SELECT RESOURCE MATERIALS AND ANNOTATED BIBLIOGRAPHY

ON THE TOPIC OF

HAZARDOUS AIR POLLUTANTS (HAPs) ASSOCIATED WITH AIRCRAFT, AIRPORTS, AND AVIATION

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EXECUTIVE SUMMARY

Purpose of the Report

The Federal Aviation Administration (FAA) Office of Environment and Energy is undertaking a review of publicly available information pertaining to the relationship(s) between aircraft and airport-related activities and the emissions of hazardous air pollutants (HAPs). Conducted in response to the rising interest in HAPs by various federal, state and local agencies and the general public, this preliminary work can thus far be characterized as "information gathering."

Therefore, the primary purpose of this report is to provide a concise survey of available information and, from these findings, obtain a basic understanding of HAPs as they pertain to airports, in general, and aircraft, in particular. The evaluation of the potential effects of HAPs on human health or the environment is not within the scope of this assessment.

From this initial undertaking, the following information summarizes what has been documented about aircraft, airports and HAPs.

Common HAPs Associated With Aircraft and Airport Operations

Under the federal Clean Air Act (CAA) and its amendments, the U.S. Environmental Protection Agency (U.S. EPA) has initially identified 188 air pollutants that are considered to be HAPs and therefore subject to the requirements of Section 112 (*Hazardous Air Pollutants*) of the Act. These include a wide variety of organic and inorganic chemicals, compounds and other substances for which there are no National Ambient Air Quality Standards (NAAQS). (The exception to this being lead, for which there is a NAAQS.)

With respect to aircraft and airports, information and data compiled by the U.S. EPA, the U.S. Air Force (USAF), and other investigators involved in the assessment of aircraft engine emissions reveals the following:

- There is very little test data and other supporting information available that identifies the most common types of HAPs in aircraft exhaust.

- The U.S. EPA has listed the following 14 HAPs (12 individual substances and two select groups of complex organic compounds) they believe are present in the exhaust of aircraft and/or their ground support equipment (GSE):

  - 1,3-Butadiene
  - Acetaldehyde
  - Acrolein
  - Benzene
  - Ethylbenzene
  - Formaldehyde
  - Polycyclic Organic Matter (POM) as 7 Polycyclic Organic Hydrocarbons (PAH)
  - nHexane
  - Xylene
  - Propionaldehyde
  - Styrene
  - Toluene
  - Lead compounds
  - POM as 16 PAH

- Formaldehyde appears to be the most prevalent HAP in aircraft exhaust followed by acetaldehyde, benzene, and toluene.

- Ten individual HAPs comprise the vast majority of HAPS that are reported to occur in aircraft and/or GSE exhaust:

- Formaldehyde	- 1,3-Butadiene
- Acetaldehyde	- Xylene
- Benzene	- Lead
- Toluene	- Naphthalene
- Acrolein	- Propionaldehyde

Agency Guidelines and Standards

Most of the U.S. EPA information on HAPs is published in support of their development of guidelines and regulations for major stationary and area sources. By comparison, there are currently far fewer and less instructive references for HAPs associated with aircraft and airports. This disparity is possibly due to the combination of the following factors: a.) the limited availability of historical or existing data, b.) the financial costs and technical difficulty in developing new information and c.) the potential that aircraft and airports are not significant sources of HAPs overall.

Nevertheless, from this limited information, the following conclusions can be drawn in connection with aircraft, airports and HAPs:

- Neither aircraft nor airports meet the definitions of the source types that are regulated under Section 112 (*Hazardous Air Pollutants*) of the CAA.

- Emissions from aircraft engines are currently regulated under Section 231 (*Aircraft Emission Standards*) of the federal CAA. Although HAPs are not directly regulated, they are indirectly controlled as elements of total unburned hydrocarbons and particulate matter.

- Airports are characterized under the U.S. EPA National Air Toxics Program as an example of complex facilities that produce aggregates of emissions, including HAPs, from multiple sources.

- Current FAA guidelines pertaining to airport air quality have not specifically addressed HAPs. However, airport-specific HAP assessments are presently under development.

Air Monitoring Data and Information

Over the past few years, several air quality monitoring studies have been undertaken to better understand the relationships, if any, between aircraft and airport operations and the levels of HAPs in neighboring communities. These studies have been conducted by both proponents and opponents of airport expansion as well as state and local environmental agencies, with conflicting or mixed results.

The review of these studies and supporting information reveals the following:

- Most monitoring efforts have thus far been relatively short-term (i.e., 3 days to a few weeks) and there have been no long-term or permanent programs conducted.

- In general, HAP levels on the airports, or in areas directly adjoining airports, are higher when compared to areas located away from the airports. However, these levels of HAPs on or near airports are not appreciably different than those measured in other areas of the urban environment.

- In most cases, the data collected on and off the airport properties cannot differentiate those HAPs that are generated by airport operations from those associated with non-airport sources (i.e., motor vehicles, stationary sources, etc.).

- Importantly, these monitoring studies do not take into account the length of time that people (either airport patrons, employees, or nearby residents) may be exposed to HAPs. Such exposure patterns are very important when assessing the potential effects of HAPs on human health or the environment. Typically, these occurrences are not of sufficient duration nor representative of the long-term, chronic exposures that are considered necessary for the onset of any concerns about HAPs. Short-term, acute, exposures to HAPs can also result in deleterious effects, but these occasions are rare.

HAPs Emission Factors

The limited availability and accuracy of emission factors are among the greatest potential limitations of any air quality HAPs analysis relying on the results of emission inventories or dispersion modeling. From the review of the available information on HAPs emissions factors (or "speciation profiles"), the most noteworthy are summarized as follows:

- The U.S. EPA has compiled a partial database of HAPs emission factors in support of their development of the National Toxics Inventory. However, these factors are intended for gross estimates of total emissions on a broad scale and are based on the measurements from only two aircraft; one military and one military/commercial.

- The USAF has compiled a more extensive database of HAP emission factors for military aircraft and auxiliary power units (APUs) based on exhaust sampling and testing. Unfortunately, the application of these data to commercial or civilian aircraft appears limited.

- The California Air Resources Board (CARB) has also recently published a draft set of speciation profiles of organic gases and particulate matter factors for a wide array of mobile sources, including aircraft.

- Published U.S. EPA emission factors (or profiles) are only available for approximately 20 HAPs and not for all of the identified compounds in the exhaust of commercial or general aviation (GA) aircraft. These HAPs emission factors (given as "percent of total organic gases or volatile organic compounds") are listed in Table 6 of this report.

- Among the most remarkable observations recorded during the testing of aircraft exhaust are:

  - The extremely low concentration of HAPs found in aircraft exhaust considering the amounts of fuel burned, the amounts of energy (or thrust) generated, and the amounts of other products of combustion produced.

  - The type and amounts of HAP emissions are strongly influenced by the engine load; varying by an order-of-magnitude (or more) from taxi/idle to full takeoff thrust.

  - Averaging HAP emission factors from different aircraft and for different operating conditions is not considered appropriate, as there is potential for great variation. For this reason, available aircraft engine emission factors for HAPs may also not be representative of untested aircraft or the aircraft fleet as a whole.

Atmospheric Dispersion Models

One of the key links between emissions of HAPs and their potential effects on human health or the environment is expressed as the measurement of its concentration (level or strength) in the ambient air. (Other important factors include exposure time periods, pathways and an assortment of chemical-specific characteristics.) Using atmospheric dispersion modeling to determine the ambient concentration of HAPs is usually much faster and less costly than monitoring and is particularly appropriate when attempting to predict future-year conditions. However, as discussed above, the limited availability of appropriate aircraft engine emission factors pose potentially significant deficiencies with this approach.

The review of available information concerning the use of atmospheric dispersion models as an aid in the assessment of HAPs associated with airports, revealed the following:

- The Emissions & Dispersion Modeling System (EDMS) prepared by FAA is specifically developed for the assessment of airport air quality and is a FAA-required model as well as the EPA-preferred for this application. The most recent version of EDMS contains the new dispersion model AERMOD, which is considered by the EPA to be superior dispersion model to its predecessors, including the Industrial Source Complex (ISC) model.

- Although EDMS has thus far not been used for the prediction of HAP concentrations, it appears to be suitable for this task. Moreover, because EDMS is specifically designed for modeling airport-related air emissions, its application for the prediction of HAPs concentrations is ultimately desirable.

- The Industrial Source Complex (ISC) model is intended for use for the dispersion modeling of criteria pollutants and HAPs from industrial and complex sources and is an EPA-preferred model for these purposes.

- For the simulation of airports using ISC, the emission sources (i.e., runways, taxiways, gate areas, fuel facilities, etc.) must be created by the user. Appropriate emission factors must also be developed and input to the model.

- To date, ISC has been used for the modeling of HAPs for at least three airport air quality analyses, most conducted in support of California-based requirements.

- Using EDMS or ISC, the modeler must convert hydrocarbons and particulate matter to HAPs using appropriate speciation factors.

The need for the modeler to create airport emission sources using ISC and to translate hydrocarbon and particulate matter emission factors to HAPs using speciation factors using ISC or EDMS, causes some degree of uncertainty in the modeling outcomes. The reactivity and transformation of hydrocarbons, particulates and HAPs to other forms are also not considered.

Conclusions and Recommendations

The results of this initial review and assessment of publicly available information pertaining to HAPs reveals several important findings. These findings are central to the current understanding of HAPs associated with emissions from aircraft, airports, and aviation sources. The most essential of these conclusions are summarized as follows:

- Most commercial airports represent a small percentage (approximately 0.5 percent) of the total overall air pollution emissions generated in an urban area, according to a 2003 report by the U.S. General Accounting Office.

- Air monitoring studies in the vicinities of several large airports have thus far not detected HAP levels that are considered elevated above those that normally occur in urban areas. These measurements have also not been able to differentiate

HAPs associated with airport sources from those that are released from motor vehicles or other mobile and stationary sources.

- These monitoring studies do not take into account the length of time that people (either airport patrons, employees or nearby residents) may be exposed to HAPs. Such time-based exposure patterns are very important when assessing the potential effects of HAPs on human health or the environment. Typically, these occurrences are neither of sufficient duration nor representative of the long-term, chronic exposures that are often considered necessary for the onset of any concerns about HAPs. Short-term, acute, exposures to HAPs can also result in deleterious effects, but these occasions are rare.

- Aircraft engine related emissions of hydrocarbons (HC) and particulate matter are predicted to decline over current and historic levels as turbine and internal combustion engines become progressively more efficient and less polluting. Because most HAPs are a subset of total HC and particulates, they are expected to follow this same downward trend.

- Measurements of HAPs in the exhaust of commercial and general aviation aircraft can be characterized as either very limited or non-existent. However, the data that is available indicates that aircraft engines are not large generators of HAPs. Of the HAPs that were identified, only a few individual compounds make up the vast majority of the total.

- The current methods of predicting HAPs concentrations near airports using computerized atmospheric dispersion models have several potentially significant limitations and the accuracy of the results is mostly unknown. The consequences of these shortcomings may be particularly meaningful to the outcome of health risk and environmental assessments that are based on these data.

Filling or bridging the current gaps in the experience and knowledge associated with airport-related HAPs will rely on the collection of additional data and information, the development of scientific assumptions, and the application of sound judgment. Because the assessment of HAPs is a complicated undertaking, the advancement of this highly specialized subject will take time and require the involvement of the aviation, scientific and environmental communities. In the meantime, the topic of HAPs associated with airports is still presently subject to public and regulatory appraisal and is expected to remain so in the foreseeable future. Therefore, the following suggestions are provided as short- and near-term guideposts for further consideration:

- <u>Focus on Fundamentals</u> – The evaluation of HAPs and their effects on human health and the environment can be a complex and multifaceted undertaking. However, the application of three fundamental concepts of toxicology can help simplify and guide the advancement of what is known about this issue;

particularly as they apply to airport-related HAPs. These include the consideration of contaminant types, exposure pathways and the resultant doses.

- Collect Monitoring Data - Ambient ("outdoor") air monitoring data for HAPs in the vicinities of airports should be collected over longer periods of time and at more locations to evaluate the possible temporal and spatial variations in concentrations. Further efforts should be undertaken to identify "signature" compounds that will help differentiate airport-related HAPs from those that occur from other mobile and stationary sources.

- Clarify Uncertainties, Limitations and Risks - Because of the low ambient concentrations of HAPs in the vicinities of airports, the assessment of these air contaminants involves great uncertainty in every step of the process. These limitations and uncertainties require better understanding and should be more clearly stated and explained when assessing the potential effects of HAPs on human health and the natural environment.

- Expand Emission Factor Database and Upgrade Models - The various models, emission factors, and methods used to predict the generation and dispersion of HAPs associated with airports as well as the assessment of risks to human health and the environment need continuous improvement. In particular, the precision and accuracy of these data and techniques require better definition.

- Standardized Assessment Protocols - The protocols for evaluating and analyzing HAPs in support of environmental assessments for airport improvement projects or actions should be conducted consistently using the most appropriate and best available techniques. In this way, the approaches and results of these assessments can be more easily compared and the conclusions better understood.

In support of this assessment, FAA's contractor (URS Corporation) undertook the task of identifying and consulting as many sources of information as reasonably available that contained information related to HAPs associated with airports, aircraft and aviation. The results of this research are published as an appendix to this report and entitled *Annotated Bibliography of Selected Works Containing Information Related to Hazardous Air Pollutants Associated with Airports, Aircraft and Aviation.*

This collection of information was not intended to be all-inclusive as new materials and information are developed and published on a regular basis. Rather, these resources serve as a baseline of information upon which new and/or missing material can be added.

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ACRONYMS AND ABBREVIATIONS

AERMOD	U.S. EPA Plume Dispersion Model
AESO	Aircraft Environmental Support Office
AGU	American Geophysical Union
AOA	Airport Operation Area
APU	Auxiliary Power Unit
AQMD	Air Quality Management District
ASPEN	Assessment System for Population Exposure Nationwide
AWMA	Air & Waste Management Association
B(a)P	Benzo-(a)-Pyrene
BAAQMD	Bay Area Air Quality Management District
BDL	Below Detectable Levels
BTEX	Benzene, Toluene, Ethylbenzene and Xylene
CAA	Clean Air Act
CalEPA	California Environmental Protection Agency
CAPCOA	California Air Pollution Control Officers Association
CARB	California Air Resources Board
CEQA	California Environmental Quality Act
CFR	Code of Federal Regulations
CO	Carbon Monoxide
DOD	Department of Defense
EA	Environmental Assessment
EC	Elemental Carbon
EDMS	Emissions and Dispersion Modeling System
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
EPCRA	Emergency Planning and Community Right-to-Know Act
FAA	Federal Aviation Administration
FAEED	FAA Aircraft Engine Emission Database
g/vehicle-mile	Grams per Vehicle-Mile
GA	General Aviation
GC/MS	Gas Chromatography/Mass Spectrometry
GSE	Ground Service Equipment
HAP	Hazardous Air Pollutant
HC	Hydrocarbon
HCHO	Formaldehyde
HDDV	Heavy-Duty Diesel Vehicle
HHRA	Human Health Risk Assessment
Hi-vol	High-Volume
HRA	Health Risk Assessment
ICAO	International Civil Aviation Organization
IEPA	Illinois Environmental Protection Agency
IRIS	Integrated Risk Information System
ISC	Industrial Source Complex Model
ISCST3	Industrial Source Complex-Short Term Model
IUATS	Integrated Urban Air Toxics Strategy

km	Kilometer
LAWA	Los Angeles World Airports
LAX	Los Angeles International Airport
lb	Pound
lbs/mile	Pounds per Mile
LDDV	Light-Duty Diesel Vehicle
LDGV	Light-Duty Gasoline-Fueled Vehicles
Lo-vol	Low-Volume
LTO	Landing and Take-off
MATES	Multiple Air Toxics Exposure Study
MEI	Maximally Exposed Individuals
MEK	Methyl Ethyl Ketone
MIBK	Methyl Isobutyl Ketone
MOBILE	U.S. EPA Mobile Source Emission Factor Model
MSAT	Mobile Source Air Toxic
MTBE	Methyl tert-Butyl Ether
NATA	National Air Toxics Assessment
NATP	National Air Toxic Program
NEI	National Emission Inventory
NEPA	National Environmental Protection Act
NESCAUM	Northeast States for Coordinated Air Use Management
NET	National Emission Trends
NIST	National Institute of Science and Technology
NJDEP	New Jersey Department of Environmental Protection
nm	Nanometer
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
NONROAD	U.S. EPA Nonroad Emissions Model
NO_x	Oxides of Nitrogen
NTI	National Toxics Inventory
O_3	Ozone
OAK	Oakland International Airport
OAQPS	Office of Air Quality Planning and Standards
OC	Organic Carbon
OMS	Office of Mobile Sources
ORD	Office of Research and Development
OTAQ	Office of Transportation and Air Quality
P&W	Pratt & Whitney
PAH	Polycyclic Aromatic Hydrocarbon
PAN	Peroxyacetyl Nitrate
PM	Particulate Matter
PM10	Particles less than 10 micrometers in aerodynamic diameter
PM2.5	Particles less than 2.5 micrometers in aerodynamic diameter
POM	Polycyclic Organic Matter
ppb	Parts Per Billion
ppbv	Parts Per Billion by Volume
RfC	Reference Concentration

SCAQMD	South Coast Air Quality Management District
Sea-Tac	Seattle-Tacoma Airport
Sec	Section
SIC	Standard Industrial Classification
SO_2	Sulfur Dioxide
SO_x	Oxides of Sulfur
SPECIATE	U.S. EPA Data System of Speciation Profiles
SVOC	Semi-volatile Organic Carbon
TAC	Toxic Air Contaminant
TAP	Toxic Air Pollutant
TEF	Toxicity Equivalency Factor
THC	Total Hydrocarbons
TOC	Total Organic Compounds
TOG	Total Organic Gas
TRI	Toxic Release Inventory
US EPA	United States Environmental Protection Agency
ug/gal	Micrograms per Gallon
ug/mile	micrograms per mile
ug/sec	Micrograms per Second
URF	Unit Risk Factor
USAF	United States Air Force
USCA	United States Code Annotated
VOC	Volatile Organic Compound

1. INTRODUCTION

Purpose of the Report

The Federal Aviation Administration (FAA) Office of Environment and Energy is undertaking this cursory examination of what is known about the relationship(s) between aircraft and airport-related activities and the emissions of hazardous air pollutants (HAPs). For the purposes of this report, the terms "air toxics," " toxic air contaminants" and "toxic air pollutants" or "TAPs" mean the same as "hazardous air pollutants" or "HAPs."

This assessment is conducted in response to the rising interest in HAPs by various federal, state and local agencies and the general public largely in connection with the environmental review process for airport improvement projects under the National Environmental Policy Act (NEPA). Under NEPA, all federal agencies (including the FAA) are required to identify and describe the potential impacts to the human and natural environments as a result of their action(s); including those to air quality. The documentation of this analysis is typically contained in Environmental Assessments (EA) or Environmental Impact Statements (EIS).

Again, because of this new interest in HAPs in these NEPA documents this preliminary work can thus far be characterized as "information gathering" and focused mainly on the following subjects:

- Common HAPs Associated with Aircraft and Airport Operations
- Agency Guidelines and Standards
- Air Monitoring Data and Information
- HAPs Emission Factors
- Atmospheric Dispersion Models

Therefore, the primary purpose of this report is to provide the FAA with a concise survey of publicly available information and, from these findings, obtain a basic understanding of what is known about HAPs as they pertain to airports, in general, and aircraft, in particular. The evaluation of the potential effects of HAPs on human health or the environment is beyond the scope of this assessment.

The FAA intends to continue its assessment of HAPs and will review new information on the subject of HAPs and airports as it becomes available. It is also anticipated that this initial work will be followed up by the development of a standardized protocol for evaluating HAPs and their health risks associated with airports.

