are not as reactive as those reported in urban areas. Breitenbach (2004) only listed 4 HRVOCs that are considered highly reactive in urban areas among the 12 specified HRVOCs listed by the Texas Commission on Environmental Quality (TCEQ). These 4 include: propylene, butadiene, butane, and ethylene. In short, the VOC definition leads to an "open ended list of compounds" (Higashi and Cassel, 2004). At this point in time, there is no published list of CAFO RVOCs or HRVOCs. It is imperative that the scientific community agree on a common CAFO RVOCs definition and a list of compounds that qualify as HRVOCs or ROG's.

1.2 The Proposed Emission Factor for ROG and Its Basis

The California Air Resources Board is proposing an ROG emission factor of 12.8 lb/hd/yr (35 lb/1000HD/day) for dairies. This number was derived from a 1938 publication (Ritzman et al., 1938) reporting total methane production of 200 grams CH_4 per cow in 24 hours (or 160 lbs/head/year, page 30 of the book). The live weight of the cow was about 610 kg (1340 lb). The

reported data were mainly from a study of a total of 10 Holstein and Jersey adult cows Prior to 1977, all researchers reported the same value of 160 lb/head/year for CH_4 emissions while some reports varied from 160.8 to 161 lb/hd/year (Hutchinson, 1948, Ehhalt, 1974; Taback, et al., 1977). In 1978, the methane emission factor was incorrectly reported as total organic gases (TOG) instead of methane (Keller and Cowherd, 1977). From 1977 on, the 160 lb/hd/yr became the incorrect number for TOG. In 1980, the EPA funded a study on livestock TOG speciation and found that 8% of the TOG is reactive (comprised of ethyl alcohol (2%), isopropyl alcohol (2%) propyl acetate (2%), ethyl amine (1%) and trimethyl amine (1%)). The remaining 92% supposedly was comprised of methane (70%), ethane (20%) and acetone (2%) and was designated as non reactive VOC (USEPA, 1980).

Eight per cent of 160 lb/hd/year gives 12.8 lb/hd/yr of reactive TOG. This number came to be used as the emission factor for ROG in the state of California. This emission factor is now the focal point of contention and the subject of discussion and inquiry. Krauter (2005) reported that his findings did not support the EPA method of calculating the emission rate of ROG by multiplying a constant percentage (8%) of the mass emission rate of TOG or methane from dairy animals. The development of an emission factor will not be as simple as the above procedure. There are numerous other factors to consider such as variations with different species of cattle, effect of nutrition on emissions and ages of cows among others. There would likely be differences between feedlot cattle and dairy facilities. The current ROG emission factor for dairy animals is not based upon sound science!

1.3   *Definition of Highly Reactive Volatile Organic Compounds*

TCEQ listed the 12 highly reactive VOCs (HRVOC) and then reduced it to four which were most critical in the Houston area. The list appears on page 3-21 of the TCEQ State Implementation Plan (SIP) revisions, adopted on December 1, 2004. The 12 highly reactive are: ethylene, propylene, all butene isomers, all pentene isomers, 1,3-butadiene, isoprene, all trimethylbenzene isomers, all xylene isomers, toluene, all ethyltoluene isomers, formaldehyde, and acetaldehyde. The top four compounds in the Houston area are ethylene, propylene, all butene isomers, and 1,3-butadiene.

Table 1 lists the compounds identified in a recent symposium on ROG in California by 2 authors (Mithloehner, 2005 and Krauter, et al., 2005). Only one compound, toluene, is common to both California and Texas reports. One author (Mithloehner, 2005) also included acetone, a compound exempted from the EPA list of RVOC. Mithloehner reported that his studies indicate that the emission factor should be 2.5 lb/hd/year. Excluding acetone from Mithloehner's list will reduce the emission factor by more than 80%, making the excreta emission factor almost negligible (0.44 lb/hd/year). The compounds listed by Krauter et al., (2005) did not match any of the compounds used to calculate the 12.8 lb/hd/yr emission factor above. Likewise, Mithloehner (2005) reported a negative emission factor for isopropyl alcohol (-0.2178 lb/hd/yr), the only compound found on the above list.

