An Abridged History of Emission Inventory and Emission Factor Activities (Tales of a Curmudgeon)

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Abstract

Newcomers to air quality management tend to expect, and take for granted, effortless and accurate accounting of emission estimates, collectively known as emission inventories. They also expect the emission estimation tools that help drive those inventories, to provide results of known certainty and be defensible to "four decimal places." An appreciation for how these inventories and the tools evolved is important aspect for one who wishes to become a true critic of the process as well as those who wish to carry those tools and estimation techniques into the uncertain future with a degree of clarity and practicality. Air quality management, and especially emission inventories, tends to have characteristics both of the sciences and of the arts, and they seem to abhor high levels of scrutiny and challenge. Current activities often may attach a degree of science beyond that which is real. This paper is intended to provide an abbreviated and personal account of some of the important aspects of both the science and art of making emission estimates and understanding the means for achieving "as close to reality" as may be practical, or even scientifically possible.

A personal perspective of many of the elements is presented, with mention of some of he players who have had key roles in the further advancement of the profession over the last forty years, and even beyond. The list of individuals mentioned is by no means complete and the omission of any person or event is purely accidental. This account is provided in an intended historical sense, but also in the lighthearted vein of a soon-to-be-retiring curmudgeon who wishes to leave some final residues of inspiration and perspective that may even be useful in going forward into the future.

Introduction

"Long, long ago, in a land far, far away," there were smoke plumes and sources of grit, grime and even "a foul and pestilent congregation of vapours.¹"

From Shakespeare's Hamlet:

I have of late but wherefore I know not lost all my mirth, forgone all custom of exercises; and indeed, it goes so heavily with my disposition that this goodly frame, the earth, seems to me a sterile promontory; this most excellent canopy, the air, look you, this brave o'erhanging firmament, this majestical roof fretted with golden fire why, it appeareth no other thing to me than a foul and pestilent congregation of vapours.

What a piece of work is a man! how noble in reason! how infinite in faculties! in form and moving how express and admirable! in action how like an angel! in apprehension how like a god! the beauty of the world, the paragon of animals

We can't really credit Shakespeare as being the one who thought up the idea or first took notice of air pollution, but he may still remain one of the most eloquent accountants of the phenomenon of air pollution. Possibly one could stretch truth a bit and say he provided some inspiration for the later birth of air quality management, regulation and control, or whatever terms one may apply.

The health effects and environmental effects of air pollution have since been demonstrated, and are often dramatic, warranting serious attention and actions. Still, it is often the visible (or "smell-able") and obvious obnoxious aspects of bad air quality that stimulate the most urgent demands for attention. The ability to begin putting numeric totals on what was being trashed into the air has played a key part in bringing fundamental attention to answering the question, "What is the problem?" From this fundamental need, things have gotten a lot more sophisticated but sometimes more obscure.

Emission inventories have long been recognized as a cornerstone of air quality management. ^{2,3} Emission inventories are required in order to establish the sources, determine their relative 'insults' on the ambient air quality and to develop mitigation strategies for the reduction and management of these emissions, among other things. The emission inventory, though a basic and fundamental component of the process, is often overlooked as Steve Bromberg recounted a few years back. ⁴ Without a clear realization of the importance, the strengths and limitations of this tool, it is difficult to make intelligent decisions on the overall air quality strategies to be employed. Fundamental flaws in the organization of thought and approaches come together in the emission inventory and it can often become the lowest common denominator of communication. This is key to its importance and its use as a tool for analysis of the larger picture.

The Early Days of Emission Estimation in the U.S.