Sources of Information

In support of this assessment, FAA's contractor (URS Corporation) undertook the task of identifying and consulting as many sources of information publicly available that contained information related to HAPs associated with airports, aircraft and aviation. Several methods were used to located and retrieve these resources including electronic database searches, agency and library file inquiries, telephone calls and direct forms of communications with groups and/or individuals knowledgeable of this highly specialized field.

The results of this research are compiled as an appendix to this report and entitled *Annotated Bibliography of Selected Works Containing Information Related to Hazardous Air Pollutants Associated with Airports, Aircraft and Aviation.* This collection of information is not intended to be all-inclusive as new materials and information are developed and published on a regular basis. Rather, these resources serve as a baseline of information upon which new and/or missing material can be added. For ease in the review and understanding of these materials, each reference is accompanied with a synopsis of what are considered to be the most important information contained therein.

Background Information

Numerous assessments have already been undertaken to evaluate (and in some cases quantify) the potential significance, or impact, of airport-related air emissions on both regional and local air quality conditions. Most of these were prepared in support of environmental assessments for planned airport improvement projects or in support of State Implementation Plans. Typically, the analyses focused on the U.S. EPA "criteria" air pollutants or their precursors (i.e. carbon monoxide (CO), nitrogen oxides (NOx), particulate matter (PM) – as well as hydrocarbons (also referred to as volatile organic compounds (VOCs) – which are a subset of hydrocarbons). In general, the results show that these pollutants associated with large commercial airports amount to approximately 0.5 percent of the total emissions generated throughout the airshed (U.S.GOA, 2003). Smaller and general aviation (GA) airports would be expected to generate even less emissions. This is in contrast to motor vehicles traveling on the area-wide network of roadways, which are estimated to be 70 to 80 percent of the airshed totals.

These studies also reveal that within most large metropolitan airports, aircraft are generally the largest source of emissions, followed by ground service equipment, on-site motor vehicles, fuel facilities and stationary sources; depending on airport and the pollutant.

By comparison, emission estimates of HAPs associated with airports are scarce and somewhat limited. Again, some HAPs data has been developed as part of the air quality impact analyses conducted for airport improvement projects environmental assessments. The U.S. EPA also includes aircraft and ground support equipment (GSE) in the National Emissions Inventory. In both cases the significance of airport-related HAPs in comparison to other sources is not clearly defined nor easily understood. However, given that most HAPs emissions are a fraction of

VOCs and follow the same general trend it is reasonable to assume that airports are a very small contributor to HAPs emissions overall.

It is also instructive to note that most internal combustion and turbine engines (including aircraft engines) have become progressively more efficient and less polluting over the past two decades. This is particularly applicable for particulate matter, VOC emissions and other products of incomplete combustion. Because this trend is anticipated to continue into the future, airport and engine related emissions of HAPs are also expected to continually decline over current levels.

Organization of the Report

In the sections that follow, the five main subject areas of this assessment are discussed individually in accordance with the same common format: Introduction and Background, Discussion of Relevant Information, and Summary of Essential Findings.

2. COMMON HAPS ASSOCIATED WITH AIRCRAFT AND AIRPORT OPERATIONS

Introduction and Background

Several documents have been prepared by the FAA, the U.S. Environmental Protection Agency (U.S. EPA) and others that identify and characterize the various sources of air pollution associated with airports and their emissions. Among these are the *Air Quality Procedures for Civilian Airports and Air Force Bases* by the FAA, the *Evaluation of Air Pollution Emissions from Subsonic Commercial Jet Aircraft* by the U.S. EPA and the *Aviation and the Environment – Strategic Framework Needed to Address Challenges Posed by Aircraft Emissions by the U.S. General Accounting Office* (FAA 1997, U.S. EPA 1999, GAO, 2003).

Importantly, these reports focus on the emissions of the EPA "criteria" air pollutants (i.e., carbon monoxide (CO), nitrogen oxides (NOx), sulfur oxides (SOx), particulate matter (PM) – as well as hydrocarbons (HC), and did not address HAPs directly. Another U.S. EPA publication, *Toxic Emissions From Aircraft Emissions: A Search of Available Literature*, compiled a listing of publications that address the subject, but did not specifically identify HAPs commonly associated with aircraft and airports (U.S. EPA 1993a).

Discussion of Relevant Information

Lists of HAPs

Under the federal Clean Air Act (CAA) and its amendments, the U.S. EPA has initially identified 188 air pollutants from stationary and mobile sources that are considered to be HAPs and therefore subject to the requirements of Section 112 (*Hazardous Air Pollutants*) of the Act. These include a wide variety of organic and inorganic materials, compounds and substances for which there are no National Ambient Air Quality Standards (NAAQS).

From this initial base list of 188 HAPs, 40 have been further designated by the U.S. EPA as having the greatest potential health threat to the general public in large urban areas and are known as the "112(k) HAPs." The major categories of HAPs in this group include smaller subsets of the volatile and semi-volatile organic compounds (VOCs, SVOCs) and heavy metals contained in the list of 188.

In addition, the U.S. EPA has recently identified 21 HAPs that are designated as *Mobile Source Air Toxics* (MSATs) to signify those that are emitted by motor vehicles and non-road engines (i.e., farm and construction equipment, heavy industrial vehicles, yard equipment, etc. – notably, aircraft are not specifically mentioned). These include VOCs and heavy metals that are more commonly associated with the combustion of gasoline and diesel fuels - including diesel exhaust particles.

The lists of CAA Sec. 112 nor the MSATs are republished here in this report as they are somewhat voluminous and in many cases duplicative of each other. Moreover, the publication of these lists here could detract from the subject of this report section: i.e. *Common HAPs Associated with Aircraft and Airports*. The bibliography contains information on where these lists can be located.

U.S. EPA Information

As explained later and with more detail in Section 3 (*Agency Guidelines and Standards*), the U.S. EPA prepares an assessment of aircraft-related HAPs on a national scale as part of the *National Toxics Inventory* (NTI). The NTI is a comprehensive accounting of all stationary and mobile sources that emit HAPs on a state and county basis. Using 1993 as the baseline and updating it every three years (i.e., 1996, 1999, etc.), this assessment is used to track changes in HAP emissions, including those associated with aircraft and airports (U.S. EPA 2000c, U.S. EPA 2001b). The 2002 NTI (published in mid-2003) was not available at the time of publication of this document.

For the purposes of the NTI, the U.S. EPA's *Office of Transportation & Air Quality* (OTAQ) developed a list of HAPs emitted from the operation of aircraft and their ground support equipment (GSE) (U.S. EPA 1997e). This initial list of 14 HAPs consists primarily of volatile organic compounds (VOCs) - 12 individual substances and two groups of complex polycyclic organic materials (POM) - and were reportedly selected based on available test data and accepted emission estimating procedures.

Within the CAA, the term VOC has different definitions depending on the context in which it is used. For this assessment, VOCs include any organic carbon-based compounds that normally exist in a gaseous state in the ambient air under normal conditions of temperature and pressure. The term polycyclic organic matter (POM) encompasses a wide variety of polycyclic aromatic hydrocarbons (PAH) that individually exist in such small concentrations in aircraft exhaust that they are collectively grouped into this category.

From the most recently available results published by the U.S. EPA in the 1999 NTI, Table 1 contains the original listing of HAPs associated with aircraft and GSE and arranges them in descending order by total annual emissions, nationwide.

From these data, formaldehyde is the most prevalent of the HAPs and represents over 42 percent of the total. Acetaldehyde, benzene, and toluene represent the second, third, and fourth next highest amounts of HAPs, respectively. Combined with formaldehyde, the top five HAPs represent over 70 percent of the total. Finally, with acrolein, 1,3-butadiene, xylene, lead, naphthalene, and propionaldehyde added, well over 95 percent of the HAPs are accounted for among the top ten substances listed. (It should be noted that lead is not a constituent of jet fuel and is included in this list as a component of GA aircraft and/or GSE fuel.)

Table 1
Aircraft-Related* HAPs Included in the
U.S. EPA National Toxics Inventory Ranked in Order

Pollutant	Total Emission (Tons/Year)	Ranking	Percent of Total	Cumulative Percent
Formaldehyde	6,408	1	42.3	42.3
Acetaldehyde	1,969	2	13.0	55.3
Benzene	1,184	3	7.8	63.1
Toluene	1,174	4	7.7	70.8
Acrolein	938	5	6.2	77.0
1,3-Butadiene	824	6	5.4	82.5
Xylene	702	7	4.6	87.1
Lead**	541	8	3.6	90.7
Naphthalene	454	9	3.0	93.7
Propionaldehyde	396	10	2.6	96.3
Ethylbenzene	211	11	1.4	97.7
Styrene	195	12	1.3	99.0
n-Hexane	71	13	0.5	99.4
2,2,4-Trimethylpentane°	30	14	0.2	99.6
Acenaphthylene°	17	15	0.1	99.7
Phenanthrene°	10	16	0.1	99.8
Fluorene°	8	17	0.1	99.9
Fluoranthene°	5	18	<0.1	99.9
Pyrene°	5	19	<0.1	99.9
Anthracene°	4	20	<0.1	100
Acenaphthene°	3	21	<0.1	100
Benzo(ghi)perylene°	1	22	<0.1	100
Benzo(b)fluoranthene°	0.5	23	<0.1	100
Benzo(k)fluoranthene°	0.5	24	<0.1	100
Benzo(a)anthracene°	0.4	25	<0.1	100
Benzo(a)pyrene°	0.4	26	<0.1	100
Chrysene°	0.4	27	<0.1	100
Indeno(1,2,3-cd)pyrene°	0.3	28	<0.1	100
Dibenz(a,h)anthracene°	0	29	<0.1	100

* Includes commercial and GA aircraft and GSE.
** Lead is not a component of jet fuel. It is listed here as a possible component of avgas fuel used in GA aircraft and/or GSE fuel.
° As polycyclic organic matter (POM) or polycyclic aromatic hydrocarbons (PAH) given as a group of 7-PAH or 16-PAH.

▭ **= Top Ten HAPs**

Additional Information

From the information contained in the bibliography, there is some corroborating information that supports the U.S. EPA listing and rank order of the most common HAPs associated with aircraft exhaust.

From the earliest measurements performed by Chase & Hurn (1970) and the study by Spicer (Spicer 1984 and 1994), formaldehyde and acetaldehyde were identified as the two most common VOCs in aircraft exhaust. Similarly, the testing and measurement of the exhaust products from military aircraft by the U.S. Air Force revealed the following HAPs in descending order of abundance: formaldehyde, benzene, toluene and xylene (USAF, 1999).

Again, this information is scarce and may be limited in its application to modern-day commercial aircraft.

Summary of Essential Findings

Based on information developed and published by the U.S. EPA, the USAF and others, several findings pertaining to the list of most common HAPs associated with aircraft and airports are apparent:

- Test data and other supporting information that identifies the most common types of HAPs in aircraft exhaust is scarce and may be limited in its application to commercial aircraft.
- The U.S. EPA has developed a list of 14 HAPs that they believe are most commonly present in aircraft exhaust. These are shown in Table 1.
- Formaldehyde appears to be the most prevalent HAP in aircraft exhaust followed by acetaldehyde, benzene, and toluene.
- Ten individual HAPs comprise over 95 percent of the group that are reported to occur in aircraft exhaust. This is also shown in Table 1.

3. AGENCY GUIDELINES AND STANDARDS

Introduction and Background

Based on the results of this assessment, most of the agency information on HAPs is published by the U.S.EPA. This material is available principally in support of their guidelines and standards for HAPs associated with major stationary and area sources which are defined below. By comparison, there are currently far fewer and less instructive references for HAPs associated with aircraft and airports. This disparity is likely due to the combination of the following factors: a.) the limited availability of historical data, b.) the difficulty in developing new data and c.) the potential that aircraft and airports are not significant sources of HAPs overall.

Discussion of Relevant Information

Federal Clean Air Act (CAA)

The CAA and its amendments authorize the U.S. EPA to develop standards and guidelines for the control of air emissions, in general, and HAPs, in particular. A summary discussion of those elements of the CAA that pertain to aircraft and airport HAPs, either directly or indirectly, follows.

Under Section 231 (*Aircraft Emission Standards*) of the CAA, the U.S. EPA established an early set of emission standards for aircraft engines on both commercial and general aviation aircraft (42 U.S.C.A.). Initially adopted in 1973, these standards apply to smoke and the exhaust products of CO, NOx and hydrocarbons (HC) – also known as VOCs. Revised in 1997 for the emissions of NOx and CO from newly manufactured and certified commercial aircraft engines, these stricter standards are in alignment with those promulgated by the International Civil Aviation Organization (ICAO) (U.S. EPA 1997a). Notably, HAPs are not regulated directly by these standards – although indirectly through the control of the other primary pollutants such as hydrocarbons.

The CAA also requires that certain HAPs be regulated under Section 112 (*Hazardous Air Pollutants*) of the 1990 Amendments (42 U.S.C.A. Sec. 112). Within this section, there are numerous references to HAPs including the initial list of 188 HAPs identified for inclusion into the regulation as well as the types of sources to which the regulation potentially applies. (See Section 2 - *Common HAPs Associated with Aircraft and Airports* for further explanation of the CAA Section 112 lists of HAPs.)

Importantly, neither airports nor aircraft are specifically included among the sources identified in Section 112 nor do they meet the definitions of the source types (i.e., “major stationary”, “area” or “mobile sources”) that are otherwise covered under this rule. For clarification, Table 2 lists the classifications of the source types regulated under Section 112 of the CAA, their definitions and the listed examples.

Table 2
Classification of HAP Sources Regulated
Under the Clean Air Act[a]

Classification	Definition	Listed Examples
Major Stationary	Sources that emit, or have the potential to emit, more than 10 tons/year of any one HAP or 25 tons/year of a combination of HAPs	Chemical plants, oil refineries, steel mills, aerospace manufacturers aircraft engine test cells.
Area	Stationary sources that emit, or have the potential to emit, less than 10 tons/year of any one HAP or less than 25 tons/year of a combination of HAPs	Hospital sterilizers, dry cleaning facilities, paint stripping operations.
Mobile	Motor vehicles and their fuels.	Automobiles, trucks, farm and construction equipment.

[a] U.S. EPA, 1999.

U.S. EPA Initiatives

In 1997 the U.S. EPA developed the *National Air Toxic Program* (NATP) to help characterize and address air toxics and their sources using a strategic combination of programs and initiatives (U.S. EPA, 2000 b, c). As part of the NATP, the U.S. EPA initiated the *National Air Toxics Assessment* (NATA) and the *Integrated Urban Air Toxics Strategy* (IUATS) – a complex and multifaceted approach to assessing HAPs and their sources.

Essentially, the purpose of the NATA is to collect and evaluate information on ambient levels of HAPs, including the near- and long-term patterns and trends; develop reliable tools and techniques for conducting emission inventories and dispersion modeling of HAPs; and identify the primary areas of concern (or "risks") to the human and natural environments associated with these air contaminants. In addition, should the information and analyses reveal HAPs or their source categories that are presently unregulated, unlisted or pose a public health risk, Section 112 of the CAA allows for these sources to be further evaluated and, if necessary, regulated as part of this initiative.

Airports are also identified under the NATA as an example of complex facilities that are viewed as "mini-cities" which can produce aggregates of pollutants (including HAPs) from multiple source types (U.S. EPA, 1999). In response to this characterization, the U.S. EPA has initially decided to use the *EPA/FAA Voluntary Aircraft Emissions Reduction Initiative* – the multi-stake-holder process currently underway to help reduce NOx emissions to also identify, evaluate and develop voluntary measures to reduce aviation-related emissions of all pollutants, including HAPs.

Regulated Aviation-Related Facilities

It is also worth mentioning that there are elements of the aviation sector that are already subject to the requirements Section 112 (*Hazardous Air Pollutants*) of the CAA with respect to the control of HAPs. In particular, aircraft engine test cells or stands are considered to be "major stationary" sources of HAPs based on their intended function, design and operation (U.S. EPA 2002a). This is particularly applicable to military installations but also applies to these types of facilities located at commercial airports and airfields.

Other sources of HAPs associated with airports are similarly regulated if their emissions exceed the thresholds listed in Table 2 and they meet the definition of a major stationary or area source. These may include aircraft repair and maintenance facilities, metal plating activities, central heating plants and other airport support services that generate air emissions.

Motor Vehicles and Non-Road Equipment

Because motor vehicles (i.e., automobiles, trucks and buses) represent a large segment of the total amount of air emissions in most urban areas, this source is of particular interest to the U.S. EPA from the standpoint of HAPs (U.S. EPA 2000a). As a result, a list of Mobile Source Air Toxics (MSATs) has been developed to signify those HAPs that are emitted from on-road, non-road and off-road vehicle engines. Included in the non-road category of HAP sources are construction equipment and airport ground service vehicles (GSE); both diesel and gasoline powered.

For diesel-powered equipment, significant reductions in VOCs, particulate matter and other pollutants are already planned due to the Tier 1 / Tier 2 / Tier 3 standards already in-place or soon phased in. For gasoline-powered equipment, effective exhaust control programs have been in place for many years. These existing or planned non-road emission control programs are also expected to result in significant reductions in HAPs from these sources.

Federal Aviation Administration

The FAA has developed and published procedures and guidelines for the evaluation of a wide variety of impacts to the human and natural environment associated with airport and airway improvement projects. These guidelines are primarily intended to assist the sponsors of the project or action comply with the environmental impact assessment and reporting requirements of the National Environmental Policy Act (NEPA), including those related to air quality, and are described below.

For all airport projects and actions these guidelines are contained in the FAA Order 1050.1D CHNG4, *Policies and Procedures for Considering Environmental Impacts* (FAA 1999). For projects and actions involving new airports or new or extended runways and concerning the Airports Office of the FAA, these guidelines are contained in the FAA Order 5050.4A, *Airport Environmental Handbook* (FAA 1985). As a supplement to FAA Orders 1050.1D and 5050.4A the FAA has also developed and published a comprehensive guidebook specifically for the preparation of air quality impact assessments required under NEPA and the CAA (FAA 1997). Commonly referred to as the *Air Quality Handbook*, these guidelines include detailed instructions on the preparation of emission inventories and conducting atmospheric dispersion modeling.

The FAA also provides guidance and other up-to-date information on air quality as it relates to airports, aircraft and other matters involving aviation at the Office of Environment and Energy, Emissions Division web site at www.aee.faa.gov (FAA 2002b).

The current listing of FAA guidelines and publications pertaining to the assessment of air quality conditions associated with airports, aircraft and aviation are provided in Table 3. Although these resources provide valuable information and tools for conducting air quality impact assessments for aircraft and airport operations, they do not currently offer any substantive guidance on HAPs. It is largely for this reason that this report is intended to identify, evaluate and summarize the information publicly available as it pertains to HAPs and serve as a foundation for follow-up action, if necessary.

Table 3
FAA Environmental and Air Quality Assessment Guidelines

Guideline	Application	Comments
Airport Environmental Handbook (*FAA Order 5050.4A*)	Provides guidelines on the requirements for, and the assessment of, air quality impacts associated with new airports, new or extended runways.	Currently under revision by the FAA Airports Office. Contains no specific references to HAPs.
Policies and Procedures for Considering Environmental Impacts (*FAA Order 1050.1D CHNG4*)	Provides guidelines on the requirements for, and the assessment of, air quality impacts associated with airport and airfield infrastructure improvements.	Recently updated by the FAA Airway Facilities Services. Contains no specific reference to HAPs.
Air Quality Procedures for Civilian Airports and Air Force Bases (*Air Quality Handbook*)	Provides comprehensive and detailed guidelines on the preparation of airport-related air quality assessments including emission inventories and dispersion modeling.	Describes methods and contains specific recommendations for conducting emissions inventory and dispersion modeling of criteria pollutants, including VOCs. Does not currently contain information or guidance specific to HAPs.