Table 1. List of ROG compounds enumerated by a recent symposium on ROG in Califiornia.

Compound	Mithloerner Cows+Excreta EF (lb/hd/yr)	Mithloerner Excreta EF (lb/hd/yr)	Krauter, et al Flux chamber EF (lb/hd/yr)
1. Propylene	0.627		
2. Dichlorodifluoromethane	0.902		
3. Bromo-methane	0.5016		
4. Acetone	*0.1254*	*2.046*	
5. Carbon disulfide	0.308	0.506	
6. Isopropyl alcohol	0.3652	-0.2178	
7. Ethyl acetate	1.3156	0.0836	
8. Carbon tetrachloride	0.2882		
9. Toluene	0.6248	-0.1848	0.2
10. p-xylene	0.3586	0.2486	
11. 1,2,4-Trimethylbenzene	0.2288		
12. 1,3,5-Trimethylbenzene	0.5192		
13. 1,3-Dichlorobenzene	0.242		
EF	6.4064	2.4816	
14. 2-pentanone, 4,4-dimethyl-			1.9
15. oxirane, tetramethyl-			2.3
16. 2-butenal			0.9
17. 1,2-dichlorobenzene			1.6
18. benzaldehyde, 4-methyl			1.0
		EF	7.9

1.4   VOC/ROG/HRVOC Sampling Protocol

There are various sampling protocols and analytical methods available to measure VOC but no standard protocol is in place that is suitable for HRVOC that is applicable to all. Many measurement methods have made reference to conforming to the two EPA TO-14 or TO-15 procedures but these methods were described mostly for VOCs from industrial or combustion sources, not from agricultural sources which are known to have different components,

The most widely used analytical techniques involves separation by gas chromatography (GC) and detection using a flame-ionization detector (FID) and speciation by mass spectrometer (MS). The FID is a nonspecific hydrocarbon detector with a sensitivity that, in general, is linearly proportional to the number of carbon atoms in a VOC molecule (Ackman, 1968). VOC detectors that can be used for real-time measurements of typical ambient air are commercially available. New portable devices that can use surface acoustics wave technology have been developed for field measurements of VOCs. Their sensitivity is not adequate to measure the low levels that may be harmful to humans. **Research to support the development of more sensitive device is needed.**

Mitloehner (2005) used a Proton Transfer Reaction Mass Spectrometer (PTRMS) to measure VOCs. This equipment is being sold for $250,000. Krauter (2005) used a GC-MS with

cryogenics and traps in conjunction with flux chamber studies. The research community has yet to agree on the most suitable equipment that will provide the best speciation and the highest recovery of VOC compounds.

Gas chromatographs (GCs) are the most common instruments used for VOC analysis. These GCs are normally housed in the laboratory and samples collected in the field have to be brought into the lab for analysis. This has caused numerous problems such as the following: (1) the volume of Tedlar bag samples is not enough to generate a good resolution because of the very low level of detection and the low concentration of odorous ROG compounds; (2) summa canisters are used to concentrate the compounds but this somehow changes the state of compounds in addition to being expensive; (3) cryogenic traps are also employed to ensure that compounds retain their state when transported but this creates reactivity problems for some compounds; (4) there is inherent adsorption on walls of Tedlar bags or canisters; (5) gas emission losses are evident during transport; (6) reaction among gases may occur during changes in environmental conditions of the compounds; and (7) the reheating of the compounds to enhance elution into the GC also alters the state of compounds from their original conditions.

One approach being proposed is to use a portable gas chromatography system, taking actual measurements in conjunction with flux chamber work. The goal is to eliminate problems enumerated above. The results, however, must still to be validated through laboratory calibration work. These comparative studies will be used to evaluate the magnitude of the problems enumerated above.