Not much is recorded, to this author's knowledge, before the turn of the 20th Century, that would constitute a serious and organized effort to isolate the emission sources of air pollution and a prolonged effective attempt to attempt to do something about them. The Smoke Prevention Society, the direct genetic ancestor of today's Air and Waste Management Association (A&WMA), was founded in Pittsburgh by local boiler dudes in 1907 and focused attention on proper care of coal burning boilers and the smoke emanating from them. Though the foundation of such an organization was undoubtedly preceded by specific events and actions that raised the issue to a crisis mode, the Society should be credited with reflecting and implementing the substantial motivation for early actions in air quality management. It was perhaps the local PTA, Sierra Club, EPA and Clean Air Act *equivalents* of the day, rolled into one. Mr. Hal Englund, formerly Executive Director of the A&WMA, when it was named the Air Pollution Control Association (APCA) has written extensively on the history of the Association and related activities from its formation to today.⁵

California, though many Easterners may not like to admit to it, has been the source of many firsts in the field of air quality management. Their regulations and groundbreaking, *even famous*, rules (e.g. Rule 66) became particularly noteworthy in the

1950's and early 1960's, especially in the Los Angeles (later better known as the South Coast Air Management District). The early field manuals for their air inspectors attempted to quantify, or promote some quantification of air pollutant emissions, in order to establish priorities and to provide a means of implementing rules to try to get the rapidly increasing air emissions and deteriorating air quality in the South Coast basin. This occurred at a time when the scientists and engineers were still struggling with ways to sample and analyze air emissions and levels in ambient air.

Ironically, on the first Earth Day, in 1970, the author [as a commissioned US Public Health Service (PHS) officer] was on temporary assignment to Ventura County, California, with orders to coach the local air pollution control agency there on how to complete an air emission inventory. I was there as a representative of the federal government, and had been sent under the "state assistance" program to help the local agency in their efforts to complete and reliable emission inventory. Truth be known, I was not sure what to do either.

Emission Factors and AP-42

The early days of formalized federal actions on air quality were delegated to and carried out by the U.S. PHS. The Taft Sanitary Engineering Center in Cincinnati, Ohio had become known for its work in water quality and establishment of water standards, especially in the late 1950's and early 1960's. Thus, the Center was an obvious place to give birth to federal studies and other activities related to air quality. This aspect grew through the mid 60's and continued as the focal point of such activities within its Division of Air Pollution, Bureau of Abatement and Control (direct predecessor of today's EPA Office of Air Quality Planning and Standards/OAQPS). That office was moved to Durham, then to Research Triangle Park, North Carolina beginning in 1967 with the move progressing over the next few years. OAQPS was also joined there by several PHS research labs and related organizations from throughout the country, in parallel with the formation of the Environmental Protection Agency (EPA) in December 1970. With that action, over 300 US PHS officers (PHS is one of the 7 Uniformed Services of the federal government, then under the Department of Health, Education and Welfare, under Secretary Elliot L. Richardson.) were permanently detailed to the U.S. EPA (First, and fifth, Administrator William D. Ruckelshaus) until such time as the Surgeon General of the PHS, and the Administrator of EPA agreed that they should be returned.

This return never happened and all of those original officers are now retired, mostly after completing the most of their careers at EPA. Over the years after that initial detail, several officers were "hired" or transferred into EPA that in addition to the original "special" group. The dual personnel system that was thus created was never in favor in EPA administrative circles and has now pretty much been abandoned with few of any new officers remaining or coming on board at EPA.

While still in Cincinnati, the Bureau developed studies to determine how to measure and control air pollution, studied health effects, developed model emission reduction programs, public education efforts, Interstate Abatement (enforcement) actions,

and carried out a general charge to analyze the problems and find solutions, even though the levels of authority and controls were rather limited, except where interstate commerce and transport of air pollution was an issue. The interstate actions and processes developed to implement those actions resulted in major contributions to fundamental approaches still utilized today.

Many of the pioneers of the "science" and processes or procedures we follow today were employed under these efforts. Many of these were hired from (where else but) the South Coast Air District of California. The list included Don Walters, Stan Cuffe, Jean Scheunneman, Bob Nelligan and many others familiar to other "old timers." A few of these individuals are still around today, though most are retired or deceased. They recruited and trained a bevy of "young officer trainees" in the mid 60's such as Jack Farmer, Kirk Foster, Norm Edmisten, Tom Helms, Phil Bierbaum, Terrance LiPuma, Darryl Tyler, Joe Tikvart, Frank Partee, Gary Evans, Chris Rehman and others, many of whom stayed in the profession, some with the government and some in private industry. Others just moved on to other challenges and opportunities.