Summary of Essential Findings

Based on the information acquired and evaluated in support of this assessment, the following material represents the essential findings relevant to agency guidelines and standards as they pertain to HAPs, aircraft and airports:

- Neither aircraft nor airports meet the definitions of the source types that are regulated under Section 112 (*Hazardous Air Pollutants*) of the CAA nor are they specifically listed among the source types that are regulated.

- Airports are characterized under the National Air Toxics Program as an example of complex facilities that produce aggregates of emissions, including HAPs, from multiple sources.

- Current FAA guidelines pertaining to air quality do not specifically address HAPs.

4. AIR MONITORING DATA AND INFORMATION

Introduction and Background

Over the past several years, interest has arisen concerning the effects of proposed airport improvement plans, projects and actions on local air quality conditions – especially as they pertain to ambient levels of odor, soot, other forms of particulate matter and HAPs. In response to these concerns, several air quality monitoring studies have been undertaken to better understand the effects, if any, aircraft and airport operations have on these conditions. Importantly, these studies have been conducted by both proponents and opponents of airport expansion as well as state and local environmental agencies.

Discussion of Relevant Information

Monitoring Methods

Air monitoring, sampling and testing are among the most reliable and accurate means of determining concentrations of air pollutants, including HAPs, in the ambient (i.e., "outdoor") air. Properly conducted, these data and information reflect "real world" conditions including the effects of local wind patterns, distance from the source(s) and other potential influences on the dispersion, transformation and, ultimately, the ground level concentration of the pollutants. The disadvantages of air monitoring include the costs, time and logistics in setting up and operating the equipment and the fact that the results are limited to the assessment of only current conditions.

Sample collection and analysis techniques vary depending on the form (i.e., gas, particle, aerosol) and/or type of contaminants (i.e., VOCs, metals, soot) of concern. Monitoring station location and sampling program duration are also two important elements that vary widely and are largely dictated by the objectives and the amount of funding available for the program. Table 4 contains a listing of some of the most common techniques used thus far to monitor ambient levels of HAPs near airports.

Monitoring Results

Table 5 lists a sampling of air monitoring studies recently conducted to measure ambient levels of HAPs on, and in the vicinity of, several major metropolitan airports. A summary of the approach and the key findings are also provided. In most cases, the actual monitoring data is very diverse and voluminous so it is not republished here. Rather, this information is referred to below and obtainable in the references provided in the bibliography.

Table 4
Common Air Sampling and Testing Techniques for HAPs

Pollutants	Methods	Approach
Particles, soot and metals	High-volume (Hi-vol) collectors with filters – including size segregation plates; glass collection plates; & Lo-vol collectors with cassette filters.	Sample filters measured gravimetrically in the laboratory or with automated light-scattering instrumentation for total mass and/or size; also analyzed with chemical "finger-printing" techniques or flame ionization spectrophometry for source and constituent types.
Gases	Stainless-steel summa canisters; Hi-vol collectors with foam cartridges; and passive absorption badges.	Analyze under laboratory conditions using gas chromatography and mass spectrophometry.

Table 5
Summary of Selected Air Monitoring Programs
Conducted in the Vicinities of Large Metropolitan Airports

Airport	Sponsor / Date	Approach Summary	Key Findings
Boston-Logan International Airport	Three studies conducted by Massport between 1994 & 1997; involving multiple sampling sites; and covered less than three weeks each.	- Assessment of VOCs, metals, soot & other atmospheric fallout near the airport & neighboring community. - Combined with chemical "finger-printing" & source apportionment estimates.	- Lower VOCs levels typically occur off the airport with elevated levels occurring occasionally under specific wind patterns. - Wind-blown soil/dust and marine aerosols comprise over 90% of the deposition. Airport contribution estimated at <1%.
Los Angeles International Airport (LAX)	Conducted by the local air quality agency over the past three years, involving multiple sampling sites, different sampling objectives and covering a couple days to a few weeks.	- Measurements of VOCs in the vicinity of the main terminal access/egress curbsides for assessment of occupational exposures. - Collection & analysis of VOCs, soot and other atmospheric fallout in neighboring communities.	- Air contaminants in the terminal area were elevated compared to off-airport concentrations. Along the curbside, VOC types are characteristic of motor vehicle exhaust. - Soot and other products of incomplete fuel combustion near the airport are in greater abundance than other background locations. However the potential sources of the contaminants were unidentifiable and indistinguishable from each other based on chemical make-up.
Chicago-O'Hare International Airport	Conducted by the airport (City of Chicago) in 1999.	- Sampling of soot and particulates combined with advanced chemical finger-printing.	- Samples bore little chemical resemblance to either unburned or burned jet fuel.
	Conducted by an opponent of the airport expansion (City of Park Ridge) in 2000.	- Sampling and testing of air samples up- and down-wind of the airport;	- Elevated levels of VOCs downwind of the airport. - Report claims that VOCs are characteristics of aircraft exhaust.
	Conducted in 2001 by the state agency (IEPA) as part of the National Urban Air Toxics Strategy.	- Measurements of HAPs both up- and down-wind of the airport and in other metropolitan locations.	- Down-wind concentrations were higher, but typical of urban areas. - Average values comparable, or lower, to other Chicago sites.

For ease in understanding the information contained in Table 5, the interpretations of the key findings with respect to HAPs are provided below, by airport.

Boston-Logan International Airport - Some of the earliest air sampling was conducted in the vicinity of Boston-Logan International Airport on behalf of Massport (KM Chng, 1994, KM Chng, 1996, TRC Environmental, 1997). These studies focused primarily on soot deposition but also included the analysis of select VOCs and metals. The sampling was combined with "chemical finger-printing" and source-apportionment estimations to help identify the source of the contaminants.

The results of this work concluded that the deposition samples collected in neighboring areas largely (>92%) contained a combination of wind-blown soil, marine aerosols and road dust. The trace amounts of petroleum-based substances were more characteristic of those from motor vehicles with the airport contribution estimated at less than 1%.

Los Angeles International Airport - A series of air sampling programs conducted at, and in the vicinity of, LAX by the South Coast Air Quality Management District (SCAQMD) attempted to measure HAPs in both the gaseous and particulate forms (SCAQMD, 1998, SCAQMD, 2000a, SCAQMD, 2000b, SCAQMD, 2000c). LAX is among the five busiest airports in the U.S.

From this work, it was determined that VOCs along the main terminal arrival and departure curbsides were indicative of automobile exhaust (i.e., CO, benzene and 1,3-butadiene) and in measurably higher concentrations than nearby off-site locations. These results are not surprising as the primary objective was to evaluate the occupational exposures of airport workers (i.e., baggage handlers, taxi/limo drives, etc.) to air contaminants in the highly restricted and congested area of the airport's main terminal.

In another study conducted at monitoring sites located adjacent to the airport, the test results revealed that levels of both soot particles and elemental carbon (products of incomplete fuel combustion) were higher when compared to other off-site locations. However, it was not possible to characterize or differentiate the VOCs as being from either the airport or nearby major roadways.

Over the past two years, a multifaceted study of HAPs in the area surrounding LAX has been proposed – including a comprehensive air monitoring plan. The participants of this study are the U.S. EPA Office of Research & Development and Region 9, the California Air Resources Board (CARB), the SCAQMD, the FAA Western Pacific Region and the Los Angeles World Airport Authority (LAWA). Following the events of September 11, 2001, this study has been delayed temporarily.

Chicago O'Hare International Airport - Some of the most recent, and perhaps the most notable, air sampling results for HAPs has occurred in the vicinity of O'Hare International Airport; one of the world's busiest. These studies, undertaken by both proponents and opponents of the airport as well as the state air quality agency reveal somewhat conflicting results.

On behalf of the City of Chicago (the airport owner), researchers undertook a monitoring program of soot and particulates augmented with "advanced chemical finger-printing" to help ascertain the source of the contaminants (KM Chng 1999). Comparable to the studies at Boston-Logan, this work concluded that the samples collected near the airport bore little chemical resemblance to potential airport-related source products such as partially burned and unburned jet fuel or jet engine exhaust.

In follow-up to the work performed at O'Hare by the City of Chicago, the neighboring community of Park Ridge underwrote and conducted their own assessment of air quality impacts associated with the airport (City of Park Ridge, 2000). Based on monitoring data collected both upwind and downwind of the airport, the results of this study concluded that HAPs originating at the airport were migrating across the fenceline into residential areas.

Most recently, the Illinois Environmental Protection Agency (IEPA) conducted an independent assessment of HAPs in the vicinity of O'Hare as part of the *National Integrated Urban Air Toxics Strategy* (IEPA, 2002). Again, these results are based on air monitoring data collected at both upwind and downwind locations as well as from locations located away from the airport. From this work, the IEPA concluded that while downwind levels of HAPs were higher, they were comparable to other sites located away from the airport and well with the range of levels considered "typical" of an urban environment.

Other Airports - Other air monitoring studies conducted in the U.S. include the sampling of HAPs in the vicinity of Teterboro Airport in New Jersey (Environ, 2001). Completed in the summer of 2001, this two-day study was commissioned by a coalition of communities opposed to airport expansion. The results were compared to state-run air monitoring stations in the Camden area. From this work it was concluded that concentrations of HAPs adjacent to the airport were higher in comparison to the state sites.

At Charlotte / Douglas International Airport a soot deposition study was undertaken in 1998 to assess the nature of these air contaminants by aircraft operations (KMChng, 1998). The approach to this short-term monitoring program was very similar to the work conducted near Boston Logan and Chicago O'Hare by the same investigators and described above. The results and conclusions were also similar and revealed that jet fuel indicators were not found in the samples collected and that regional emissions of these pollutants are more likely the source, both on and off the airport.

Another air monitoring study was undertaken in the vicinity of Seattle-Tacoma International Airport (Sea-Tac) by the Port of Seattle in 1993 (Port of Seattle, 1995). The results indicate that the highest HAP levels occur on the airport, but that off-site the up- and down-wind measurements were not easily differentiated nor were the levels significantly different from levels found in other urban areas.

In Europe, the monitoring of HAPs has taken place near at least three airports with similar results reported by the U.S. counterparts (Tesseraux, 1998, TNO, 2000, Tsani-Bazaca, 1997). For example, measurements around Hamburg Airport show no elevated levels of PAHs; at Amsterdam Schipol Airport VOC concentrations were not significantly different than those measured elsewhere in the urban airshed; and at Gatwick International Airport near London, hydrocarbon concentrations were reported to be much lower when compared to a central London site.

Summary of Essential Findings

The review of available reports and supporting information pertaining to the measurement of HAPs on, and in the vicinity of, airports and airfields, reveals the following:

- A small number of air monitoring programs have been conducted for HAPs and have produced mixed results.
- Most monitoring efforts have thus far been relatively short-term (i.e., 3 days to a few weeks) and there have been no long-term or permanent programs conducted.
- In general, HAP levels on the airports are higher when compared to off site concentrations. However, these off-site levels are not appreciably different than those measured in other areas of the urban environment.
- In most cases, the data cannot differentiate those HAPs that are generated by airport operations from those associated with non-airport sources (i.e., motor vehicles).

5. EMISSION FACTORS

Introduction and Background

During the course of this survey it was revealed that the availability and accuracy of emission factors were among the greatest potential limitations of any air quality HAPs analysis relying on the results of emission inventories or dispersion modeling. This view was shared by both consultants and agency personnel alike and documented in the published materials contained in the bibliography. Although predominantly centering on aircraft engines, this concern extended to other airport-related sources (i.e., APUs, GSE, motor vehicles) of HAPs as well.

Emission factors for mobile sources are usually expressed by units of mass of pollutant emitted per unit of operational time, distance traveled or volume of fuel consumed (i.e., ug./sec., lbs./mile, ug./gal.). For example, the FAA EDMS model (the latest version at this time is Version 4.11) provides aircraft emission factors for the criteria pollutants (i.e., CO, NOx, HC) as grams / kilograms of fuel burned and by mode (i.e. taxi-idle, take-off, cruise, etc.). The U.S. EPA MOBILE model provides motor vehicle emission factors as g./vehicle-mile traveled.

Emission factors are derived in a variety of ways including direct measurements of the source, theoretical calculations, or a combination of both. Typically, those that are based on source testing under actual operating conditions are considered the most reliable.

Discussion of Relevant Information

Aircraft

As discussed previously in Section 3 (*Agency Guidelines and Standards*), the U.S. EPA is presently undertaking a comprehensive evaluation of HAPs and their sources nationwide. In support of this *National Air Toxics Assessment* (NATA), emission estimates are prepared and updated every three years for the *National Toxics Inventory* (NTI). For the preparation of these NTIs as well as some earlier air toxic assessments, the U.S. EPA established a set of HAP emission factors, or speciation profiles, for airport-related sources including aircraft and GSE. This information is quite limited and the derivation of these factors are explained in a series of four internal U.S. EPA technical memorandums prepared mostly by Mr. Richard Cook of the *Office of Transportation & Air Quality* (OTAQ) (U.S. EPA 1993c, 1997c, 1997d, 1998b, 2001e).

From these memorandums, it is revealed that the only available emission profiles for aircraft HAPs are contained in the U.S. EPA *Air Emissions Species Manual for Total Organic Compounds* (TOCs) (U.S. EPA 1990a). This early U.S. EPA manual has since been reformatted into an electronic database of emission factors under the designation of "SPECIATE" (U.S. EPA 1999).

In either case, profiles are provided for a number of HAPs that the U.S. EPA associated with aircraft and are given as a percentage of the total organic gases (TOGs) or total VOCs for a typical landing / take-off operational (LTO) cycle. Later, these "speciation" factors were adjusted to reflect varying operating characteristics of the individual segments of the LTO – take-off, landing and idle. It is also noteworthy that these data are presented as composites for the general categories of commercial, air taxi, general aviation and military aircraft and are not representative of individual aircraft. In subsequent guidance memos, U.S. EPA provides conversion factors for TOG-to-VOC and PAH-to-VOC as well as supplemental data for several specific HAPs that were not originally included in the initial materials provided by OTAQ.

Table 6 contains these U.S. EPA aircraft-related HAP emission (or speciation) factors provided here for informational purposes only. Any user of these emission factors should refer to the original U.S. EPA technical memorandums mentioned above for a full understanding of the derivation and application of these data.

Table 6
Aircraft-Related HAPs Emission Factors[a]
(Fraction of Total Organic Gases or Volatile Organic Compounds)

Pollutant	Commercial	Air Taxi	General Aviation
1,3 Butadiene *	0.0180	0.0157	0.0098
Acetaldehyde**	0.0465	0.0432	0.0062
Acrolein **	0.0253	0.0234	0.0006
Benzene *	0.0194	0.0179	0.0405
Ethylbenzene *	0.0017	0.0015	0.0015
Formaldehyde *	0.1501	0.1414	0.0269
POM° as 7-PAH **	1.049E-6	7.234E-6	9.062E-6
POM° as 16-PAH **	1.166E-4	6.829E-5	2.954E-5
Propionaldehyde *	0.0095	0.0090	0.0090
Styrene **	0.0044	0.0042	0.0037
Toluene*	0.0052	0.0049	0.0049
Xylene*	0.0048	0.0044	0.0044
Individual PAHs			
Anthracene**	4.05E-07	n.a.	4.03E-07
Benzo(a)anthracene**	6.39E-08	n.a.	6.10E-08
Benzo(a)pyrene**	3.53E-08	n.a.	3.34E-08
Benzo(ghi)perylene**	5.88E-09	n.a.	5.54E-09
Chrysene**	5.72E-08	n.a.	5.68E-08
Fluoranthene**	8.50E-07	n.a.	8.43E-07
Napthalene**	4.29E-04	n.a.	4.30E-04
Phenanthrene**	3.79E-06	n.a.	3.75E-06
Pyrene**	1.03E-06	n.a.	1.03E-06

n.a. = not available   *as TOG fraction   **as VOC fraction

°POM - polycyclic organic matter as polycyclic aromatic hydrocarbons (PAH). For some PAHs, there were no individual factors given by the U.S. EPA.

[a] Provided here for informational purposes only. Any user of these emission factors should refer to the original U.S. EPA technical memorandums mentioned above for a full understanding of the derivation and application of these data, including the appropriate VOC to TOG conversion factors.

Importantly, the source of the U.S. EPA HAPs emission factors and chemical species profiles for commercial aircraft are based largely on the work by Spicer (Spicer 1984, Spicer 1994). Conducted in the mid-1980's and reported in scientific literature during the mid-1990's, these data were derived from the testing of two aircraft engines: one commercial and one military, for a variety of PAHs.

While it is acknowledged that the work by Spicer was thorough and considered high quality (including the testing of engine emissions under varying power settings), the data is recognized as being appreciably limited as only two aircraft engines were tested.

As a practical matter, these HAPs data are intended to be used for the making of preliminary, or "gross," estimates in support of macro-scale analyses of aviation-related emissions. They were not intended to provide exact estimates of emissions from any particular aircraft or airport facility. U.S. EPA indicates that due to unconfirmed assumptions, many uncertainties, and lack of data, these emission factors are imprecise and deficient (FAA 2002a). Nevertheless, in the absence of better data, these HAPs emission factors have subsequently been used in support of air quality analyses for some recent airport environmental impact assessments.

The California Air Resources Board (CARB) has also recently published a draft set of speciation profiles of organic gases and particulate matter factors for a wide array of stationary and mobile sources, including motor vehicles, off-road equipment, and aircraft (CARB, 2002). Reportedly, the aircraft HAPs emission profiles for this database were also derived from U.S. EPA information.

Finally, the U.S. military has performed testing of aircraft exhaust for HAPs for two primary purposes: 1.) to quantify HAPs emission associated with base operations and closures under the NEPA environmental assessment process and 2.) to obtain regulatory permits for engine test cells under the CAA. Conducted largely by the USAF, these test results exist for at least 18 military aircraft under different power settings (i.e., idle, approach, etc.) and two APU types (USAF 1999).

Non-Road and Motor Vehicles

As part of the NTI, the U.S. EPA was also required to develop HAPs emission factors for a variety of on-road and non-road vehicles. As was done, and discussed above, for the calculation of aircraft-related HAPs, the approach was to relate emissions of specific POM/PAH to the total exhaust HC emissions.

Again, the basis and derivation of these emission factors is summarized in four internal memorandums prepared by the U.S. EPA OTAQ (U.S. EPA 1997e, f, 1998c, 2001e). Simply stated, these estimates originate from the measured relationship between benzo-(a)-pyrene (B(a)P), other HAPs and total hydrocarbons (HC) in the exhaust of gasoline and diesel fueled vehicles. The B(a)P/HC ratios are applied to the U.S. EPA motor vehicle emissions model -

MOBILE5b (or later version such as MOBILE6.2) HC emission rates for all vehicle classes (i.e., LDGV, LDDV, HDDV, etc.) to obtain the necessary HAP emission factor in units of ug/mile.

Additional Information

Contained in the documents that reported on the testing of aircraft exhaust for HAPs were some potentially significant observations and comments concerning the generation of HAPs. Among the most remarkable observations is the extremely low concentration of HAPs found in aircraft exhaust. The low HAP concentrations and the high volumetric flow rates characteristic of the engine exhaust make it difficult to measure these contaminants.

Another common observation is that the type and amounts of HAP emissions are strongly influenced by the engine load, varying by an order-of-magnitude (or more) from base load to idle (Spicer 1984, 1994). For this reason, averaging HAP emission factors from different aircraft and for different operating conditions is not considered appropriate.