1.5   Ozone Forming Potential of VOC/ROG/HRVOC

VOCs have different ozone forming potential. In addition, the presence of other precursors such as NO_x will affect the ozone forming potential of some gases. To understand the contribution of CAFO VOCs to ozone formation and gain insight into effective control strategies, measurements of individual compounds are essential. This is a difficult task because of the large number of compounds involved.

It has been reported in the literature that the ozone forming potential of RVOC is affected by the level of NO_x within the vicinity. When the instantaneous RVOC-to-NO_x ratio is less than 5.5:1, OH radicals react predominantly with NO_2, removing radicals and retarding O_3 formation. Under these conditions, a decrease in the NO_x concentration favors O_3 formation. At a sufficiently low concentration of NO_x, or a sufficiently high RVOC-to-NO_2 ratio, a further decrease in NO_x favors peroxy-peroxy reactions, which retard O_3 formation by removing free radicals from the system (Seinfeld and Pandis, 1998).

Other authors define incremental reactivity to mean the amount of ozone formed per unit amount of VOC added (reported as carbon) to a VOC mixture. Mechanistic reactivity reflects the presence of radicals and NO_x sources and sinks in the VOC reaction mechanism subsequent to initial loss process (Wark et al., 1998). Compounds with low incremental reactivity are considered un-reactive and vice versa. But the reactivity is also a function of ratio of VOC to

NO_x. Generally, the higher the VOC to NO_x ratio, the lower the reactivity (but not true for all compounds) as mentioned earlier.

Once VOCs have been identified for ROG regulation, the next step would be a thorough study of the reactivity of each individual compound in relation to the presence of other precursors and factors for the formation of ozone. ***Thus, it is not enough to know and measure the concentration of a specific VOC. One must also determine its reactivity in the presence of other compounds in the air.***

A European group uses non-methane volatile organic compounds (NMVOC) for ozone forming potential calculations (Hobbs, et al., 2001). They have listed 50 most important NMVOC and more detailed speciation of 600 compounds (NAEI, 1999). Because they were aware of the different ozone generating potential through photochemical reactions of NMVOC, they defined photochemical ozone creation potential (*POCP*) and normalized the potential on relative basis. The ozone creation potential for each NMVOC compound is typically normalized by defining ethene as having a creation potential of 1. The reactivities of all other compounds are rated relative to ethene. Table 2 shows a list of some compounds and their respective ozone forming potential. Ethylene, propylene, butadiene and butylenes have high reactivity indicating high yields of ozone formation in the presence of NO_x and sunlight. In addition to measuring HRVOCs in CAFOs, the emission level of NO_x on those facilities must be established to evaluate the ozone forming potential of HRVOCs.

An excellent analysis of VOC as a precursor to ozone from biogenic sources is provided by Higashi and Cassel (2004).

Table 2. Ozone forming potential of some VOC compounds.

Compound	Incremental Ozone
1. Methane	0.014
2. C2-C6 alkanes	~2
3. Isobutylene	6.4
4. Ethylene	9.1
5. M-xylene	10.6
6. Isoprene	10.7
7. Propylene	11.6
8. Butadiene	13.1
9. 1-butene	10.3
10. Cis-2-butene	13.2
11. Trans-2-butene	13.9

1.6   *VOC Emission Factors in Published Literature*

Emissions of volatile organic compounds (VOCs) from stationary and biogenic sources are significant, but only limited data are available in most regions of the world. The United States (EPA, 1995) and Europe have accumulated extensive data on the quantities and sources of their

VOCs emitted to the atmosphere on a global scale. However, these estimates are not suitable for actual on-farm inventory.