One of the major chores of this group of officers and civil servants was to establish techniques, measures, demonstrations and other means to put some handles on this "air pollution beast," and thus ultimately protect the health of the public. One aspect observed was the need to establish a means to measure both ambient air quality and emissions and to develop management processes to develop and implement standards to this purpose. One such aspect was the recognition of the need to somehow quantify or estimate emissions. The South Coast staff brought some related basic techniques and understandings with them.⁶ The Taft Center recruits had some other ideas and technologies available. Robert Martin of that staff produced the first "published" listing (as far as the author has been able to determine in 35 years) of emission factors, in 1964. This listing was focused mostly on combustion and a few major processes. This informal document was only about 25 pages of typewritten information. In addition, a series of industry-specific documents on "Air Pollution Aspects of XYZ industry" was produced and published by the PHS in the mid to late 60's. The Air Pollution Engineering Manual (AP-40) was also produced from South Coast materials to summarize the information that was available on the topic. The latter document has been revised (Edited by Wayne Davis of the University of Tennessee) and republished by the A&WMA in recent years. AP-40 was not presented as a compilation of information to serve the same purpose as AP-42, but it did contain a few emission factors.

About this time, a young PHS engineer officer named Robert (Bob) Dupree took on the "awesome task" of making a broad compilation of emission estimation information and emission factors that could be used by states and by the PHS in the interstate abatement actions and other studies that were a primary focus of the organization. He compiled all such information that he could get his hands on, including the preceding documents, field notes and guesses, quotes of individuals who were experimenting, and other profound and inspired information. Thus, (the First Edition of) "A Compilation of Air Pollutant Emission Factors" (better known perhaps as AP-42⁷) was published behind yellow covers in a 5 ½" x 8 ¼" format, in 1968. It is approximately ¼ inch thick. Thus an icon was born! This document continues today

with few people recognizing that the "AP-" designation was attributable to the entire series of AP, for "Air Pollution," documents that came out of this organization (PHS) in this time period. When EPA was formed in December of 1970, AP-42 had become sufficiently established and referenced, that it was the only document allowed by the publishing emperors of EPA to retain the AP designation. This designation was challenged on several occasions but survives today even though still updated on occasion as a living document on-line.

It was with the Second Edition of AP-42 in the first days of EPA, where the author's career path first crossed with that of the document. A consulting company in Cincinnati named PEDCo (led by George Jutze, a former Bureau of Abatement and Control employee) had been awarded a contract (somewhere in the vicinity of \$50,000, if I recall properly) to update Duprey's document. Dick Gerstle, an engineer with PEDCo, was the chief author and project officer on this effort. When the author became a member of the National Inventory of Air Pollutant Emissions Inventory and Control Branch headed by Joe Fensterstock (Informally, members of this group were called NIAPECR's), I was given charge to edit, review, supplement and otherwise transform the contract report from this effort into a refreshed and extended "reference" document documenting the state-of-knowledge available. This took several months. It was finally published, still short of its goal; but it was needed desperately for state and federal efforts then underway. That document did establish the modular format which allowed supplements to be published with new sections that could be added as they were developed rather than having to republish the entire document and trash all that paper.

After that document was published, I was able to shake loose from the responsibilities for trying to further update the document and incorporate new findings on that, and several subsequent occasions, throughout my PHS/EPA career. However, it seemed to have the characteristics of a boomerang and always seemed to come back to me after a time. Sometimes this was through reorganizations or other realignments, but it was always enjoyable to try to live up to an expected reputation of a "world expert" in various fields and industries in which I may have never even visited or experienced. I did get to see many industry processes first hand and develop a good (my assessment) understanding of what they were fundamentally about and develop a "gut feel" as to why they might have high or lower emissions, but there was never time or resources to tackle everything.