Summary of Essential Findings

From the review of the available information discussed above and contained in the bibliography, the most noteworthy as it pertains to HAP emissions factors is summarized as follows:

- The availability and accuracy of emission factors are among the greatest potential limitations of HAP analyses relying on the results of emission inventories or dispersion modeling.
- The U.S. EPA has compiled a partial database of HAP emission factors in support of their development of the National Toxics Inventory. However, these factors are intended for gross estimates of total emissions on a broad scale and are based on the measurements from only two aircraft. Emission factors are only provided for select compounds and not for all of the identified air toxics in aircraft exhaust.
- The CARB has also published a list of HAP emission profiles for a wide assortment of mobile sources including aircraft.
- The USAF has compiled a more extensive database of HAP emission factors for military aircraft and APUs.
- Among the most remarkable observations reported during the testing procedures include the following:
  - The extremely low concentration of HAPs found in aircraft exhaust.
  - The type and amounts of HAP emissions are strongly influenced by the engine load; varying by an order-of-magnitude (or more) from base load to idle.
  - Averaging HAP emission factors from different aircraft and for different operating conditions is not considered appropriate.

Several other studies have been undertaken and just recently presented at the 2003 Air & Waste Management Association conference that discuss the application of currently available emission factors, dispersion models and health risk assessments in connection with airport- and aircraft-related HAPs (Hayes, 2003, Vanderbilt, 2003, Pehrson, 2003 and CDM, 2003). These collective works aid in the better understanding of the current issues, potential limitations and need for additional information connected with the assessment of HAPs associated with airports.

6. ATMOSPHERIC DISPERSION MODELS

Introduction and Background

One of the key links between emissions of HAPs and their potential effects on human health or the environment is expressed as the measurement of its concentration (level or strength) and exposure period. Simply stated, without knowing the concentration and exposure (i.e., dose) of an air contaminant, or HAP, it is virtually impossible to predict, assess or otherwise associate a response to such a substance or chemical.

In basic terms, the concentration of HAPs can be determined in two ways: 1.) by absolute "real-time" monitoring (or sampling and testing) of HAPs in the field (as discussed previously in Section 4: *Air Monitoring Data and Information*), or 2.) by simulation and prediction using appropriate HAPs emission factors and atmospheric dispersion modeling.

The second approach, using emission factors and dispersion modeling to determine the ambient concentration of HAPs, is usually much less costly than monitoring and is particularly appropriate when attempting to predict future-year conditions. Modeling also permits the prediction of contaminant concentrations over a wide range of locations and averaging times as well as giving some indication as to the impact of different sources on individual receptors. For these reasons, this approach has been used in a limited extent for determining what effect, if any, airport-related sources of HAPs have on ambient concentrations of these substances.

Discussion of Relevant Information

Available Models

Based on the search of available literature and other sources of information conducted as part of this work, it was revealed that only two atmospheric dispersion models have been used thus far for the assessment of airport-related HAPs: the U.S. EPA model Industrial Source Complex (ISC) and the FAA Emissions Dispersion & Modeling System (EDMS). The attributes and applications of these two models as they pertain to the modeling of HAPs associated with aircraft and airports are contained in Table 7 and discussed below.

Industrial Source Complex Model (ISC)

Historically, the Industrial Source Complex (ISC) model is considered to be a "work horse" among the atmospheric dispersion models available because of its widespread use for a variety of applications and sources (U.S. EPA 1995). The latest version of the model (ISC3) is designated as a "Preferred Model" by the U.S. EPA and is considered appropriate for the dispersion modeling of criteria pollutants and HAPs from industrial facilities and other complex sources (40 CFR Pt. 51).

Table 7
Atmospheric Dispersion Models

Model	Design Application	Status	HAPs Use
Industrial Source Complex Model (ISC3)	- Industrial complexes - Rural or urban areas - Flat or rolling terrain - 1-hour to annual avg. times - Distances < 50 km - Criteria pollutants & HAPs	EPA - preferred model for complex sources.	- EPA NATA population exposure studies. - LAX Master Plan EIR/EIS - O'Hare (Park Ridge) study - John Wayne / Orange Co. Airport Study.
Emissions and Dispersion Modeling System (EDMS)	- Aircraft operations, point and mobile sources at airports and air bases. - Generates input file for AERMOD - Simple terrain - Distances < 25 km - 1-hour to annual avg. times - Criteria pollutants and hydrocarbons	EPA - preferred and FAA - required model for airports	- U.S. EPA National Emissions Inventory (emissions inventory used to compute HC emissions; dispersion modeling not conducted.)

As discussed above in Section 3 (*Agency Guidelines and Standards*), the U.S. EPA is currently developing baseline information on HAPs under the NATA; including the assessment of population exposures to HAPs in urban areas. When dispersion modeling is conducted to estimate either short- (one hour) or long-term (annual) concentrations of HAPs at locations ranging from the urban to the neighborhood scale – ISC3 is used for this application.

The ISC model also has the ability to predict ambient concentrations of pollutants in both a grid pattern and at discrete receptors. This is particularly useful in computing ground-level HAPs concentrations as contours of equal concentrations or when the determination of the "maximum exposed individual" (MEI) is an important element of the human risk assessment. ISC is also able to accommodate several years of wind data without consuming significant computer memory or causing extended computer run times of the model.

Importantly, ISC was not specifically developed or designed for airport use. For this highly specialized application, the user must create line, volume, area and point sources to represent aircraft landing and take-off patterns, runway/taxiway systems, terminal gate areas and other potential sources or locations of airport-related emissions. Moreover, because ISC is solely a dispersion model, it does not contain emission factors nor is it capable of computing an emissions inventory. Rather, the user must first calculate the types and amounts of criteria pollutant or HAP emissions externally (or separately) for input into the ISC model.

Notably, the U.S. EPA has developed a replacement for ISC called AERMOD, which is reported to have improved performance characteristics. (See further discussion of AERMOD below under EDMS.)

ISC was used recently in support of two air quality analyses for two airports in California: Los Angeles International Airport (LAWA 2000) and the John Wayne/Orange County Airport (Lindberg 1997). These analyses were conducted for fulfillment of California-specific requirements called for under the California Environmental Quality Act (CEQA). ISC was also used in support of a HAPs analysis in the vicinity of O'Hare International Airport in Chicago (City of Park Ridge, 2000).

Emissions and Dispersion Modeling System (EDMS)

In cooperation with the U.S. EPA, the FAA has also developed a model for the specific application of assessing air emissions from airport facilities. Called the Emissions and Dispersion Modeling System (EDMS), this model is also designated by the U.S. EPA as a "Preferred Model" and identified by the FAA as the "required" model for aviation-related air quality assessments involving aircraft, auxiliary power units (APUs) and ground service equipment (GSE) (FAA 2001).

Uniquely, the EDMS is a combined emissions and dispersion model capable of producing an emissions inventory of all airport sources and also calculates the resultant ambient concentrations of the criteria pollutants emitted by these sources. The latter is achieved by the EDMS generating the input files for AERMOD - the new dispersion model developed by the U.S. EPA to replace and update ISC (see discussion above on ISC).

The EDMS is based on extensive FAA research and ongoing coordination with the U.S. EPA to help ensure the proper characterization of airport-related sources of air emissions, which can be modified by the user to help simulate the unique operational and design elements of individual airports. The latest version of EDMS is EDMS 4.1, and the model is continually updated by the FAA.

Importantly, the EDMS database for aircraft, GSE, motor vehicles, fuel facilities, etc. do not currently contain emission factors or speciation profiles for HAPs. For an emissions inventory, the total amounts of hydrocarbons computed by EDMS, by source type, can be used as the basis for the estimation of HAPs. This is achieved by the modeler using appropriate hydrocarbon- (or particulate matter) to-HAPs conversion or "speciation" factors, as was discussed for ISC above.

The dispersion of air pollutants can either be run directly within the EDMS using AERMOD or externally as a separate algorithm. In either case, the size, location or other unique characteristics of the individual airport emission sources (i.e. aircraft landing and take-off patterns, runway/taxiway systems, terminal gate areas, etc.) are automatically prepared for AERMOD by EDMS. Because EDMS does not currently contain HAPs emission factors, the computed concentrations of hydrocarbons are converted to HAPs by the modeler using appropriate speciation factors.

Using AERMOD as the dispersion model, EDMS also has the capability to predict ambient concentrations of pollutants in both a grid pattern and at discrete receptors using real-world meteorological data. The most recent version of EDMS (version 4.1) was developed by the FAA based on EPA guidance on the application of AERMOD. The intended purpose of AERMOD is to replace ISC3 by updating it with current and newly developed state-of-the-art modeling techniques.

EDMS has been used in support of the assessment of airport-related HAPs; but primarily only as a means to compute the amounts of VOCs emitted by the airport as a whole or by one or more of the individual elements (i.e., aircraft, GSE, etc.). EDMS is particularly well suited for this application as it contains all the necessary and appropriate algorithms and databases that characterize most modern airports. These include aircraft landing and take-off operational (LTO) times-in-modes; aircraft/aircraft engine combinations; GSE fleet characteristics; and emission factors for aircraft, GSE and the other various sources of emissions at the airport.

Summary of Essential Findings

The available information concerning the use of atmospheric dispersion models as an aid in the assessment of HAPs associated with airports, revealed the following:

- The EDMS prepared by FAA is specifically developed for the assessment of airport air quality and is an EPA-preferred as well as a FAA-required model for this application.

- The most recent version of EDMS (version 4.1) contains the new dispersion model AERMOD, developed by the EPA as a replacement and upgrade to ISC.

- EDMS has been used in support of airport HAPs assessments primarily as a means to compute hydrocarbons. Its use as a dispersion model for HAPs is limited but it is considered to be suitable for this purpose.

- Because EDMS is specifically designed for modeling airport-related air emissions, its application for the prediction of HAPs concentrations is ultimately desirable.

- The ISC model is intended for use for the dispersion modeling of criteria pollutants and HAPs from industrial and complex sources and is an EPA-preferred model for these purposes.

- For the simulation of airports using ISC, the primary emission sources (i.e., runways, taxiways, gate areas, fuel facilities, etc.) must be created by the user and input into the model. Appropriate emission factors must also be developed separately and input to the model.

- ISC has been used for the modeling of HAPs for at least three airport air quality analyses; most conducted in support of California-based requirements.

- Using any available model, the modeler must convert hydrocarbons or particulate matter to HAPs using appropriate speciation factors.

The need for the modeler to create airport emission sources using ISC and to translate hydrocarbon and particulate matter emission factors to HAPs using speciation factors using ISC or EDMS causes some degree of uncertainty in the modeling outcomes. . The reactivity and transformation of hydrocarbons, particulates and HAPs to other forms are also not considered.

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ANNOTATED BIBLIOGRAPHY OF SELECTED WORKS

CONTAINING INFORMATION RELATED TO HAZARDOUS AIR POLLUTANTS (HAPS)*

ASSOCIATED WITH AIRPORTS, AIRCRAFT AND AVIATION

(Updated July 1, 2003)

The following is a listing of reports, papers and other documents or sources of information pertaining to HAPs with a special emphasis on airports, aircraft and aviation. Several methods were used to identify, locate and retrieve these resources including electronic database searches, agency and library inquiries, telephone calls and direct communications with groups and/or individuals knowledgeable of this highly specialized field. Most of these materials were obtained by URS Corp. in the performance of its services to CSSI and the FAA under this Technical Directive and are retained at its offices in Tampa, Florida.

This list is not intended to be inclusive as new materials and information are developed and published nearly every day on HAPs - even as they relate to airports and aircraft. Rather, this listing is intended to serve as a baseline upon which new and/or missing material can be added.

For ease in the review and assimilation of these materials, they have been organized according to some general subjects or themes (i.e., Agency Information, Airport Studies, Emission Factors, etc.). In addition, each citation is provided with a synopsis of what are considered to be the most significant or relevant information contained therein, according to URS staff.

* For the purposes of this document, the terms "Toxic Air Contaminants", "Toxic Air Pollutants" (or "TAPs") is intended to mean the same thing as "Hazardous Air Pollutants" or ("HAPs").

A-1. AGENCY INFORMATION

This material consists of publications and other sources of information available from federal, state and local agencies involved in environmental protection, air quality and TAPs in the U.S.

42 U.S.C.A. Federal Clean Air Act (*Air Pollution Prevention and Control*) Sections 7401 to 7671.

Last amended in 1990, codifies U.S. Congressional actions taken over the past 30 years in support of ambient (outdoor) air quality throughout the nation.

- Title II: *Mobile Sources and Fuels* contains provisions pertaining to aircraft emission standards.
    - Refers to standards for vented fuel, smoke and exhaust (HC, NOx and CO) emissions established in 1973 and 1984.
    - Refers to adoption of ICAO standards for CO and NOx in 1997.
    - Refers to FAA/EPA Multi-stakeholder process for reducing NOx emissions.
- Title III: *Hazardous Air Pollutants* contains provisions pertaining to HAPs. Also referred to as Section 112.
    - Defines "major" source as any stationary source of HAPs that emits, or have the potential to emit, 10 tons/year or more of a listed pollutant and/or 25 tons/year of a combination of pollutants.
    - Defines area source as every thing else, except motor vehicles and non-road vehicles regulated under Title II.
    - Provides list of 188 HAPs subject to this provision.

FAA, 2002a, *FAA / EPA Conference Call on Toxic Air Emissions & Airports, notes prepared by M. Kenney, URS Corporation, May 17, 2002.*

This conference call was conducted to enable FAA and US EPA staffs preliminary discuss their respective interests, work and plans in connection with TAPs. Other objectives were to establish points-of-contact, identify common interests and information gaps, and exchange information.

- FAA indicated that this is a cursory examination of what is known about airports and TAPs. It is an "information-gathering" process.

- EPA is evaluating the subject on an multifaceted basis, obtaining information from many different departments (OAQPS, ORD), regions and individuals.

- Joe Wood (OAQPS) is serving as the clearing-house. Eventually, the information will be published on their web-site. (Since this conference call, Suzanne King (EPA-Region 5) now serves as the U.S. EPA clearing house manager for airport-related HAPs.

- EPA (Rich Cook – OTAQ) reaffirmed that the TAP emission factors being used now are largely from the work by Spicer; now over 10-year old and limited to two aircraft.

- Based on this discussion, the largest of the information gaps is associated with the limited aircraft emission factors.

- Dean Smith, EPA-Region 9 (in conjunction with ORD) is trying to obtain a profile of aircraft exhaust at LAX with an emphasis of those that cause health effects. Funding at LAX for this study has been curtailed.

FAA, 2002b, Office of Environment and Energy, Emission Division, Web-site - http://www.aee.faa.gov/

Contains up-to-date information, materials and models pertaining to air emissions associated with airports and aircraft.

- Provides access to the *Airport Air Quality Handbook* and provides information about the latest emission inventory and dispersion modeling tools.

- Does not currently contain any specific information on HAPs.

FAA, 1999, *Policies and Procedures for Considering Environmental Impacts* (FAA Order 1050.1D CHG4), Airway Facilities Services, June 14, 1999.

Provides updated guidance on the preparation of Environmental Assessments (EAs), Environmental Impact Statements (EIS) and other documents required under the National Environmental Protection Act (NEPA) for airport improvement projects and actions by the FAA Office of Environment and Energy.

- Contains information and provides direction on how to address air quality issues including necessary approvals and types of analyses.

- Does not contain specific information or guidance concerning HAPs

FAA, 1997, *Air Quality Procedures for Civilian Airports & Air Force Bases*, Office of Environment & Energy and the USAF, April 1997.

Provides guidance on conducting air quality impact assessments for airport improvement projects and actions required for compliance with the National Environmental Policy Act and the Clean Air Act.

- Contains comprehensive and detailed methodology on preparing emission inventories and conducting dispersion modeling of the EPA criteria air pollutants, including VOCs.
- Does not contain specific guidance for the assessment of HAPs.

FAA, 1985, *Airport Environmental Handbook*, (FAA Order 5050.4A), October 8, 1985.

Provides guidance on the preparation of Environmental Assessments (EAs), Environmental Impact Statements (EIS) and other documents required under the national Environmental Protection Act (NEPA) for airport improvement projects and actions by the FAA Airport's Office.

- Contains information and provides direction on how to address air quality issues including necessary approvals and types of analyses.
- Does not contain specific information or guidance concerning HAPs.

U.S. EPA, 2002a, *National Emission Standards for Hazardous Air Pollutants: Engine Test Cells/Stands*, Proposed Rule, 40 CFR Part 163.

Proposes national emission standards for HAPs for test cells/stands.

- Identified engine test cells/stands as major sources of HAPs, including toluene, benzene, mixed xylenes, and 1,3-butadiene.
- Proposed rule will reduce HAP emissions in the 5th year following promulgation, by an estimated 135 tons.

U.S. EPA, 2001a, *Work Plan for the National Air Toxics Program and Integrated Air Toxics State/Local/Tribal Program Structure*, Office of Air Quality Planning & Standards, September 2001.

Outlines and explains the EPA ongoing activities and plans for addressing the agency's mandate under the CAA Amendments of 1990 to evaluate, and if necessary, reduce air toxics.

- For stationary sources, focuses on the sources and/or industry groups of the 188 listed TAPs. Defines "major" stationary source as those that emit, or have the potential to emit, 10 tons/year or more of a listed pollutant and/or 25 tons/year of a combination of pollutants.

- For area sources, focuses on controlling sources of the 30 "area source" TAPs and identifying these sources.

- For mobile sources, focuses on the study of motor vehicle emissions of TAPs, including the list of 21 mobile source air toxics.

- Aircraft and airports do not meet the definitions of stationary and area sources and are not mentioned in the discussion of mobile sources.

U.S. EPA, 2001b, *Documentation for the Draft 1999 Base Year Aircraft, Commercial Marine Vessel, and Locomotive National Emission Inventory for Criteria and Hazardous Air Pollutants*, prepared by Eastern Research Group, Inc., prepared for Emissions Factor and Inventory Group (MD-14), Emissions, Monitoring and Analysis Division.

As part of the National Emissions Inventory (NEI) of hazardous air pollutants for all areas of the U.S., this document demonstrates how the aircraft-related components of the 1999 NEI were computed.

- Includes commercial, air taxis, GA and military aircraft; and support equipment.

- EPA identified the following HAPs believed to be emitted from aircraft, based on Cook memos:

- 1,3 butadiene	- Polycyclic Organic Matter (POM)
- 2,2,4-trimethylpentane	- Propionaldehyde
- acetaldehyde	- Styrene
- acrolein	- Toluene
- formaldehyde	- Xylene
- lead	- Ethylbenzene
- benzene	- nHexane

- LTOs and times-in-modes obtained from FAA databases and input into FAA EDMS for VOCs.

- TAP emission estimates for all aircraft estimated by applying speciation profiles to VOC and/or PM-10 emission estimates.

- Emissions for support vehicles and equipment were estimated by apportioning the criteria estimates in the TRENDS report by multiplying the 1998 emission estimates by the percent change in LTO activity between the 1998 and 1999.