The three EPA references in (2001) on VOC emission factors – Alexander, 1977; Brock and Madigan, 1988; and Tate, 1995 - came from microbiology textbooks. Thus, the basis for determining VOC emission factors is rather weak. Despite the paucity of data, attempts are being made to shed light on the estimation of emission factors for VOC. For example, some VOC emission factors for pesticides have been determined by the Environmental Monitoring Branch of the Department of Pesticide Regulation in Sacramento, California (California Environmental Protection Agency, 1998, 1999, 2000). The applicability of these efforts to VOC emissions from AFOs is unknown at this time. There is a need for research on the CAFO VOCs similar to those being conducted by the pesticide industry.

Ongoing studies to determine emission rates of VOCs were included in an EPA (2001) document. Scientists from Ames, Iowa, developed techniques to collect and measure VOCs emitted from lagoons and earthen storage systems (Zahn, et al., 1997). They found that 27 VOCs were prevalent in most samples and could be classified as phenols, indoles, alkanes, amines, fatty acids, and sulfur-containing compounds. Emission rates for many of these were determined at several sites, and the data have been transferred to EPA and state air quality specialists.

According to EPA (2001), estimates of VOC emissions from confinement facilities, manure storage facilities, and manure application sites are difficult because of lack of reasonable methods for estimating CH_4 production. However, CH_4 does not provide an appropriate basis for predicting VOC volatilization potential in livestock management systems. Gas-transfer velocities for CH_4 and VOCs differ by several hundredfold (MacIntyre et al., 1995). In addition, surface exchange rates for some VOCs are influenced by solution-phase chemical factors that include ionization (pH), hydrogen bonding, and surface slicks (MacIntyre et al., 1995). Physical factors such as temperature, irradiance, and wind are also major factors in the emission rates of sparingly soluble VOCs from liquid or semisolid surfaces (MacIntyre et al., 1995; Zahn et al., 1997). The differences in wind and temperature exposures between outdoor and indoor manure management systems can account for between 51 and 93 percent of the observed differences in VOC emissions (MacIntyre et al., 1995). This analysis suggests that exposure factors can account for differences observed in VOC flux rates, VOC air concentrations, and odor intensities. ***Therefore, the equation used to model the emission factor for VOCs in EPA (2001) cannot be extrapolated for the majority of livestock operations.***

Receptor modeling techniques can provide information on air quality impacts due to VOC emissions from AFOs. For example, Watson et al., (2001) reviewed the application of chemical mass balance techniques for VOC source apportionment. Multivariate methods have also been applied to source apportionment of ambient VOCs (Henry et al., 1995). Receptor modeling techniques to apportion VOCs from AFOs maybe limited because many of the expected compounds may be formed in the atmosphere, react there or have similar emission profiles from many sources.

2.0   Analysis and Proposed Strategy

2.1   Common Definition of HRVOC

The scientific community must agree on a common definition of VOC and subsequently enumerate reactive VOCs and highly reactive VOCs emitted from CAFOs. Whether this is a partial list or complete list will be a good starting point for future measurements. It was also shown that VOCs listed for urban areas are different from those emitted by animal feeding operations. Only propylene and toluene are common from the list enumerated by Mithloerner (2005) and propylene was in fact emitted from cows breathe rather than excreta. There will likely be a different HRVOC list emitted from CAFOs compared with those reported from urban centers.

2.2   Evaluate the Reactivity of Compounds Emitted by CAFOs

Some studies have been made to evaluate the reactivity of VOC (e.g. Hewitt, 1999, and Wark, et al., 1998). These studies however are very general in nature and group compounds according to different chemical classes. Groups having the highest maximum incremental reactivity (MIR) are sometimes difficult to recover from sample trapping devices. The standard deviation from these data showed that they vary by several orders of magnitude (Higashi and Cassel, 2004). Table 3 shows the list of compounds and their incremental reactivity as against VOC:NO_x ratio. Toluene, which appears common to the list of ROG compounds discussed in Section 1.3 has in fact a negative O_3 forming potential as VOC:NO_x ratio is increased.