During this same time period, Whitmel "Commas" Joyner became an icon of the organization and AP-42. Whit was charged with keeping us engineers in the group grammatically correct and the final document presentable to others who were concerned with such fine points of the English language. He persisted in completing this impossible task (and hanging on to his MAC while everyone else went the PC route) for many years and caused many an engineer to get "steamed" because their commas were not in the right place. Perhaps I should have tried to get him to edit this paper!

In later years, AP-42 joined the electronic world. While the technology was evolving, we developed and used fax on demand which was useful for some time, and began to take advantage of some of the first capabilities of the Internet when they came

available. During these years, the ClearingHouse for Inventories and Emission Factors (CHIEF) was established. The late Tom Lahre was the primary author of the name CHIEF. He was in the section of which I was chief at the time and was always addressing me as "Chief." When it came time to have a name for the system, we just had to come up with some appropriate words to go with "CHIEF."

One of the large pushes into the electronic world was with the advent of the CD-ROM. Our Division Director, Bill Laxton, and William Greenstreet, head of EPA's IT functions at RTP at the time, "volunteered" AP-42 to be the agency's first pilot CD. Anne Pope was assigned the function of leading this project and was ably assisted by Theresa Kemmer Moody, then of Radian Corporation and Ann Ingram of Unisys (or whatever they were named at the time). Talk about micromanagement! We (mainly Anne, Ann and Theresa, had to transform a written document into electronic format, establish key word connections (tags) and a myriad of other new technology steps that were totally foreign to us and most anyone else at the time. The result was that first CD produced by EPA, which we named AirCHIEF, though there has always been disagreement over what should be in caps and what not. Later, the technologies and capabilities advanced such that everything that was developed was transformed to web pages, etc. as we see today.

Somewhere in the growth and development of emission factors, the author observed the similarity of emission factors to the definition of an engineer that was published in a magazine at the Civil Engineering Department at his alma mater and with a few word changes, the following definition was born, and may still be appropriate:

- An **Emission Factor** is a number which passes as an accurate tool for approximation of emissions,
 - is prolifically developed from information that is extremely incomprehensible,
 - calculated with micron level precision,
 - involving extremely vague assumptions,
 - based on debatable data from inconclusive tests and incomplete experiments,
 - using instruments of problematic accuracy,
 - by persons of doubtful reliability and rather dubious mentality.(adapted)⁸ (Though, I disavow that any of the very competent emission factor staff ever lived up to the final quality!)

Emission Inventory Technologies and Techniques

Similar to emission factor activities, the emission inventory technologies development efforts were progressing from a crude list of estimates to a more formalized and procedural-ized activity. There have been a number of lunges forward in quality of results and techniques to produce those results, over the past several years. Only some of the major ones are discussed below.

Rapid Survey Techniques-A Beginning

During the mid to late 1960's the PHS had begun to put together various documents to help understand the technologies of air quality and to provide some training

materials and information that could be used by state, locals and others to develop reliable emission inventories that would enable various authorities to analyze the major causes and control efforts. The emission inventory group at the time had apparently written several white papers and technical reports attempting to assess various aspects of the problems of emission quantification. These papers were then assembled into a rough draft that was circulated to various staff of the PHS Bureau of Abatement and Control. Two of these individuals were Kirk Foster and Guntis (Sam) Ozlins. Kirk was involved in many documents but primarily field monitoring and development of techniques and technologies. Sam was one of the persons working to review and formalize the document "Rapid Survey Techniques⁹" that had been drafted by various members of the group over an extended time. When the document was produced, it became listed as Sam's document and became the "inventory bible" of the day, used in the U.S. and around the world. It is still sometimes referenced as a primary document, but has been largely replaced by the EIIP and other specialized guidance documents today.

NEDS

In the early 1970's, there was no serious computer software and other infrastructure available to compile and analyze national emissions. George Duggins, a PHS officer, and programmer, in NIAPEC Branch at the time, had a small plethora of routines he had compiled, joined, and otherwise made into a "system" that could be used to produce various pieces of the data needed. All computer work was done on mainframe (IBM-360) computers that took up large rooms and cooling systems to produce the computing power inferior to the desktops of today. Dr. Jim Hammerle, who had taken over a Chief of the Branch, took it upon himself, was commissioned by the needs of the Clean Air Act of 1972, etc., to produce a computerized system that would interface with the state programs and compile a national point source inventory. Such an inventory was envisioned as necessary to then be combined with area source data (in those days mobile sources were still considered a "sub-slice" of area sources) into a complete national inventory (emission trends report). He was able to work with other branches and individuals to draw together the resources needed. He requested Jerry Mersch, a computer programmer (originally from Cincinnati), to "write a little program" to do what was needed.