- Summary of national 1999 aircraft emission in the NEI follows:

Pollutant	Emissions (tons/year)	Rank by amount for HAPs
VOC	44,782.91	na
NOx	93,907.15	na
CO	414,091.86	na
SOx	7,996.14	na
PM10	8,299.92	na
PM2.5	6,435.48	na
1,3-Butadiene	823.83	6
2,2,4-Trimethylpentane	29.70	13
Acetaldehyde	1,969.28	2
Acrolein	937.51	5
Benzene	1,183.47	3
Ethylbenzene	210.76	10
Formaldehyde	6,408.31	1
Lead	540.81	8
n-Hexane	70.87	12
Propionaldehyde	396.40	9
Styrene	194.99	11
Toluene	1,174.08	4
Xylene	701.45	7

- Summary of national 1999 aircraft 16-PAH emission estimates follows:

<u>Pollutant</u>	**Emissions (ton/year)**
Acenaphthene	2.97
Acenaphthylene	16.76
Anthracene	3.47
Benzo(a)anthracene	0.41
Benzo(a)pyrene	0.41
Benzo(b)fluoranthene	0.49
Benzo(ghi)perylene	1.06
Benzo(k)fluoranthene	0.49
Chrysene	0.41
Dibenz(a,h)anthracene	0.00
Fluoranthene	4.58
Fluorene	7.56
Indeno(1,2,3-cd)pyrene	0.33
Naphthalene	454.25
Phenanthrene	10.42
Pyrene	5.07
TOTAL	**508.68**

- VOC speciation profiles (as a fraction) for commercial aircraft follows:

Pollutant	**Speciation profile**
Acetaldehyde	0.0519
Acrolein	0.0253
Styrene	0.0044

- PAH profiles (as a fraction) for commercial aircraft:

Pollutant	**Specication profile**
Benzo(a)anthracene	6.39E-08
Benzo(a)pyrene	3.53E-08
Chrysene	5.72E-08
Anthracene	4.05E-07
Benzo(ghi)perylene	5.88E-09
Fluoranthene	8.50E-07
Naphthalene	4.29E-04
Phenanthrene	3.79E-06
Pyrene	1.03E-06

- TOG Speciation Profiles (as a fraction) for Commercial Aircraft:

Pollutant	**Speciation profile to TOG**
1,3-butadiene	0.018
Benzene	0.0194
Ethylbenzene	0.0017
Formaldehyde	0.1501
Propionaldehyde	0.0095
Toluene	0.0052
Xylene	0.0048

- No speciation profiles for turbine engines for benzo fluoranthene, benzo fluoranthene, dibenz anthracene, indeno pyrene, acenaphthene, acenaphthylene, and fluorene.

U.S. EPA, 2001c, *A List of Compounds Emitted from On-Road and Non-Road Mobile Sources*, prepared for the U.S. Environmental Protection Agency, by Sierra Research Inc., Report No. SR01-02-01.

Involved the detailed review of 46 references that contained information pertaining to air emissions from on- and non-road sources, including aircraft.

- Identified 24 IRIS Database HAPs emitted by jet exhaust in levels above detection limits.

- Ranked the references and collection techniques from which the information and data was obtained (A thought F). The Spicer work was graded "B", the EPA (Cook) February 1993 memo was graded "D" and the 2000, 1996 Base Toxic Inventory for Aircraft Sources was graded "D".

U.S. EPA 2001d, *The Projection of Mobile Source Air Toxics from 1996 to 2007: Emissions and Concentrations*, DRAFT, prepared for Dr. Madeleine Strum, prepared by William Battye.

Uses the 1996 National Toxics Inventory (NTI) and the Assessment System for Population Exposure Nationwide (ASPEN) dispersion model to predict nationwide ambient concentrations of toxic air pollutants for the years 1996 and 2007:

- Projections are based on the conservative assumption that particulate HAPs will increase or decrease in proportion to changes in nonroad engine usage between 1996 and 2007 and national average growth factors.

- Separate growth factors were used for lead emissions from aircraft; mainly from general aviation fuel usage.

- Airports were processed as point sources at the county-level.

- Gaseous HAP emissions from airports are projected to increase 27% from 1996 to 2007; the most prevalent of these include:

  - Formaldehyde, acetaldehyde, benzene, acrolein, 1,3-butadiene, toluene (in descending order).

- Particulate HAP emissions from airports are projected to increase 34% from 1996 to 2007; the most prevalent of these include:

  - Lead and total polycyclic organic matter.

- HAP precursor emissions from airports are projected to increase 13% from 1996 to 2007; the most prevalent of these include:

  - Formaldehyde, acetaldehyde, propionaldehyde and acrolein.

- Limitations and uncertainties are as follows:

  - Considerable uncertainties associated with the emission factors, activity, allocation surrogates, and speciation data used to develop the nonroad inventories.

  - Projection of emissions using surrogates such as VOCs and airport activity levels introduces significant additional uncertainty into the 2007 inventory.

  - Nonroad equipment was grouped into six sources: two-stroke gasoline, four-stroke gasoline, diesel, locomotives, commercial marine vessels, and aircraft, prior to spatial allocation.

  - Analyses suggest ASPEN may underestimate concentrations of more reactive species; ASPEN may significantly underestimate concentrations of metals; ASPEN does not reliably capture localized impacts.

U.S. EPA, 2000a, *Control of Emissions of Hazardous Air Pollutants from Mobile Sources,* 40 CFR Parts 80 and 86, August 4, 2000.

This document describes EPA's program to address emissions of HAPs from mobile sources (both on-highway and non-road) under the National Air Toxics Program.

- Establishes the List of 21 Mobile Source Air Toxics (MSATs):
  - Acetaldehyde, Acrolein, Arsenic, Benzene, Diesel Exhaust, Ethylbenzene, Formaldehyde, Hexane, MTBE, Naphthalene, Nickel, POM (Sum of 7 PAHs), 1,3-Butadiene, Chromium, Dioxin/Furans, Lead, Manganese, Mercury, Styrene, Toluene, Xylene.
- The individual compounds included in the MSAT will be evaluated for the need for additional controls, particularly those associated with motor vehicles.
- Construction equipment, airport ground support equipment (GSE) and aircraft are included in the non-road category.
- Existing non-road emission control programs will also result in significant reductions in gaseous MSATs.
- EPA proposes to focus on developing better HAPs emission factors for non-road equipment.

U.S. EPA, 2000b, *Review of Draft Air Toxics Monitoring Strategy Concept Paper*, Science Advisory Board, Air Toxics Monitoring Subcommittee, EPA-SAB-EC-00-015.

An evaluation of the strategy developed by the Office of Air Quality Planning & Standards (OAQPS) to address air toxics monitoring under the National Air Toxics Assessment (NATA).

- With the intent of providing the best technical information regarding air toxics emissions, ambient concentrations and health impacts, this advisory board comments on the following:
  - Development of emission rates
  - Compilation of emission inventories
  - Measurement of ambient concentrations
  - Analysis of patterns and trends
  - Performance of dispersion modeling
  - Estimation of human and environmental exposures
- Identifies the need to considerer groups of substances that serve as fingerprints for specific sources of emissions.

- Also recognizes the potential for inappropriate uses of the data which cannot confidently distinguish contributions from individual sources.

U.S. EPA, 2000c, *Documentation for the 1996 Base Year National Toxics Inventory for Aircraft Sources,* prepared by Eastern Research Group, Inc., prepared for Emissions Factor and Inventory Group (MD-14), Emissions, Monitoring and Analysis Division, June 2, 2000.

Describes the methodology and results for compiling the aircraft component of the National Toxics Inventory (NTI) of Hazardous Air Pollutants.

- Contains "top-down" totals for 14 different HAPS from aircraft operations at 600 airports nation-wide.
- Used as a baseline (year 1996) to track future-year changes.
- Summary of national 1996 aircraft emissions follows:

Pollutant	Emission Estimate (ton/year)
1,3-Butadiene	911.08
Acetaldehyde	2,245.62
Acrolein	1,062.46
Benzene	1,160.93
Ethylbenzene	167.38
Formaldehyde	7,281.75
Lead compounds	545.00
n-Hexane	41.33
POM as 7-PAH	0.09
PON as 16-PAH	6.06
Propionaldehyde	454.77
Styrene	206.92
Toluene	860.85
Xylene	573.72
TOTAL excluding POM as 7-PAH	**15,517.87**

- Available speciation profiles or emission factors were either old and/or very limited in terms of coverage.

- Very limited number of HAPs data points were available to characterize the entire aircraft type.

- In some cases, there were no emissions data specific for aircraft type and surrogate data from related aircraft type had to be used to estimate emissions.

U.S. EPA, 1999. *Evaluation of Air Pollutant Emissions from Subsonic Commercial Aircraft*. Office of Air & Radiation. EPA 420-R-99-013, April 1993.

Provides a good overview of airport-related emissions of criteria pollutant based on a survey of 10 major airports.

U.S. EPA, 1997a, *Control of Air Pollution From Aircraft and Aircraft Engines: Emission Standards and Test Procedures;* Final and Proposed Rule, 40 CFR Pat 87.

This rule adopts the current voluntary NOx and CO emissions standards of the United Nations International Civil Aviation Organization (ICAO) bringing the U.S. aircraft standards into alignment with the international standards.

- Applies to newly certified engines and newly manufactured engines, not existing engines.

- Does not address VOCs or HAPs.

U.S. EPA, 1997b, *Development and Comparison of 1990 and 1996 Mobil3e Source Hazardous Air Pollutant Emissions Estimates*, prepared by Richard Billings, et. al., Eastern Research Group, Inc., Rich Cook and Laurel Diver, US EPA.

Hazardous Air Pollutant (HAP) mobile source inventory (including aircraft) developed for inclusion into the National Toxics Inventory (NTI).

- The CAA includes many mandates for the U.S. EPA related to HAPs. The CAA presents a list of 188 HAPs and the EPA is to identify their sources, quantify their emissions by source category and assess public health and environmental impacts.

- The NTI was developed as a tool for the EPA to meet these requirements…also used for the EPA National Air Quality Emissions trends report.

- Onroad, aircraft and non-road grouped together.

- Total aircraft emissions increased by 6 percent between 1990 and 1996, despite operations increased much more.

- Commercial aircraft represented 84 % of total.
- Decrease attributable to FAA mandate to reduce noise pollution by 2000.

- HAPs were developed from airport operational data combined with FAEED emissions factors and default times-in-modes.

- National VOC estimates for all aircraft categories were speciated to obtain national estimates for individual HAPs (using EPA OMS data.)
  - Overall aircraft emissions of HAPs increased by 6 percent between 1990 and 1996.
  - Commercial aircrafts modest increase in emissions compared to the sizable increase in LTOs may be attributable to a change in the aircraft fleet (smaller, more fuel efficient).
  - See Summary of Aircraft emissions (tons/year).

U.S. EPA, 1993a, *Toxic Emissions From Aircraft Emissions: A Search of Available Literature*, Office of Air Quality Planning & Standards, EPA –453/R-93-028.

A literature search completed through EPAs online library system as well as several other databases available on-line through university libraries and educational institutions. Focused on hydrocarbon emissions and TAPs from jet engines and the health effects thereof.

- Provides references and abstracts of over 50 citations that were identified under this task.
- Most of the pertinent references are military-based.
- Mentions a computer program that has been developed that allows estimation of emissions by species or groups of species for common engines. (Aircraft Environmental Support Office (AESO), *Toxic Compounds in the Exhaust of Gas Turbine Engines*, Aircraft Environmental Support Office, Naval Aviation Depot, North Island, San Diego CA, AESO Report No. 3-19, May, 1991.). this was developed to satisfy regulatory requirements for engine test cells.
- Provides table of emissions factors for select PAH compounds for the CFM56 engine at idle.
- Did not give specific citations associated with health effects.

U.S. EPA, 1993b, *SIC Code 45 Transportation by Air*, prepared for the Toxic Release Inventory (TRI) Branch of the Office of Pollution Prevention and Toxics, U.S. Environmental Protection Agency.

Under the Emergency Planning & Community Right-to-Know Act (EPCRA), airports were considered and assessed for possible inclusion into the TRI list of industries that are required to report their annual emissions:

- If required under EPCRA, air carriers would need to report annual emissions of CO, NOx and SOx as par of the TRI.

- Aircraft maintenance facilities would need to report emissions of some solvents (i.e. dichloromethane).

- To date, this SIC Code is not required to report under EPCRA

U.S. GAO, 2003, *Aviation and the Environment – Strategic Framework Needed to Address Challenges Posed by Aircraft Emissions*, Report to the Chairman, Subcommittee of Aviation, Committee on Transportation and Infrastructure, House of Representatives, U.S. General Accounting Office, February.

In response to the question of what efforts are being undertaken to reduce emissions from airports both in the U.S. and abroad, this report compiles information on a series of topics including airport emission inventories, emission reduction strategies and aircraft engine technologies. With the primary focus on emissions of NOx, the report offers recommendations for further action, including the collection of additional baseline information, the establishment of goals and timeframes for emission reduction options, and the refinement of roles of NASA and other governmental agencies as well as the aviation industry in the reduction of aviation-related emissions of NOx.

A-2. EMISSION FACTORS AND MODELS

This material consists of reports, technical papers and other sources of information that provide explanation and documentation as to the sources of emission factors for HAPs.

Applied Modeling Inc. 2002, *Comparative Use of ISCST3, ISC-PRIME and AERMOD in Air Toxics Risk Assessment*, Tran, Khanh, 2002.

> Provides comparative assessment of the three atmospheric dispersion models and give recommendations for further improvements.

California Air Resources Board, 2002, *Draft California Emission Inventory Development and Reporting System (CEIDARS), Organic Gas Speciation Profiles and Particulate Matter Speciation Reference Information*.

> A draft compilation of emission factors and speciation profiles for particulate matter and a wide range of organic gases from stationary and mobile sources used for emission inventories and dispersion modeling in California. Compiled into spreadsheets and obtainable at the following web site: www.arb.ca.gov/emisinv/speciate/speciate.htm.

CDM, 2003, *A Preliminary Study and Analysis of Hazardous Air Pollutant Emissions from a Commercial Airport Using Modeling and Source Speciation Profiles,* (by Wei Guo, John Pehrson, Teresa Raine, James LaVelle and Vincent Tino), Presented at the Air & Waste Management Conference.

> Provides a thorough explanation of the techniques, materials and other sources of information used to prepare a HAPs emissions inventory, conduct dispersion modeling and carry out a health risk assessment for an airport. Contains an extensive listing of HAPs speciation profiles for a wide variety of airport-related sources including aircraft, GSE, motor vehicles, heating plants, maintenance facilities, flight kitchens and restaurants.

40 CFR Pt. 51, *Guideline on Air Quality Models*, Appendix W to Part 51, July 1, 1999.

> Contains the listing of EPA's designated "Preferred Air Quality Models" and descriptions of their applications.

Chase, J.O. and R.W. Hurn, 1970, *Measuring Gaseous Emissions from an Aircraft Turbine Engine,* Proceeding of Society of Automotive Engineers Meeting.

> The first published work on the sampling and testing of aircraft engine exhaust:
>
> - Involved P&W YTF-33-P1 military engine (equivalent to the JT3D) operating at idle, cruise and approach to test instrumentation and sampling procedures.
> - Hydrocarbon emissions approximately 100 times greater at idle than at power.

- Formaldehyde was the predominant aldehyde.

- Jet exhaust contained little, if any, NO_2.

FAA, 2002, *A Review of Literature on Particulate Matter Emissions From Aircraft,* Federal Aviation Administration, Office of Environment and Energy, (Draft Letter Report).

The purpose of this research was to conduct a literature review with an emphasis placed on measured mass data from aircraft. From this, a first order approximation is suggested that could be used to estimate the mass PM emitted from most air carrier aircraft:

- Most PM emitted by modern aircraft has an aerodynamic diameter of less than 2.5 micrometers.

- PM includes both volatile and non-volatile components. Soot is the most prevalent, non-volatile component. Metals are emitted, but in extremely small amounts.

- The smoke number does offer useful information about the visible plume behind the aircraft, but not an accurate means for any mass prediction technique.

- Volatile particles in the aircraft exhaust form as a result of nucleation process from precursor aerosols.

- Directly emitted PM is primarily soot particles composed of carbon-containing products resulting from the incomplete combustion process in the engine.

- Concludes that the measurement of PM near airports have been inconclusive for the most part.

FAA, 2001, *Emissions & Dispersion Modeling System (EDMS) Reference Manual*, Office of Environment & Energy, prepared by CSSI, May 2001.

A computer model developed by the FAA and the DOD for the assessment of air quality impacts associated with airport and airbase improvement projects. Contains both an emissions inventory element and atmospheric dispersion model component. Updated periodically and designated by the FAA as the required model and by the U.S. EPA as the preferred model for conducting airport air quality assessments.

- Contains emission factors for CO, NOx, HCs, SOx and PM for aircraft, APUs, GSE, motor vehicles, training fires and other airport sources.

- Does not contain emission factors for HAPs.

Feitelberg, Alan, et. al. 1997, *Survey of Gas Turbine Hazardous Air Pollutant Emission Factors,* GE Corporate research & Development, Presentation at the AWMA Meeting.

The purpose of this study was to prepare a detailed review of the available data on turbine HAP emissions and determine appropriate HAP emission factors.

- HAP emission factors are strongly influences by engine load. Therefore averaging HAP emission factors for different load conditions is not appropriate.

- Because HAPs occur at concentrations below detectable levels (BDL), it is common practice to replace these data with the BDL value giving rise to false or misleading information.

- Not all reported HAP data reports ambient HAP levels at the test site.

- Given the relatively low HAPs levels and the high volumetric flow rates of turbine exhaust, effective HAP control technologies are difficult to achieve.

- Five categories of HAP formation:

    - Unburned organic fuel – Organic HAPs (benzene, hexane, etc.) reaching the exhaust unchanged.

    - Organic and inorganic HAPs in the ambient air – HAPs that exist in the air at the test site and pass through the engine.

    - Incomplete Combustion – HAPs such as formaldehyde are intermediates in the combustion of organic compounds and can reach the exhaust.

    - Erosion & Wear of Engine Components – Some alloys and coatings contain inorganic HAPs (i.e. Chromium) and can erode away during engine use.

    - HAPs emissions for most turbines are extremely low and all detection limits should be 1 ppb or less.

- Article provides mean and median HAPs emission data for liquid fueled turbines at base load in ppb or lb/100,000 lb fuel.

Hayes, Stanley, 2003, *Characterizating Air Toxics Composition of Jet Exhaust for Airport Health Risk Assessments,* (ENVIRON Int. Corp.), presented at the Air & Waste Management Association Conference.

Presents a thorough and technical assessment of the derivation of available aircraft engine emission factors (or speciation profiles) for HAPs now available. Identifies and discusses some of the potentially important limitations (including the small data sample size and the engine testing approaches). Provides explanations of aircraft engine design and operational characteristics as a means of demonstrating the effects of these parameters of HAPs formation.

Kimm, L.T., 1997, *Aircraft Engine and Auxiliary Power Unit Emissions From Combusting JP-8 Fuel*, for presentation at the Air & Waste Management Association's 90th Annual Meeting & Exhibition, June 8-13, 1997, Toronto, Ontario, Canada.

Methodology statement for the sampling of criteria pollutants and HAPs as products of incomplete combustion in military aircraft engines and APUs using JP-8 fuel.

- Pollutants include - filterable and condensable particulates, aldehydes and ketones, semivolatiles and VOCs, NOx and total hydrocarbons.
- Ambient air sampling also conducted to qualify background emissions.
- Used three different test cells: one for tracer gas measurements, one for non-conventional isokinetic sampling, and the third for conventional isokinetic sampling.
- The sampling will be completed in June 1997.

Lozano, E., 1968, *Air Pollution Emissions From Jet Engines*, Journal of the Air Pollution Control Association.

One of the earliest published, and most often cited, works on the measurement of emissions from jet engines:

- Pollution emissions from three types of jet engines were determined.
- Pollutants measured included nitrogen oxides, aldehydes, carbon monoxide, hydrocarbons and odors.
- The principle aldehyde present in jet engine exhaust is formaldehyde.

Pehrson, John, 2003, *Toxic Air Contaminant Emissions from Aircraft – A Literature Review of Aircraft Engine Measurements,* (other contributors include Wei Guo, Teresa Raine, Vincient Tino, and Roger Johnson – Los Angles World Airports), presented at the Air & Waste Management Association.

Provides an extensive compilation of aircraft engine HAPs emission profiles based on the testing of engines by others, including Spicer. Also discusses the adoption and application of these findings into aircraft HAPs databases developed by the U.S. EPA and California Air Resources Board. Identifies some of the uncertainties and limitations of these data and calls for additional research.