Table 3. Incremental reactivity as a function of VOC:NOx ratio

Compound	Incremental	reactivity	as against	VOC:NOx ratio
	4	8	16	40
Carbon monoxide	0.011	0.022	0.012	0.005
Ethane	*0.024*	*0.041*	*0.018*	*0.007*
N-Butane	0.10	0.16	0.069	0.019
N-Octane	0.068	0.12	0.027	-0.031
Ethene	0.85	0.90	0.33	0.14
Propene	1.28	1.03	0.39	0.14
Trans-2-Butene	1.42	0.97	0.31	0.054
Benzene	0.038	0.033	-0.002	-0.002
Toluene	0.26	0.16	-0.036	-0.051
M-Xylene	0.98	0.63	0.091	-0.025
Formaldehyde	2.42	1.20	0.32	0.051
Acetaldehyde	1.34	0.83	0.29	0.098
Benzaldehyde	-0.11	-0.27	-0.40	-0.40
Methanol	0.12	0.17	0.066	0.029
Ethanol	0.18	0.22	0.065	0.006
Urban mix	0.41	0.32	0.088	0.011

Source: NRC, 1991

2.3   Developing a Standard Procedure for Sampling HRVOC

Higashi and Cassel (2004) have enumerated several techniques and approaches in measuring VOC. There were about 5 methods presented but no method has yet excelled from among the others to be categorized as a standard method. Commonalities to most of the analytical techniques enumerated are high cost and greater skills needed with any of the instruments used. Most of the instruments enumerated above uses gas chromatograph (GC) for the speciation of compounds. However, the use of a GC will require several types of detectors and columns and each one is sensitive to just a given set of compounds. Thus, a GC with one set of detectors and columns may only be able to speciate a discrete set of compounds. Other compounds will require another set of detectors and columns. Thus, any listed compounds reported must be qualified with the type of detector and columns used.

There are about 16 different types of detectors used in the market (SRI Instruments Operation Manual and Reference Guide, 2000). For example, thermal conductivity detector (TCD) speciate compounds according to its unique thermal conductivity parameter. Flame ionization detector (FID) is the detector of choice for general hydrocarbon analysis. Nitrogen/phosphorus detector (NPD) is specified for the analysis of organic compounds containing nitrogen and phosphorus. This is ideal for the analysis of pesticides and herbicides. Thermionic ionization detector (TID) is also used for the detection of N-P compounds (Patterson, 2000). The photo ionization detector (PID) is used for the analysis of aromatic molecules such as benzene and toluene. These are just some of the most common detectors used and the range of columns to use in conjunction with these detectors is also numerous.

2.4   Abatement Procedures for ROG Mitigation

It is difficult to recommend mitigation procedures if the magnitude of VOC or HRVOC or ROG compounds are not yet known. The California Air Resources Board (CARB) is faced with a mandate to regulate ROG to attain a certain reduction of ozone each year but if the ROG emission factors are in error, the magnitude of ozone reduction will also be in error. Many technologies are available for control of VOCs in other industries. For example, the surface coating industry is known to be a major contributor of anthropogenic VOC emissions and control technologies are dominated by three separate types – carbon adsorbers, catalytic incinerators and thermal incinerators (Hall, et al., 1999). These devices may not be applicable directly to CAFOs because most emissions are non-point sources. Different sets of studies are needed to establish the best management practices (BMPs) applicable to CAFOs. Such studies could take place in the next 2 to 3 years.

The complexity of the chemistry of the formation of ozone from precursor emissions of VOCs and NO_x has made it difficult to develop reliable control strategies designed at reducing photochemical oxidants. The effect of the VOC:NOx ratio further complicates the problem. The development of control strategies currently requires the use of photochemical models such as the Urban Airshed Models which is a three dimensional multi-grid model (Wark, et al., 1998).