Many meetings, discussions and decisions resulted over several weeks to develop the format and content of the National Emissions Data System (NEDS). Decisions were made on data elements, lengths of fields, etc., many of which still carry over to today. These data components were put onto forms for punch cards which were filled out by state personnel for each point source, stack, control device, etc. John Bosch and Charles Mann were two contemporary EPA employees still around with memories of those days. One of the assignments that I was given (with a deadline of approximately two weeks) was to design and define a systematic way of linking emissions from process operations to emission calculation capabilities in the system. Thus, the much-cursed Source Classification Codes (SCC's) were born. In the beginning, the list was only about half that of its ultimate point source list, as others have been added and revised over the years (~30 years) but the same structure and most original codes still remain (Yes, even with units!). The area source codes were a brainchild and a passion of David Mobley and

implemented by effort of Dennis Shipman and the contractor (Radian) in the early 1990's.

After the NEDS was working, it needed data. Contractors were hired to go to each state and compile the point source data that the states had, and to code these data onto those despised NEDS forms. Many an engineer left the air quality field after spending days or months filling out these forms which were then processed through the punch card stage and then into the computer. Once the data were in the system, they needed to be reviewed and "validated" so that they became "owned by" the states to which they applied. Therefore, boxes and boxes of green and white lined IBM paper were produced which had then to be packaged and shipped to the states, with the requests, threats, etc. as necessary to get them reviewed and corrections returned. One of the secretarial staff in those days got the assignment of printing and shipping about 75 boxes of NEDS reports back to the states. As I recall, she developed a bad back and left soon thereafter. Of course, there was no CERR in those days, but there was a tooth-less regulation that the CERR replaced that was put on the books to try to make these data of value for the modeling and State Implementation Plan (SIP) processes that were of emphasis in that era.

Regional Air Pollution Study (St. Louis)

In the late 60's, St. Louis was the site of considerable first of its kind studies on air pollution. Jack Farmer was one of the PHS officers involved in producing a plethora of manuals and reports on air quality management and means to develop models and other links between air emission sources and ambient monitoring data. Subsequently, in the mid-70's when technologies and diffusion models were advancing considerably, and funding became available to do additional field research, new studies were commissioned. Where would be better than in mid-America, already base-lined, St. Louis? Thus a series of studies, jointly planned and carried out by the Office of Air Quality Planning and Standards (OAQPS-a policy and implementation office) and the several labs under the Offices of Research and Development (ORD), were initiated. James Hammerle headed the inventory aspects of these efforts in OAQPS. The St. Louis effort became known as the Regional Air Pollution Study (RAPS) and involved multiple projects ranging from ambient monitoring, aerial flights and measurements, chase cars on the freeways trying to determining average speeds and driving cycles, modeling, intensive emission inventory data collection (from collecting steam charts for local utilities – no CEMS – and large boilers to analysis of volatiles content and vapor pressures of local gasoline, airport traffic data collection, etc. Charles Masser, a former NASA engineer, and myself, were two of the most involved from the inventory side. Many trips were made to St. Louis to complete this study and it was one of the first times when quantification of uncertainties in inventories was defined as an area for future work.

NECRMP

The North East Corridor Regional Modeling Program (NECRMP – pronounced knee cramp) was another major emission inventory and modeling interface research and practical evolvement project, which contributed to today's levels of advancements in

inventories and modeling. This effort involved the states in the Northeastern part of the country, primarily from Washington, D.C. and northward. Success of the project depended upon the participation of each of the states and the EPA regions involved, with one of the major tasks being completing a refined emission inventory. This effort took several years and many contractor project reports, etc before the data from that operation were incorporated into the database.