Spicer, C.W. et. al., 1994, *Chemical Composition and Photochemical Reactivity of Exhaust from Aircraft Turbine Engines*, Annals Geophysicae.

The most cited and authoritative report on the measurement of hydrocarbon compounds in aircraft exhaust conducted at Battele Labs in the 1980's:

- Exhaust sampling of the military General Electric TF-39 (CF6-6 on the DC-10 tri-jet) and CFM-56-3 (Boeing 737-300) engines.

- Sampling conducted using a four-arm, 12-port sampling probe mounted in the exhaust just behind the engine.

- At idle, the predominant (30 to 40%) hydrocarbon species are ethene, propene, acetylene, methane, acetaldehyde and formaldehyde; other component being the remnants of unburned fuel.

- Total hydrocarbons and unburned fuel emissions are greatly reduced at 30 to 80% thrust, with the exception of methane.

Spicer, C.W. et. al., 1984, *Composition and Photochemical Reactivity of Turbine Engine Exhaust,* prepared by Battelle Laboratories, prepared for the Air Force Engineering & Services Center, March, 1984.

Considered to be the pioneering work on the measurement of HAPs in aircraft exhaust. Conducted under controlled conditions on two military aircraft General Electric TF-39 and CFM-56-3 operating at varying operational modes.

- Author's acknowledge that additional information is required for determining the importance of aircraft HAPs on ambient air quality, including:
    - Emission inventories of all significant sources in the area.
    - Models that accurately describe the dispersion characteristics of aircraft emissions.
    - Knowledge of meteorological conditions in the study area.

- Compared to other sources, benzene levels from aircraft are comparable to those from automobiles.

- Suggests that formaldehyde is the most important class of HAPs from aircraft when considering health effects.

USAF, 1999, *Aircraft Engine and Auxiliary Power Unit Emissions Testing, (Vols. 1 & 2) Detailed Sampling Approach and Results,* prepared by Environmental Quality Management, March 1999

Volume 1

Executive Summary of 2-year effort to test, characterize and evaluate exhaust emissions (including HAPs) from military aircraft engines.

- List of constituents included: particulates, aldehydes, semivolatiles, volatile organic compounds (VOCs), and total hydrocarbons (THCs).
- Eleven HAPs were identified as being the most frequently detected as combustion products.
- Suggests looking at the data to find surrogates to predict non-tested HAPs.
- Benzene, toluene and xylene are the most significant VOCs
- Formaldeyde is a surrogate for the aldehyde group accounting for over 90%.
- Most HAPs occur during the idle mode and afterburner modes.

Volume 2

Results of emission sampling and development of emission factors for military jet engines and auxiliary power units (APU). Evaluated select criteria air pollutants and HAPs.

- Formaldhehyde contributes 60 to 70 % (depending on engine setting) to the total HAPs emission rate.
- Benzene makes up about 10 to 15% of the HAPs emission rate; combined with formaldehyde, toluene and xylene, these four compounds represent over 90% of the VOCs.
- Provides emission factors for 18 engines at different power settings (idle, approach, intermediate) for the following 10 HAPs:

- Formaldehyde	- Napthalene
- Acetaldehyde	- Benzene
- Acrolein	- Ethylbenzene
- Toluene	- Xylenes
- Isobutyraldehyde	- Styrene

- These factors are used extensively by DOD/USAF for engine test cell permitting.
- Recommends that the totals for formaldehyde and benzene provide a reasonable estimate of the total HAPs since they make up more than 75% of the total HAPs present.

U.S. EPA, 2002b, *MOBILE6.0 – User's Guide*, Office of Air & Radiation, EPA 420-R-02-001, January 2002.

Computer program containing emission factors for the criteria air pollutants for six motor vehicle classes.

- Includes factors for CO, VOCs, NOx and SOx; PM to be added.
- Does not contain HAPs emission factors for motor vehicles.

(Note: The next update, MOBILE6.2, is scheduled for release in 2003 and reportedly contains PM and HAPs emission factors for motor vehicles.)

U.S. EPA, 2002c, *AERMOD: Description of Model Formulation*, Cimorelli, A.J., Perry, S.G., et. al. EPA 454/R-02-002d, October 2002

Provides overview and discussion on the formulation, the model structure and the performance of the AERMOD dispersion model.

U.S. EPA, 2001e, *Revised Methodology and Emission Factors for Estimating Mobile Source PAH Emissions in the National Toxics Inventory*, Memorandum from Richard Cook, Office of Transportation and Air Quality (OTAQ) to Laurel Driver, Office of Air Quality Planning and Standards.

One of several internal EPA memos serving the basis for determining TAPs emission factors for aircraft.

- Provides select (nine) PAH/VOC emission fractions for the "sum of 16 PAHs" for aircraft turbine engines.
- Also provides data for other mobile vehicles.

U.S. EPA, 2000d, *AP-42: Compilation of Air Pollutant Emission Factors – Mobile Sources*, Vol. 2, 5th Edition, November 24, 2000.

Listings and look-up-tables of emission factors for HC, CO, NOx, SOx and PM for a wide variety of mobile sources including aircraft and non-road vehicles.

- For aircraft and GSE, largely replaced by EDMS and does not include HAPs emission factors.
- Defers to EPAs Nonroad Emissions Model for construction equipment and other nonroad sources.

U.S. EPA, 1999, *SPECIATE*, Office of Air Quality Planning of Standards, www.epa.gov/ttn/chief/software/speciate.

EPA's repository of Total Organic Compound (TOC) and Particulate Matter (PM) selected profiles for a wide variety of sources for use in source apportionment studies.

- Contains speciated emission rates (given as a percentage of VOCs for a landing and take-off (LTO) operation) for HAPs for commercial, general aviation and military aircraft.
- The basis for the HAPs emission factors are from the work by Spicer, Cook and others.

U.S. EPA, 1998a, *NONROAD – User's Guide for the National Nonroad Emissions Model*, Draft Version, prepared for the National Vehicle & Fuel Emissions Laboratory, prepared by ENVIRON Corp., June 1998.

EPA's source of emission factors for criteria air pollutants (i.e. CO, NOx, VOCs, SOx, PM) for nonroad vehicles and equipment.

- Source of emission factors for construction equipment and vehicles.
- Does not contain HAPs emission factors.

U.S. EPA, 1998b, *Piston Engine Particulate Matter Emission Factors, Toxic Emission Fractions and VOC to TOG Correction Factor for Aircraft,* Memorandum From Richard Cook, Office of Mobile Sources to Patricia Morris, Region 5.

One of several internal EPA memos serving the basis for determining TAPs emission factors for aircraft.

- Provides emission factors as fractions of total organic gases for benzene, formaldehyde and 1,3 butadiene for commercial, military and air taxi (both piston and turbine) engines. Also provides VOC to TOG correction factors for some aircraft types.

U.S. EPA, 1998c, *Guidance on Mobile Source Emission Estimates in the 1996 National Toxics Inventory*, memorandum from Rich Cook, Office of Mobile Sources to Laurel Driver and Anne Pope, Office of air Quality Planning and Standards.

One of several internal EPA memos serving the basis for determining TAPs emission factors for aircraft.

- Provides guidance in the development of mobile source emission estimates for the 1996 National Toxics Inventory focusing mostly on gasoline.

U.S. EPA, 1997c, *PAH/VOC Emission Factors for Aircraft* Memorandum from Rich Cook, Office of Mobile Sources to Joe Touma, Office of Air Quality Planning and Standards.

One of several internal EPA memos serving as the basis for determining TAPs emission factors for aircraft.

- Provides fractions of the sum of the 7 PAHs (7-PAH) and sum of 16 PAHs (16-PAH) for commercial and military aircraft based on data from Spicer.

- General aviation data was derived from non-catalyst LDGV emission factors as a surrogate.

U.S EPA, 1997d, *PAH/VOC Emission Fractions for Aircraft*, Memorandum From Richard Cook, Office of Mobile Sources to Joe Touma, Office of Air Quality Planning and Standards.

One of several internal EPA memos serving the basis for determining TAPs emission factors for aircraft.

- Provides emission fractions for polycyclic aromatic hydrocarbons / volatile organic compounds for the sum of 7 PAH/VOC and 16-PAH/VOCs used for the Houston emission inventory.

U.S. EPA, 1997e, *Source Identification and Base Year 1990 Emission Inventory Guidance for Mobile Sources HAPs on the OAQPS List of 40 Priority HAPs*, Memorandum From Richard Cook, Office of Mobile Sources to Anne Pope.

One of several internal EPA memos serving the basis for determining TAPs emission factors for aircraft.

- Provides emission fractions of VOCs for acetaldehyde, styrene and acrolein for aircraft.

- States that there is no guidance in estimating emissions of metals from aircraft due to lack of data.

U.S. EPA, 1997f, *Revisions to Nonroad Toxic Emission Estimates in National Inventory of Sources of Emissions For Five Candidate Title III Section 112(k) Hazardous Air Pollutants: Benzene, 1,3 Butadiene, Formaldehyde, Hexavalent Chromium and Polycyclic Organic Matter*, Memorandum form Richard Cook, Office of Mobile Sources to Anne Pope, Office of Air Quality Planning and Standards.

One of several internal EPA memos serving the basis for determining TAPs emission factors for aircraft.

- Provides information for the development of “non-road” toxic emission estimates in support of the nationwide inventory for benzene, 1,3 butadiene, formaldehyde and acetaldehyde.

U.S. EPA, 1995, *ISC3 – User's Guide for the Industrial Source Complex Dispersion Model*, Vol. 1, User Instructions, Office of Air Quality Planning & Standards, EPA-454/B-95-003a, September, 1995.

Computer model developed by the EPA for the analysis of the dispersion of air emission from a variety of sources made up of point, area, volume and line sources. Identified as a "preferred model" by the EPA for complex modeling applications.

- Has been used in support of airport-related air quality analyses of air toxics.

U.S. EPA, 1993c*, Piston Engine Particulate Matter Emission Factors, Toxic Emission Fractions and VOC to TOG Correction Factors for Aircraft, Memorandum for Richard Cook*, Office of Mobile Sources to Patricia Morris, Region 5.

First of several internal EPA memos that collectively became the basis for nearly all subsequent emission inventories using EPA emission factors for TAPs.

- Provides guidance on aircraft toxic fractions of Total Organic Gases (TOG) for commercial, military, piston and turbine aircraft engines.

- Provides Volatile Organic Compounds (VOC) to TOG correction factors.

U.S. EPA, 1990a, *Air Emissions Species Manual, Volume 1: Volatile Organic Compound Species Profiles, Second Edition*, Prepared by Radian Corporation.

Provides speciated volatile organic compound profiles from several source categories.

- The profiles can identify the relative amounts of individual compounds in a given emission stream.

- For a given source category, the appropriate VOC species profile should be identified and the total VOC emission factor should be multiplied by the weight fractions for each compound in the profile to determine compound specific emission factors.

U.S. EPA, 1990b, *Toxic Air Pollutant Emission Factors – A Compilation For Selected Air Toxic Compounds and Sources*, 2nd Edition, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, EPA-450/2-90-011.

An early and comprehensive compilation of emission factors for individual TAPs, sources of TAPs and processes involving TAPs.

- Includes gasoline/ diesel use, internal combustion and limited aircraft engine exhaust.

U.S. EPA, 1990c, *Determining POM/PAH Emission Factors for Mobile Sources*, Memorandum from Pam Brodowicz, Office of Mobile Sources to David Mobley, Emission Inventory and Factors Group.

One of several internal EPA memos serving as the basis for determining TAPs emission factors for aircraft.

- Outlines an approach used to develop emission factors of polycyclic organic matter (POM) for motor vehicles based on the ratio of Benzo(a)pyrene to 14 other POMs.

- Cites many uncertainties and assumptions due to the limited database for POM.

U.S. EPA, 1990d, *Toxic Air Pollutant Emission Factors – A Compilation for Selected Air Toxic Compounds and Sources*, Second Edition, Office of Air Quality Planning & Standards.

First comprehensive EPA compilation of emission factors for TAPs from many industrial, manufacturing and mobile sources:

- Emission factors are expressed by units of mass of pollutant emitted per unit of mass, volume, heat, input, distance, or duration of a process that emits the pollutant.

- Emission factors are derived in a variety of ways including source tests, theoretical calculations, or a combination of both tests and calculations.

- Factors are usually averages of all available tools and do not generally consider the influence of various process design parameters such as temperature, age of equipment, reactant concentrations, etc.

- Cannot estimate the error that results from using these factors to calculate toxic air emissions.

- Emissions factors are intended to be used for making preliminary estimates.

- The difference in emission estimate and actual emissions could vary significantly.

U.S. EPA, 1979, *Chemical Composition of Exhaust from Gas Turbine Engines*, prepared by D. J. Robertson, J. H. Elwood, and R. H. Groth, United Technologies Corporation for EPA Emissions Measurement and Characterization Division.

Report assesses the hazards associated with emissions from small aircraft turbine engines burning conventional kerosene type fuels.

- Involved a Pratt & Whitney PT6A-45; focused on polynuclear aromatic hydrocarbons (PAH), phenols, nitrosamines and total organics.

- Hydrocarbon particulates a small fraction of the total organics emitted.
- Aromatic compounds were present in an order magnitude more than the PAH; maximum PAH was less than 2 ppb.
- Benzofluoranthene, benz(a)pyrene and benzophenanthrene were below 0.1 ppb; no nitrosamines were found.
- Concentrations of PAH decreased with increase engine power.

Van Schaack, 1994, *Developing an Emission factor for Hazardous Air Pollutants for an F-16 Using JP-8 Fuel,* (Thesis), Department of the Air Force, Air Force Institute of Technology.

Developed method for estimating emission factors for selected HAPs for an F-16 aircraft engine operating on JP-8 fuel.

- Notes that the emission factor for an aircraft is not a constant value: it will vary for the different operating modes: idle, approach, etc.
- Cites Spicer et al 1984 and 1990 (Battelle Labs) as the source of the initial data.
- Mentions small size of exhaust particles and why they may be occupationally and environmentally significant.
- Selected 9 HAPs on two criteria: concentration of these HAPs found in the exhaust and the health effects.
- Fuel/air ratio is one of the most important engine parameters affecting exhaust emissions (i.e. better atomization and mixing of the fuel) leads to improved combustion efficiency. The higher the combustion efficiency of the engine, the lower the VOCs.
- Type of fuel will result in different levels of emissions.

Washington State Department of Health, 1999, *Chemicals in Jet Fuel Emissions* (Question 8 of the August 1998 Work Plan), prepared by the Office of Environmental Health Assessment Services.

Attempts to answer the question "what are the chemicals in jet engine exhaust emissions and what happens to them after they are emitted?".

- Jet fuels are kerosene-based consisting of hydrocarbons ranging from 9 to 16 carbons in length.
- Most are either VOCs that evaporate easily or SVOCs which evaporate less easily.

- Major hydrocarbons in jet fuel include alkanes, cycloalkanes and alkenes. Aromatic hydrocarbons (i.e. toluene, xylene and benzene) and polycyclic aromatic hydrocarbons (i.e. benso(a)pyrene and chrysene) are also found.

- No pollutant unique to aircraft emissions has been identified.

A-3. AIRPORT STUDIES

This material consists of air quality studies and other environmental assessments conducted at airports in the U.S. that involved TAPs. Because these studies are often better recognized by the airport from which the information was derived, the list is organized by the names of the individual airports.

Boston-Logan International Airport

Condon, S., 2000, *Correspondence to Town of Winthrop Board of Health* from Commonwealth of Massachusetts Office of Health and Human Services.

> Formal written review from the Director of the Commonwealth's Bureau of the Environmental Health Assessment on the Winthrop Community Health Survey conducted in 1999.
>
> - Indicates that there are several methodological problems with the report making it difficult to interpret the overall scientific merits of the results.

Dumser, B., 1999, *Winthrop Community Health Survey*, Winthrop Environmental Health Facts Subcommittee, Brian Dumser, PhD, Chair of the Subcommittee.

> Results of a survey taken by a voluntary group of residents from the town of Winthrop Massachusetts; one of the neighborhoods that adjoin Logan International Airport.
>
> - Conducted by volunteers using questionnaires and interviews and based on 838 responses.
> - Claims that there is a clear increase in respiratory disease and disease symptoms in areas of the town that are adjacent to the airport.
> - Finding no other likely explanation for this finding, the group proposes that airport activities are negatively affecting the residents of Winthrop.

KM Chng, 1996, *Logan Airport Soot Deposition Study*, Draft Report, prepared for Massport.

> Soot sampling program and source apportionment study to evaluate atmospheric fallout of VOCs in the vicinity of the airport and in adjoining neighborhoods.
>
> - Sampling collected at four sites: one on the airport (near runway end) and three in nearby communities surrounding the airport.
> - Focused on PAHs and used chemical fingerprinting profiles from jet fuel aircraft exhaust for source identification.

- Results suggest that soot deposition in the communities around the airport results from general urban contamination rather than from aircraft sources at the airport.

KM Chng, 1994, *Logan Airport BTEX Monitoring Program*, prepared for Massport.

Short-term air monitoring study to measure ambient levels of benzene, toluene, ethylbenzene and xylenes (BTEX) on the airport and in adjoining communities.

- Samples collected over two weeks in the summer of 1993 at six sites: two on the airport and four in the adjoining communities.
- Results indicate that BTEX levels are consistently lower in the communities surrounding the airport than on the airport.
- Elevated levels of BTEX occurred off the airport at a neighboring site when wind was blowing from the airport to the site.
- It could not be determined if the aircraft or the motor vehicles contribute to the BETX concentrations.

TRC Environmental, 1997, *Soot Deposition Study: Logan Airport & Surrounding Communities*, presented to Massport Logan International Airport.

Particle deposition sampling program and source apportionment study to evaluate atmospheric fallout of trace metals in the vicinity of the airport and in adjoining neighborhoods.

- Collected atmospheric fallout in Petri dishes at nine sites both on and off the airport over a several week period.
- Sampling sites included ends-of-runways and nearby residential neighborhoods.
- Tested for the following compounds:
    - Sulfur, chlorine, calcium, tin, chromium, manganese, iron, nickel, copper, zinc, lead and selenium.
- Also used chemical profiles for jet engine exhaust, motor vehicle brake and tire wear and marine aerosols for chemical fingerprinting.
- Many variables, primarily meteorological, make the direct correlation between source emissions and ambient concentrations very difficult.
- Concludes that soil and/or road dust represents about 92% of the collected deposition with marine aerosols representing 2.3 % and the airport less than 1% in the neighboring communities.

- On the airport, tire and brake ware from the aircraft and motor vehicle represent about 8% of the total.

Los Angeles International Airport

Boyle, Karleen, 1996, *Evaluating Particulate Emissions from Jet Engines: Analysis of Chemical and Physical Characteristics and Potential Impacts on Coastal Environments and Human Health*, Transportation Research record No. 1517 – Aviation, National Academy Press.

The results of this study suggest that the range of particle emissions from some jet engines cluster below 1.5 um and that these emissions contain heavy metals.

- Using settling plates at field sites around LAX and under the take-off path, indicate measurable deposition.
- Analysis reported elevated levels of zinc, copper and beryllium in fallout samples.

LAWA, 2000, *LAX Master Plan Draft EIS/EIR, Human Health Risk Assessment*, Technical Report 14a., prepared for the Los Angeles World Airports Authority.

Extensive air quality analyses (including emission inventories, dispersion modeling and health risk assessments) were conducted in support of federal and state environmental impact assessments for the proposed improvements to the airport. The objective of the Human Health Risk Assessment (HHRA) was to determine the increased incremental health risk, if any, associated with the implementation of the LAX Master Plan for people working at the airport and for people living working or attending school in communities near the airport.