3.0 Conclusions and Recommendations

The justification for regulating emissions of RVOC is to reduce ozone formation in areas that are either severe or extreme non-attainment for ozone. The assumptions are that reducing RVOC emissions will result in fewer days when ambient concentrations exceed the ozone NAAQS and generally provide a healthier environment for the public in these areas. In addition, it is assumed that any reduction in RVOC will result in a corresponding reduction in ozone formation. Reducing RVOC emissions by CAFOs based upon a questionable emission factors will create far reaching negative impacts in the near future. Will reductions in RVOC emissions from CAFOs reduce ambient concentrations of ozone? CAFOs will struggle to reduce emissions because the management practices needed to reduce emissions are unknown and the costs of implementing unknown Best Management Practices (BMPs) are also unknown. CAFO management will have no choice but to attempt to abide by regulations once they are in place. There is little scientific knowledge on the specific compounds that are emitted by CAFOs that result in ozone formation. There have been no studies indicating that the NO_x needed for ozone formation is available in the rural areas typical of CAFO locations. The assumption is that the RVOC is transported to areas where NO_x is present and/or NO_x is transported to the CAFO location. This assumption has not been studied. It is possible that the RVOC emitted by CAFOs is diluted as it is transported to the location of the essential NO_x component to the point that minimal or no ozone is formed or visa versa.

The reactivity of VOCs is very important when addressing the precursors of ozone. Some VOCs are not reactive and in the presence of NOx and sunlight form no ozone. Other VOCs have low reactivity. For example, some RVOCs may have a reactivity of 1:1; one unit of RVOC in the presence of precursors will form one unit of ozone. It would seem appropriate to evaluate and quantify emissions of the highly reactive VOC (HRVOC) with a reactivity of 10:1; one unit of HRVOC can result in 10 units or more of ozone. If the goal is to reduce ambient concentrations of ozone, the focus should be on reduced emissions of HRVOCs rather than VOCs. We do not have emissions data or the reactivity of VOC emitted by CAFOs.

The current policy of using the 12.8 lb/head/year of RVOC (based upon a 1938 publication) will likely receive significant and warranted criticism from the scientific community. The CARB has limited knowledge of mass emission rates of RVOC or HRVOC from CAFOs and is under pressure to respond to EPA mandates in the near future (July 1, 2005). The CARB response is, "we have a number and we will use it". CAFOs will be mandated to reduce VOC emissions in the near future no matter whether their VOC emissions result in ozone formation or not. Implementing emission reduction methods (BMPs) without knowing emission rates is problematic. Work is proceeding with thorough assessments of current research data. It is essential that new research efforts be funded to address protocols for the appropriate CAFO RVOC emission concentrations and emission rates and their corresponding reactivity's. The goal of this research will be reductions of ambient concentrations of ozone.

The following strategies are recommended to achieve the goal of properly regulating emissions of RVOCs from CAFOs that will result in measurable reductions in ozone formation:

a. First, the scientific community must agree on a common definition of VOCs, RVOCs (ROGs) and HRVOCs and provide a list of such compounds that are commonly found to be emitted by CAFOs.
b. Second, conduct comprehensive studies to determine the emissions rates of the compounds with a corresponding emissions inventory of concentrations of NO_x at the emission site (vicinity) for the different seasons, environmental conditions and selected CAFO types. In addition, studies must be conducted to determine impacts on ozone formation.
c. Third, develop protocols to measure RVOC and/or HRVOCs that are reliable, repeatable, affordable and with established uncertainties.
d. Fourth, develop BMPs that can be implemented to reduce VOC emissions. This task can be conducted while the first three steps above are in progress.

A minimum of three year lead time is needed to establish the CAFO RVOC and/or HRVOC emission rates and impacts on ozone formation. The current implementation of ROG regulation must be delayed and the scientific community must work with CAFO owners and state regulators to provide regulations that are appropriate for CAFOs. Mandated RVOC reductions must effectively reduce ambient concentrations of ozone.

4.0   References

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