AIRS

NEDS had hardly gotten out of those boxes and into use for development of national inventories, etc. when someone decided that a research objective should be to invent a better mousetrap than NEDS. Jerry Slaymaker and Gerry Nehls of the National Air Data Branch, were some of the designers of the "after NEDS" plans and the formulation of the details of the emissions side of the Aerometric & Inventory Reporting System (AIRS) fell to PHS officer Charles (Chuck) Mann with assistance from Sue Kimbrough. The AIRS also eventually had ties to enforcement and compliance, air quality data and other agency needs. The management of these efforts and that of developing graphics and other output reports migrated to Ed Lillis and his branch.

AIRS had means to be fed directly as state participants/users and through external reporting capabilities. In its later years, the National Emission Trends (NET) became the means for states to report their data to the National Emissions Trend Report. Due somewhat to its structure and perhaps to internal struggles, AIRS became billed as a cumbersome "dinosaur" and a few years later, the plug was pulled. Tom Link and others of that group, however, had developed some very nice graphics and reports that have been sorely missed. A new system is now in the "Phoenix Bird form" and is being raised from the "ashes of AIRS" into a new replacement that is intended to be used by facilities and by states to report their data to EPA.

Uncertainty in Emission Factors and Inventories

Even before the button was pushed for NEDS to leap into the process of compiling the first computerized national point (and area/mobile) source inventory, questions were raised as to how good it was. John Bosch and others commissioned assessments based on the statistical and engineering probabilities of error and their magnitude. The first study was a fully probabilistic and accounting perspective analysis and was done by one of the national accounting firms at the time. The second, called "Source Inventory and Emission Factor Analysis" (SIEFA) looked at the uncertainty more from the standpoint of an engineering aspects and reason, and was completed by PEDCo. Environmental of Cincinnati. This analysis started with the number of tests upon which a factor was based, the number of those facilities in the country and other such uncertainties and came up with a plausible uncertainty for the national totals. One of the starting points for such a study is the assumption that many errors cancel each other out. Thus, it may not be a surprise that the expectations for the national totals were reasonably good, though the estimates for a single piece of equipment or facility may be fairly uncertain. (For example, if the particular facility in question was one where the person entered tons instead of pounds, it would be in much greater error than the "typical" facility that is represented by the category average).

In later years, from late 70's and thereafter, many efforts have been made to more precisely assess the errors in emissions from inventories. One of the key critics of the inventory is always the modeling community. Frequently, especially with VOC, they contend that their models are not seeing enough VOC and that the inventories need to be twice as large as they are being assessed as. Of course, the modeler's creed is something like:

"If the results of the model do not reproduce reality, then the input data are wrong."

The current day's NARSTO and other similar efforts demonstrate that these analyses have evolved considerably over the years and gotten very sophisticated. It is still not clear, however, that there is an answer to the question of how good the inventories really are. As the old philosopher once said

"An emission inventory may not always be right, but it ain't never wrong!"

The Clean Air Act

The Clean Air Act (CAA)¹⁰, with its various amendments through 1990, has produced more and more programs that demand increasing "exactness" in quantification of emissions. The basic emission inventory of the 1970-era represented knowingly "gross" emissions in a jurisdiction in an effort to define the relative impact of facilities, one to another. This provided a basis and rational way to develop program(s) and efforts that would result in reductions in the appropriate groupings of facilities, for the correct pollutants and with an approximate fairness of application of the "pain" and economics of the resulting emission controls. As air quality management has evolved and become more refined, modeling has become extremely important and critical to the precision and "dependability" of the results. The 1990 Amendments brought new levels of "expectation" for additional uses such as assessment of emission fees, emission trading programs and other such applications. Such efforts and applications, the author believes, have been implemented without serious analysis and consideration of uncertainties and variabilities that are inherent.