- Each source of TAPs at the airport was identified through a survey.
- An impact was considered significant in incremental risks or hazards to Maximally Exposed Individuals (MEI) for any of the build alternatives exceeded regulator thresholds.
- Used methods of estimating risks developed by the California Environmental Protection Agency (CalEPA) and the U.S. EPA.
- Approach: identify most important sources of TAPs, TAPs likely to be associated with potentially greater health impact, and the area around LAX that may be adversely affected.
- Under CEQA, a significant impact was considered to occur of an incremental increase greater than regulatory thresholds over the established environmental baseline was predicted for the MEI.

- Threshold of greater than 10 in 1,000,000 or a chronic or acute hazard of grater than 5.

- Levels of significance was assessed using results of air dispersion modeling to compare impacts associated with the No action alternative, the build alternatives and the baseline 1996 conditions.

- Cancer risks were expected to be higher in 2005 than 2015 due to increased emissions with older aircraft.

- Cancer risks are overstated as they assume he the people living or working at the airport would be exposed to operational or construction emissions for 20 years.

- Non-cancer risks were dominated by acrolein from jet engines.

South Coast Air Quality Management District, 2000a, *Air Monitoring Study in the Area of Los Angeles International Airport, Part I*.

Air monitoring study of VOCs and PM conducted in the vicinity of LAX in response to concerns of residents pertaining to aircraft emissions and airport expansion.

- Conducted over three days in September 1999 at 7 sites near the airport.

- Not possible to characterize or differentiate the VOC contribution from either the airport or the major arterials.

- VOCs collected near major arterials were similar concentrations as those collected in the basin during the MATES II study.

- Key contaminants detected were benzene, butadiene, and elemental carbon.

- All key contaminants were lower at residential sites than at Aviation and Felton School sites.

- Fallout samples depict greater abundance of larger than PM10 sized combusted oil soot particles than other Basin locations.

- Higher elemental carbon at the LAX Aviation Blvd. site is suggestive of an influence from airport operations, though it cannot be determined whether it is from aircraft or trucks servicing the airport, or both.

- Combusted oil soot particles were generally greater than 50 microns in size, suggest aircraft as the source of these larger soot particles.

- Most chlorinated VOCs were not found at levels above method detection limits (0.1 ppbv). The levels of hydrocarbons found were generally lower than the levels detected in the MATES II program. The only chlorinated hydrocarbon species consistently detected were perchlororthylene, methylene chloride and chloromethane. Perchlororthylene is associated with dry cleaning and the other two compounds with parts cleaning.

- Limited number of samples taken and are not appropriate to do a risk assessment.

South Coast Air Quality Management District, 2000b, *Air Monitoring Study at Los Angeles International Airport Terminals*, Part II.

Companion to Part I study (and initial 1998 study), focusing on the LAX main terminal area. Conducted during November, 1999 in the passenger loading and unloading areas.

- Sampling occurred one week prior to and during the Thanksgiving Day week: one of the busiest weeks at LAX and typical period of stagnant atmosphere.
- Most chlorinated VOCs were not found at levels above the method detection limits (usually 0.1 ppb).
- Halocarbons generally lower than the levels detected in the MATES II study.
- Above average concentrations for benzene and 1,3-butadiene as compared to basin wide averages.
- Key pollutants detected were carbon monoxide, benzene, 1,3-butadiene, and elemental carbon.
- Elemental carbon concentrations were higher at all terminals then other harbor area measurements.
- Mobile source emissions cause higher levels of benzene, 1,3-butadiene, elemental carbon, and CO than comparable studies in the South Coast Air Basin.
- Based on meteorological conditions and the peak traffic, these measurements likely represent near-worst case at LAX.

South Coast Air Quality Management District, 2000c, *Inglewood Particulate Fallout Study Under and Near the Flight Path to Los Angeles International Airport*, Rudy Eden.

Air monitoring study conducted in the vicinity of LAX to evaluate atmospheric fallout in neighborhood located under and near the airport flight paths:

- Conducted during the weeks of April 28 and May 30, 2000 within the Inglewood area; at 14 locations, primarily residences.

- Quartz fiber filters were used to sample for fallout mass, organic carbon (OC), and elemental carbon (EC), and total carbon determinations.

- Glass plates were also used to collect deposition or fallout samples.

- Combusted oil soot particles were not present in abundance in the majority of samples collected, but no conclusions can be drawn because of limited sample period.

- No discernable pattern of either carbon mass or total fallout mass under LAX's flight path.

- Concentration and growth of gasoline and diesel powered vehicle traffic in and around the airport is an emission concern.

South Coast Air Quality Management District, 1999, *Multiple Air Exposure Study in the South Coast Air Basin (MATES-II)*, Draft Final Report.

Prepared by AQMD, this multi-faceted study provided a general evaluation of cancer risks associated with TAPs from all sources in the South Coast Air Basin. Included air monitoring, dispersion modeling, emission inventories and risk assessments:

- The contribution to risk is dominated (80%) by mobile sources (i.e. motor vehicles, trains, ships, aircraft, etc.). About 10% of the risk is attributable to stationary sources

- About 70% of all risk is attributable to diesel particles and about 20% to other toxics (benzene, butadiene and formaldehyde) associated with mobile sources

- The study did not have sufficient resolution to determine the fractional contribution of current LAX operations to TAPs in the airshed.

- Cites the potential level of uncertainty with risk values that are derived from animal or epidemiological studies when applied to the general population.

South Coast Air Quality Management District, 1998, *Air Monitoring Study at Los Angeles International Airport*.

Short term air quality monitoring study at LAX for 3 weekends in May and June 1998:

- Performed sampling and testing of CO, PM and VOCs at two curbside locations to address worker exposures.

- VOCs indicative of auto exhaust (ethylene, propane, isopentane, benzene, toluene).

- The curbside samples contained VOC values two to four times higher than off-site stations.

Oakland International Airport

Alameda County Superior Court, 2001, Berkeley Keep Jets Over the Bay Committee vs. Board of Port Commissioners, Appeal.

This court ruling concluded that the assessment of TACs prepared for the Oakland International Airport EIR:

- Erred in using outdated and inappropriate information (i.e. TAC species profiles) in assessing air contaminants from jet aircraft.
- Failed to support the decision not to evaluate the health risks associated with the emissions of TACs with meaningful analysis.
- Did not meet the standard of a "good faith effort" at full disclosure required by CEQA.
- TACs that have been detected in aircraft exhaust include acetaldehyde, benzene, 1,3-butadiene, benzo(a)pyrene, acrolein and styrene were not considered.
- Requires the Port to reevaluate the available methodologies for assessing TACs and conduct the appropriate analyses.
- Quoting a source from the BAAQMD, suggests that the CAPCOA guidelines are applicable to airports and that it is technically feasible to perform a health risk assessment for an airport

Fox, Philis, 1997, *Summary Comments From Airport Workers on the Oakland Airport EIR,* prepared for The Plumbers and Steamfitters, U.A. Local 342.

Toxic air pollutants inventory prepared; increase in emissions due to the project was estimated using the EPA CARB models; and cancer risks estimated using the EPS and CA risk assessment procedures. Concluded that:

- Off-site health impacts of the project were estimated to significantly increase cancer and respiratory disease in residential neighborhoods around the airport and among airport employees.
- Estimates substantially underestimate the actual health risks, because most toxic emissions were omitted due to lack of data.

Schussman (2002), *Profile: Health Risk Assessment at Oakland International Airport*, presentation by Barara Schussman of McCutchen, Doyle, Brown and Enersen to the ACI Environmental Affairs Committee.

A chronology legal appraisal of the limitations associated with the proposed air quality analysis of HAPs and associated health risk assessment required for the planned improvements to OAK.

- Port of Oakland and FAA publish a Draft EIS/EIR (September 1996) stating that there is no approved, standardized protocol for assessing the risk associated with mobile source emissions of TACs and there is o standard for evaluating the significance of the risk TAC emissions are quantified but the impact is characterized as unknown.

- FAA issues a Finding of No Significant Impact and a Record of Decision in December 2000.

- State Court of Appeal decided that the Port of Oakland had not used the correct speciation profile for determining the quantity of TAPs and should have prepared a health risk assessment.

- The Port of Oakland is now performing a health risk assessment and reevaluating the methodology for preparing it.

O'Hare (and Midway) International Airport

Illinois Environmental Protection Agency (IEPA), 2002, *Chicago O'Hare Airport Air Toxic Monitoring Program, June-December,* Final Report, Bureau of Air.

Air monitoring program designed to determine if the emissions associated with O'Hare airport have a measurable impact on air quality in areas adjacent to the airport. Conducted as part of the *National Integrated Urban Air Toxics Strategy* ("National Strategy") under the Federal CAA:

- Sampling on 16 days over six month period (June – December, 2000); 5 days with upwind and 5 with downwind conditions.

- Two sites near O'Hare in Bensenville and Schiller Park (one upwind and one downwind, plus two in industrialized area of Chicago) with a focus on Urban Air Toxic compounds and HAPs.

- Average levels at O'Hare were comparable with levels at other Chicago sites.

- While downwind concentrations were higher, the levels are still in the “typical urban” range and lower than levels found in other large urban areas.

City of Park Ridge, 2000*, Preliminary Study and Analysis of Toxic Air Pollutant Emissions from O’Hare International airport and the Resulting Health Risks Created by These Toxic Emissions in the Surrounding Residential Communities*, Volumes I-IV.

The City of Park Ridge, with financial assistance from the communities of Des Plains, Niles and Itasca, commissioned a multi-faceted study of air toxic emissions from O’Hare International Airport. The results of this assessment are published as a four-volume set. In particular, this volume provided:

- Volume I – *Executive Summary and Background*
    - Includes introduction and purpose statement of study; summarization of results, findings and conclusions; and background information of the regulation of TAPs and human health risk assessments.
- Volume II – *Preliminary Modeling Evaluation of Risks Associated with Emissions From Chicago O’Hare Airport, by Environ Corp*.
    - Provides criticism of *Findings Regarding Aircraft Emissions, O’Hare International Airport and Surrounding Communities* (KM Chng 1999).
    - Claims KM Chng may have underestimated VOC emissions from O’Hare by factor of 2 to 3 based on comparison to US EPA *National Emission Trends* database for 1996 (“NET-96”).
    - Criticizes KM Chng work for evaluated only 4 TAPs plus a group of PAH in comparison to the 33 TAPs identified by the U.S. EPA and 14 associated with aircraft, according to the NET-96.
    - Claims that KM Chng analysis did not quantify risks associated with TAPs at O’Hare with only a mass (i.e. weight) comparison to other sources.
    - Provides criticism of *Findings Regarding Source Contributions to Soot Deposition, O’Hare International Airport and Surrounding Communities* (KM Chng 1999).
    - Claims that Advanced Chemical Fingerprinting that KM Chng used in its analysis has potentially significant limitations for air sampling.
    - Converted VOCs (and PAHs) from KM Chng to TAPs for input to ISC dispersion model.

- Used inhalation unit risk factors (URF) for benzene and benzo(a)pyrene; derived others using toxicity equivalency factors (TEF) based on BaP; then derived Hazard Quotient for comparison to modeled reference concentration (RfC).
- Concluded that cancer risk associated with 1,3-butadiene from aircraft above EPA criteria exists.
- Concluded that dry deposition of PAHs is not significant.

- Volume III – *Preliminary Downward Site Sampling Investigation for Air Toxic Emissions From O'Hare International Airport*, by Mostardi-Platt Assoc.
  - Sampling and testing of air samples upwind and downwind of O'Hare using composite, grab and wipe samples.
  - Over 200 VOC species found, 92 identified and 78 in increased levels downwind of the airport.
  - Wipe samples did not reveal any PAHs.
  - Concludes that the airport contributes to the elevated levels of VOCs downwind.
  - Very comprehensive report, but not very objective.
- Volume IV – *Preliminary Risk Evaluation of Mostardi-Platt Park Ridge Project Data Monitoring Adjacent to O'Hare Airport*, by Environ, Inc.
  - Preliminary evaluation of potential risks associated with inhalation exposures to TAPs measured near O'Hare International Airport.
  - Concludes that cancer risks are 5-fold greater at the airport fence line when compared to background conditions in Naperville Illinois.
  - Concludes that non-cancer health effects along the fence line are also elevated over background conditions.
  - The chemicals that contribute most significantly are aldehydes, benzene and naphthalene,

KM Chng, 2001, *Toxic Emissions – Chicago O'Hare Airport Case Study*, presentation to the Institute of Transportation Studies, University of California, Airport Air Quality Symposium.

Summary report on an emissions inventory and source apportionment study of TAPs from both airport and non-airport sources located within a 10-mile radius of O'Hare:

- Concludes that in 1998 the airport represents 2.6% of the total VOCs in the study area.

- Specific species of VOCs and HAPs are reported as follows:

    - Benzene 3.2 %, 1,3 Butadiene 13 %, Formaldehyde 20.7%, 7-PAH 1.6%.

KM Chng, 1999, *Findings Regarding Source Contribution to Soot Deposition, O'Hare International Airport and Surrounding Communities*, prepared for the City of Chicago, December 1999, KM Chng Report No. 991102.

Air monitoring program conducted in the vicinity of O'Hare on behalf of the City of Chicago and focusing on atmospheric fallout:

- Six sites (one background) over 30 days (August – September, 1999).

- Soot and particulate samples collected on 8"X10" glass plates.

- Compared with Jet-A fuel, gasoline, "swipe" samples from aircraft (B 737) and motor vehicle exhaust & typical urban dust sample form National Institute of Science & Technology (NIST).

- Analyzed using "advanced chemical fingerprinting" (gas chromatography/mass spectrometry (GC/MS) and a "source ratio analysis" (a.k.a. double-ratio plots) of certain polynuclear aromatic hydrocarbons (PAHs). Source-specific ratios of certain PAHs provide information on the source of the petroleum and combustion products.)

- Samples collected near O'Hare bore little chemical resemblance to either unburned jet fuel or soot from jet exhaust.

- Instead they were chemically similar to particles from burning heavy fuels and motor vehicle exhaust and the NIST sample.

- Concluded that the contamination is from regional background pollution rather than jet fuel or aircraft engine exhaust from aircraft using the airport.

Massport, 2001, *Review of Documents Concerning Air Quality In and Around O'Hare International Airport*, Chicago, Illinois, (unpublished), prepared by P. Barry Ryan, Ph.D., for the Massachusetts Port Authority.

Peer-review summary of the studies at O'Hare International Airport undertaken by the City of Chicago and the City of Park Ridge.

- Review of study performed by KM Chng, entitled Findings Regarding Source Contributions to Soot Deposition. O'Hare International Airport and Surrounding Communities, 1999.

    - Generally agrees with the KM Chng conclusion that O'Hare Airport has minimal impact on the surrounding community.

    - Suggests that KM Chng "over-interpreted" the results based on limited sampling and testing.

- Review of four-volume study undertaken by the City of Park Ridge entitled Preliminary Study and Analysis of Toxic Air Pollutant Emissions from O'Hare International airport and the Resulting Health Risks created by These Toxic Emissions in the Surrounding Residential Communities, 2000. .

    - Volume I (Executive Summary): No comments.

    - <u>Volume. II</u>: Using dispersion modeling, suggests that the analysis may be more scientifically defensible than the KM Chng work. However, states that modeling requires use of assumptions, best judgment and other uncertainties. Resultant cancer risk estimates should be considered within a factor of 2 to 5.

    - <u>Volume III</u> : Characterizes the report as a poor presentation, calling into question the quality of the overall data.

    - <u>Volume IV</u> : Suggests that the reported increase in risk down wind of O'Hare is perhaps incorrectly attributable wholly to the airport.

U.S. EPA, 1993d, *Estimation and Evaluation of Cancer Risks Attributable to Air Pollution in Southwest Chicago*, Final Summary Report, submitted to U.S. EPA Region 5, Air and Radiation Division, by ViGyan.

Early and controversial EPA study conducted at the request of U.S. congressman to assess cancer risks in a 16 square-mile area of Chicago:

- Based on emissions inventories of industrial, residential, manufacturing and other (including Midway Airport) sources and the Complex (Source) Dispersion Model.

- Airport-related pollutants included particulates, THC, VOC, TOG, benzene, formaldehyde and 1,3-butadiene using EPA (R. Cook) aircraft engine emission data.

- Risk assessment concluded that road vehicles in the study area create the greatest risk.

- Concluded that emissions from aircraft engines may have a significant risk on residents living adjacent to the airport.

Seattle-Tacoma International Airport

DesMarais, D.L. 1995, *Review of the McCulley, Frick and Gilman Air Quality Survey For SEA-TAC Airport And Summary of the Available Information On Air Pollution From Jet Aircraft*.

Review of the monitoring program and data collected in the vicinity of Sea-Tac:

- An estimation of cancer risk increase developed for the Midway Airport in Chicago by EPA was used for SEA-TAC emissions values for benzene, formaldehyde.
- Using a similar approach taken in1993 by the U.S. EPA for the South Chicago (Midway Airport) study, this evaluation also shows that Sea-Tac contributes to a cancer risk increase.

Port of Seattle, 1995, *Final Report: Air Quality Survey*, Seattle-Tacoma International Airport, by McGulley, Frick and Gilman, January.

Air monitoring study of carbon monoxide (CO) and select volatile organic compounds (VOCs) around Sea-Tac International Airport conducted on behalf of the Port of Seattle in 1993. Samples were collected both on and off the airport site and under differing airport operational and meteorological conditions. The CO levels were within air quality standards and the VOCs were within the ranges expected in urban areas.

McCulley, Frick & Gilman, Inc., 1995*, Air Quality Survey, Seattle-Tacoma International Airport*, Final Report, prepared for Port of Seattle Aviation Planning Department.

Air monitoring program conducted in the vicinity of SeaTac International Airport.

- Sampled VOC/TAPs using EPA-approved methods in and around the AOA. (A remote sensing infrared spectrometer was also used but did not provide quantitative data.)
- Benzene detected in every sample and freon, toluene, ethylbenzene, xylene, and 1,2,4-trimethylbenzene were found in all but a few samples.
- Ethyl alcohol (ethanol), acetone, isopropyl alcohol, butane, isopentane, and pentane were found in almost every sample. MEK, MIBK, hexane, and benzaldehyde occurred less frequently.

- Ratios of several key VOCs were indicative of automobile exhaust and did not resemble the VOC profiles associated with aircraft emissions.

Moore , J. D. ,1998, *A Reporter's Perspective on Brain Tumor Clusters,* National Brain Tumor Foundation's Quarterly Newsletter, by Jeannine Daigle Moore, Producer Health Unit Kiro TV Seattle.

A non-technical review of work conducted on the assessment of cancer risks near Sea-Tac.:

- State epidemiologist Dr. Juliet Van Eenwyk concludes that cancer levels within a 3-mile radius of the airport were 10% above normal; characterizing this as a slight rise and qualifying that only 1992 and 1995 data was used.

- For glioblastoma (a type of brain cancer), 21 cases instead of the expected 12 cases were reported and Dr. Van Eenwyk affirmed that a 75 percent increase over the normal rate could be a statistical anomaly.

Pacific Northwest National Laboratory, 2001, Pacific Northwest 2001 (PNW2001), *A Field Study of Air Quality In the Seattle/Puget Sound Region 15 August to 10 September*, by Leonard A. Barrie and W.R. Barchet.

The intent is to conduct an air quality measurement research campaign in late August to early September of 2001 in parallel with similar effort by a large multiagency Canadian group led by the Meteorological Service of Canada.

- PNW2001 will involve a coalition of researchers from the Department of Energy, Environmental Protection Agency, Washington State Department of Ecology and regional universities.

- A key component of this campaign will be aerial surveillance with the Battelle Gulfstream 1 aircraft instrumented with atmospheric chemistry and meteorological sensors in parallel with ground based air chemistry and meteorological measurements at selected locations in Puget Sound.

- Evaluation and improvement of an EPA supported air quality model for the region.

- Goals include a better understanding of the formation of ozone and particulate matter, observations of chemical and meteorological distributions through the region, and promote the use of air quality models and this data base.

- Data analysis workshop to be held December 2002 at AGU in San Francisco.

- Proposed measurements include gases: PAN, NOx, NO/NOx, O3, CO, SO2, HCHO, selected VOCs, aerosols, meteorological, and radiation.

Seattle-King County Department of Public Health, 1999, *Literature Review on Risk Factors for Glioblastoma Multiforme,* assisted by Washington State Department of Health, Office of Environmental Health Assessment Services.

An extensive review of the scientific literature related to environmental causes of glioblastoma multiforme.

- Has found that no proven risk factors for this disease in people have yet been identified.
- Experimental studies have shown that nitrosamides are by far the most potent chemical that cause brain cancer in rodents and primates. (Kleihues et al. 1976, Magee et al. 1976, National Academy Press 1981, Bogovski and Bogovski 1981).

VanEenwyk, 1999, *Cover letter from Washington State Department of Health for Latest Results of Investigations of Health Concerns in the SeaTac Community*, by Juliet VanEenwyk, PhD, Director, Non-Infectious Conditions Epidemiology, Washington State Department of Health.

Further interpretations of health studies conducted in the vicinity of Sea-Tac:

- Data consistently indicated the area south of SeaTac had somewhat elevated rates of glioblastoma compared to the rest of King County; areas to the west, north and east, did not.
- Between 1985 to 1997, only 1992 showed an elevation in the number of people with glioblastoma suggesting that whatever caused the elevated levels in 1992 is not continuing.
- VOC (such as benzene and 1,3 butadiene) have not been adequately measures in the SeaTac area.
- Cannot draw additional conclusions based on other data, because there have been few studies involving air quality.

Washington State Department of Health, 2000, Addressing Community Health Concerns Around SeaTac Airport, Response to the Question, "*Is it possible to monitor jet engines exhaust emissions or to model their path using data on prevailing winds and takeoff patterns?*" prepared by the Washington State Department of Ecology and Puget Sound Clean Air Agency in consultation with the Seattle & King County Departments of Public Health, SeaTac Airport Area Community Representatives, U.S. Environmental Protection Agency, University of Washington and Washington State University.

Outlines an approach to monitoring and modeling jet engine exhaust emissions.

- In the SeaTac Airport area there are statistically significant higher rates of the following:

- Lung cancer cases within one mile of the airport compared to the rest of King County and Washington State.

- Oral and pharyngeal cancer cases within one mile of the airport compared to Washington State.

- Deaths from lung cancer and chronic obstructive pulmonary disease in an area three miles to the west and north and one mile to the east and south of the airport compared to King County.

- Hospital admissions for asthma and pneumonia/influenza in an area approximately three miles to the west, north and east and one mile to the south of the airport compared to King County.

Washington State Department of Health, 1999, *Cancer Rates in the Proximity of SeaTac International Airport (Questions 1 and 2 of the August 1998 Work Plan)*, Office of Epidemiology.

Interpretation of epidemiological studies conducted in the vicinity of Sea-Tac:

- In general, the 10 most prevalent cancers around SeaTac were consistent with the 10 most prevalent cancers in both King County and Washington State. However, depending upon the comparison group, some were higher than expected in one or more of the areas around SeaTac, and other cancers were found to be less than expected.

- Of the cancers for which observed cases were found to be higher than expected, review of the literature did not reveal any definitive causes of the increased numbers that can be specifically attributed to proximity to the airport.

Other U.S. Airports

Environ Corp., 2001, *Screening Air Quality Evaluation of the Teterboro Airport, Teterboro, New Jersey*, prepared of the Coalition for Public Health and Safety, Moonachie, New Jersey.

Short-term study to measure ambient concentrations of select TAPs near the airport and determine if TAPs from the airport can be distinguished from background sources.

- Sampling conducted over a 2-day period in June 2001 at six locations both on and off the airport.

- Tested for VOCs, PAHs and aldehydes using automated equipment, wipe samples and laboratory methods. Meteorological conditions also recorded.

- Reported that benzene, toluene, ehtylbenzene, xylene, 1,3-butadiene and trimethylbenzene levels near the airport were higher than reported by NJDEP at other locations.
- Concludes that airport operations appear to be affecting air quality in the immediate vicinity of the airport. However, for many TAPs, the differences between upwind and downwind concentrations is very small.
- States that cancer risks associated with TAPs in the airport vicinity exceed federal guidelines, but this does not necessarily indicate a significant health concern.

Lindberg, David E*., 1997, A Human Health Risk Assessment of the John Wayne and Proposed Orange County International Airports in Orange County, California*, with, John Castleberry and Robert O. Price.

Human health risk assessment prepared in accordance with California Air Pollution Control Officers Association (CAPCOA) guidelines and guidance from the South Coast Air Quality Management District (SCAQMD):

- 23 toxic substances were included in the assessment, 10 are recognized by the California Air Resources Board as potential carcinogens.
- Toxic substance emissions were quantified for aircraft operations, GSE operations, fuel trucks, and fuel storage tanks.
- Speciation factors were obtained from EPA *1996 Base Year National Toxics Inventory.*
- Primary TAPs from aircraft included formaldehyde, acetaldehyde, benzene, and 1,3-butadiene.
- Ground level concentrations at the airport was predicted using the EPA Industrial Source Complex-Short Term (ISCST3) computer.
- Identified two distinct areas of elevated cancer risks – one in the vicinity of each airport.
- Primary contributors to cancer risks are diesel PM-10 (about 67%) and 1,3-butadiene (about 20%), benzene (5%), formaldehyde (5%).
- GSE produce most PM-10 emissions and aircraft in idle or taxi mode produces most 1,3-butadine emissions (about 95%).
- Estimates generated in the risk assessment are expected to over-predict the real risk the human health.

- Higher estimates of lifetime excess cancer risk are observed in areas close to the passenger terminal (diesel exhaust) and aircraft taxiways (1,3-butadiene.)

KM Chng, 1998, *Charlotte / Douglas International Airport – Soot Deposition Study*, prepared for the City of Charlotte Aviation Department, March.

The approach to this short-term monitoring program was very similar to the work conducted near Boston Logan and Chicago O'Hare by the same investigators and described above. The results and conclusions were also similar and revealed that jet fuel indicators were not found in the samples collected and that regional emissions of these pollutants are more likely the source, both on and off the airport.

Los Angeles Unified School District, 1999, Santa Monica Municipal Airport, *A Report on the Generation and Downwind Extent of Emissions Generated from Aircraft and Ground Support Operations*, Prepared by Bill Piazza, Environmental Health and Safety Branch, Prepared for Santa Monica Airport Working Group.

Report of a health risk assessment conducted by opponents of the planned improvements to the airport:

- Cancer risks for the maximum exposed individual that reside in close proximity of the airport were 13 to 26 in million for the different aircraft type operational scenarios: clearly exceeding the federal Clean Air Act "acceptable risk criterion" of one in a million.

European Airports

Clark, Alistair, et. al.,1983, *Air Quality Measurement in the Vicinity of Airports*, Environmental Pollution Series, Imperial College, Great Britain.

Provides a limited overview of early air monitoring studies in England and the U.S:

- In general, pollutant concentrations are similar near the airport in comparison with urban areas, with motor vehicles having a large influence on air quality at airports.

- Cites study by Shabad & Smirnov, 1972 that reported benzo(a)pryene levels in soil and vegetation in diminishing content with increasing distance from the runway.

Tesseraux I, et.al. 1998, *Aviation Fuels and Aircraft Emissions. A Risk Characterization for Airport Neighbors Using Hamburg Airport as an Example*. (Abstract), published in Zentralbl Hyg. Umweltmed.

Reports of annoying odors in some areas around airports attributable to aircraft engine emissions rather than fuel vapors.

- Measurements around Hamburg Airport show no elevated levels of PAHs; considered to be a tracer for aircraft emissions.

TNO, 2000, *Assessment of the Air Quality in the Vicinity of Amsterdam Airport Schiphol*, by Tom R. Thijsse and Maarten van Loon, TNO Environment, Energy and Process Innovation, Department of Environmental Quality.

Air sampling and source-apportionment program of VOCs around Amsterdam-Schiphol Airport:

- Used passive badge samplers stationed at 59 sites around the airport

- Badges (3M type 3500) were mounted on trees, fences, traffic signs, or lantern posts at a height of three meters.

- Approximately 66% of the VOC concentrations may be related to large-scale transport from distant areas.

- Local motor vehicle traffic contributes approximately 28% to the concentrations; air traffic and fuel storage is estimated to contribute 3%.

- Estimate of the contributions from road and air traffic were made using a Chemical Mass Balance based on source profiles.

TNO 1999, *Annoyance, Sleep Disturbance, Health Aspects, Perceived Risk, and Residential Satisfaction around Schiphol Airport: Results of a Questionnaire Survey*, E.A.M. Franssen, et. al., Netherlands Organization for Applied Scientific Research (TNO) National Institute of Public Health and the Environment.

Conducted in 1996, this survey was conducted in an area 25 kilometers (15 miles) around the Amsterdam-Schiphol airport using written questionnaires:

- More people reportedly concerned about health effects due to air pollution from aircraft (42 percent) than about health effects from aircraft noise (18 percent).

- Estimated that 80,000 to 108,000 people (5-7 percent) are seriously annoyed by odor from aircraft, 100,000 to 125,000 (6-8 percent) by dust, soot and smoke from aircraft, and 150,000 to 210,000 (10-14 percent) by aircraft vibrations.

- Relatively more adults living within the 10 km of the airport reported one or more respiratory complaints: chronic coughing, coughing up phlegm and bronchitis, and allergy.

- The relationship with distance to the airport cannot simply be attributed to air pollution from aircraft, because of lack of detailed data on this source.
- Impossible to estimate the attributable proportion of respiratory complaints and the use of medicines for allergies and/or asthma to air pollution from aircraft.
- The study design cannot account for the bias from non-respondents.

Tsani-Bazaca, Elvira, et. al., 1997. *Ambient Concentrations and Correlations of Hydrocarbons and Halocarbons in the Vicinity of an Airport*, Civil Engineering Department, Imperial College, London.

Early monitoring program of VOCs in the vicinity of Gatwick International Airport:

- 16 volatile hydrocarbons present in engine exhaust and 2 halogenated hydrocarbons have been measured in ambient air at 6 sites around Gatwick Airport.
- Some reported success with the comparison of hydrocarbon profiles of jet fuel, avgas and motor vehicle fuel as a means of identifying or differentiating the source of emissions.
- Hydrocarbon concentrations were up to two orders below those measured at a central London site.

University of Birmingham, 2000, *Respiratory Disease Around Birmingham International Airport*, *Final* Study Report.

A multi-faceted health risk assessment of air emissions around a busy European airport:

- The area potentially affected by aircraft fumes was defined using the aircraft noise contours delineated from ground level meters (called flight-path zones).
- No increase in deaths or hospital admissions except for chronic obstructive pulmonary disease; reportedly a chance finding instead of being associated with the airport.
- Questionnaire sent to over 9,000 people asking about general health, mental health, respiratory symptoms, annoyed by noise and fumes from the aircraft, smoking, damp house, pets, etc.: showed no significant effect on general or respiratory health attributable to activities of the airport.
- Spirometry tests were carried out on a random sample of 150 questionnaire responders (75 each from exposed and control areas) and several wore passive NO_2 diffusion tube for a week to assess personal exposure - unable to demonstrate any significant effects of exposures.

- Concluded that people who report nuisance from aircraft noise and pollution may also report a wide range of health outcomes more frequently, regardless of their actual exposure to aircraft noise and fumes.

A-4. OTHER INFORMATION

Brasseur, G.P. et. al., 1998, *European Scientific Assessment of the Atmospheric Effects of Aircraft Emissions*, published in Atmospheric Environment, Vol. 32, No. 13.

Provides good and comprehensive technical explanations of the formation of aircraft emissions including VOCs.

- Indicates there is only limited information on the exact composition of the hydrocarbons emitted - citing the works by Stolarski, Lazano and Spicer.
- Concentrations of different hydrocarbons strongly dependent on the operating conditions of the engine.
- Only 8 to 10 species contribute up to 80 percent of the total emissions of hydrocarbon species.
- Reports that particle size measurements at the engine exhaust are distributed between 30 and 100 nm.

Brooke, A.S., 1995, *Methodology for Assessing Fuel Use and Emissions of Aircraft Ground Operations,* Department of Aeronautical and Automotive Engineering and Transport Studies, The University of Technology, Loughborough, Leicestershire.

Methodology developed to identify the factors controlling aircraft fuel use and emissions during ground movements.

- Fuel use and emissions are related directly to the time which the engines are running and the characteristics of the engine.
- The main factor controlling taxi time is taxi distance.
- Secondary factors affecting taxi time include mass of aircraft, weather, number of movements per hour, and the pilots' familiarity with the airport.
- Further work needed to establish the relationship between engine settings and emissions at low power and emissions during the start-up cycle.

Health Council of the Netherlands, 1999, *Public Health Impact of Large Airports,* Gezondheidsraad, September 2, 1999.

Multifaceted report on the health effects of living and working near a large airport based on research conducted by an international team of experts.

- With respect to air pollution and air toxics, the report offers the following:
    - To date, there is inadequate evidence to link long term exposure to community air pollution.
    - No airport-specific carcinogenic compounds have been identified.
    - Epidemiological studies on air pollution and public health near airports is scarce.
    - Very few data exist on the toxicology of jet engine emissions.
    - No convincing indicators that airport air pollution causes extra health risks compared to other urban areas.

NESCAUM, 2002, *Controlling Airport-Related Air Pollution (Draft), prepared by the Northeast States for Coordinated Air Use Policy and Center for Clean Air Policy, January 2002.*

A multifaceted study to assist policy makers at both national and state levels to have a better understanding of the contribution of the aviation sector to air pollution problems, including HAPs.

- Assessed 13 HAPs using EPA emission factors, combined with estimates of total hydrocarbon emissions at Logan, Bradley and Manchester Airports, to develop the emission inventories for 1999 and 2010.
- Concludes that airport HAPs greatly exceed those of the largest stationary sources in the three New England states.
- Predicts mostly increases in HAPs at Bradley and Manchester with a few decreases at Logan in 2010, depending on the individual HAP.

USSR Academy of Medical Sciences, 1972, *Aircraft Engines as a Source of Carcinogenic Pollution of the Environment [Benzo(a)pyrene Studies]*, Prepared by L. M. Shabad, and G. A. Smirnov, Institute of Experimental and Clinical Oncology of the, U.S.S.R, Atmospheric Environment Pergamon Press 1972. Vol. 6, pp.153-164, Printed in Great Britain.

Aircraft engine soot; and soil, vegetation, and snow from around the airport runway were analyzed for benzo(a)pyrene.

- Soot was obtained by scraping the nozzles of turbine engines and the exhaust pipes of piston engines.
- Soot contained varying quantities of benzo(a)pyrene.

- Benzo(a)pyrene concentration in soil were the highest closest to the runway.
- Vegetation samples had varying amounts of benzo(a)pyrene.
- Concentrations of benzo(a)pyrene in snow decreased with distance from the runway.
- Soil samples collected under the traffic corridors in the districts of highly developed industry and traffic demonstrated that the airport does not contribute detectable quantities of benzo(a)pyrene to the area.
- Soil samples collected under the traffic corridors in the area around the airport demonstrated that the airport does contribute detectable quantities of benzo(a)pyrene to the area.
- Reports that with an increase in the power output of an aircraft engine the concentration of benz(a)pyrene in exhaust becomes higher.
- Benzol extracts of soot samples which contained 0.1 percent benzo(a)pyrene was applied to animals to test for carcinogenic effect.
- Soot was determined to cause epidermal carcinoma in laboratory animals.

CAPCOA, 1993, *Air Toxics "Hot Spots" Program – Revised 1992 Risk Assessment Guidelines,* prepared by the Toxics Committee of the California Air Pollution Control Officers Association, October, 1993.

California guidelines for the preparation of health risk assessments required under the Air Toxics Hot Spots Information and Assessment Act of 1987.

- Present a consistent approach to the assessment of risks so all sources can be compared to one another.
- Recognizes the significant levels of uncertainty associated health risk assessments.

Vanderbilt, Pamela, 2002, "*Health Risk Assessment of Air Toxics from Airports: "The State of the Science & Strategy for the Future*", CH2M Hill, presented to the Airport Air Quality Symposium, San Diego, California, February 28, 2002.

Overview power-point presentation on the current requirements, tools, issues and problems associated with conducting HRA for HAPs, with an emphasis in California.

- Points out that airports are not specifically identified as a "major source" under Section 112 of the CAA.

- Suggests that Significance Criteria are too vague on both national and state levels, but Thresholds of Significance are too stringent.

- Studies contain layers of uncertainty from 1.) HAP emission and speciation factors for aircraft engines, 2.) toxicity impacts based on animal studies, and 3.) application of hypothetical risk estimates to the maximum exposed individual.

- Suggest putting more emphasis on the "drivers" of the risk (i.e. Acrolein, 1,3-butadiene and diesel.)

Vanderbilt, Pamela, 2003, "*Health Risk Assessment of Air Toxics from Airports: "The State of the Science, May 2002*", CH2M Hill with John Lowe, presented to the Air & Waste Management Association.

Contains a thorough and multifaceted summary of what is currently known about HAPs associated with airports and aviation. Includes discussions of the potential limitations associated with the available air monitoring data, aircraft engine emission factors and dispersion modeling techniques. Also gives a concise overview of airport-related human health and environmental risk assessments using these data and the potential effects of these limitations on their outcomes.

Cooper, Frank, 2001, *Recent Trends in the Health Risk in California's Ambient Air: A Historical Analysis of Air Toxics Monitoring Data,* publication unknown.

Summary of HAPs air monitoring data in LA, San Jose and Fresno and analysis of trends.

- The four air contaminates that continue to contribute the greatest carcinogenic risk in the ambient air are diesel particulate, 1,3-butadiene, benzene and formaldehyde.

- The primary sources of these HAPs in California are motor vehicles.

- Because of the pervasiveness of motor vehicle traffic, health risks are wide-spread throughout the urban areas and not confined to specific sources.

Heartlands Research Institute, 1999, *Pulmonary Function and Respiratory Symptoms in a Population of Airport Workers*, Prepared by Tunnicliffe WS, O'Hickey SP, Fletcher TJ, Miles JF, Burge PS, Ayres JG, Heartlands Hospital, Green East, Birmingham, UK.

An examination as to whether occupational exposure to aircraft fuel or jet stream exhaust might be associated with respiratory symptoms or abnormalities if lung function.

- Surveyed by questionnaire, measured lung functions, skin prick test, and exhaled carbon monoxide.

- Findings support an association in male airport workers with high occupational exposures to aviation fuel or jet stream exhaust and excess upper and lower respiratory tract symptoms.

Pleil, J. et.al., *Personal Exposure to JP-8 Jet Fuel Vapors and Exhaust at Air Force Bases*, Environmental Health Perspectives, Vol. 108, No. 3.

A health risk assessment of military personnel exposed to JP-8 fuel and exhaust:

- Using personal samplers and other industrial hygiene techniques, concludes that exposures to JP-8 vapors and exhaust are measurable.

- It is likely that this exposure is restricted to fuel system maintenance workers and other personnel involved in pre-flight functions in the immediate vicinity of the aircraft.

Childers, J. et al., *Real-time and Integrated Measurement of Potential Human Exposure to Particle-bound Polycyclic Aromatic Hydrocarbons (PAH) from Aircraft Exhaust*, Environmental Health Perspectives, Vol. 108, No. 9.

A program designed to monitor the exposures of military personnel to particle-bound PAHs during aircraft maintenance procedures.

- Determined that naphthalene is the most prevalent PAH associated with these exposures.