One very positive note for emission factors resulted from the ramp-up funding that accompanied the passage of the Act. Prior to 1990, little funding was available for testing for emission factors. Brief special issue testing was accomplished from time to time, such as for the National Dioxin Study (Combustion Sources), the RAPs (mentioned elsewhere), and other similar efforts. For the most part, any testing that was needed for emission factors had to be small increments that could be coerced from those funded to testing for New Source Performance Standards (NSPS), National Emission Standards for Hazardous Air Pollutants (NESHAPS) and other standards. Emission factor funding was used sparingly when available and always had to be protected so that it was not appropriated for other needs. Though I have not personally gone back and reviewed the actual numbers, it seems to me that the costs that are retrospectively credited to testing as

shown in current EPA planning charts include those that were spent on testing for the standard development drivers rather than just the increment for adding pollutants or additional analyses for emission factors. After the passage of the Act, funding suddenly and generously totaled almost \$7 Million but had to be spent in a relatively short two years. This funding required the ramping up from near zero to this overwhelming amount with the same staffing. This made it very difficult to develop priorities and determine best next steps and get delivery of needed results in a logical and productive manner.

Substantial effort was spent developing lists, writing scopes of work and providing oversight of contractors as opposed to actually having time to collect and evaluate data on a more personal basis. The expectations of the administrative and management chains were also that the tasks of completing testing, sample analyses, evaluation of the literature data and amalgamation of all data into a final AP-42 Section, getting external reviews, revisions to reflect reviews and new data, etc. etc., should be doable with in a few months. This was obviously not possible (the old '9 women having a baby in one month' analogy). Consequently, a several-year prioritized test and gap filling plan was concurrently developed. This plan first initiated a thorough review, documentation and revision of existing information and publication of an updated (5th Edition) AP-42. Funding was expected to continue for several years (at maybe \$2-3 Million per year) to support this continued testing and data evaluation effort. However, this all occurred at about the same time as the global warming issues were being raised in EPA Headquarters. Also this issue happened to be a personal concern of Vice President Al Gore, and consequently, Administrator Carol Browner, and needed funding. Since one of the larger pots of funds on the agency's budget table were those for emission factors, those funds quickly went the way of climate change. Testing and gap filling plans made had to be suspended indefinitely. The program went back to the scavenging mode after this short interlude. Of course, there was always (and will likely will remain) the occasional industry funded projects where the industry felt they were getting a bad deal and it would be worth their while to spend some of their own funds to produce more favorable databases.

Permit Uses/Emission Fees

Whether one is the payer, or the payee, of emission fees and trading transactions, it is critical that the "currency rate" and value be constant and reliable. One would not likely take a European vacation without knowing what the currency and exchange rates were and that they were expected to remain stable. One would not wish to have to renegotiate them on each occasion that one wished to make a purchase. This would soon lead to economic chaos and personal bankruptcy, or windfall wealth, depending on which side of these negotiations one could consistently maintain. Many papers have addressed the emission factor analogy to this situation. If one begins to look into the nature and precision of emission factors, they will soon discover that many factors are, by nature, very accurate and not in need of improvement or error analysis. However, many (and I contend that it is a majority) emission factors have a great deal of inherent variability.¹¹

Since the emission factor development and subsequent calculation of emissions does not have the luxury of even the odd questions having the correct answer "in the back of the book," one does not know what the actual 'truth' is. In rare situations where there have been parametric tests funded, such as the multi-million dollar Canadian studies¹² on dioxin emissions from municipal incinerators in the 1980's, it becomes obvious to most even-casual observers that there are many variables that can make a difference in the generation and estimation of emissions. Factors such as design, maintenance, temperatures, control device selection and design, fuels, synergistic combinations of minor constituents of fuels, etc. can cause two fold and even 10-fold or more variation in emissions measured. Even measured data are often suspect and subject to errors¹³ and concerns regarding validity, so how can emission estimates using average conditions as applied to another facility be any less of concern? The test method and procedures and the manner the data are reported are definitely important to the interpretation and use of the data.

Point and Regional Dispersion Modeling Interfaces

There are about 250 major source categories in AP-42. Each source category averages at least three major processes. Each of these processes is likely to have several variables, each of which should be tested parametrically, somewhere between 10 and 30 repetitions would be required for a valid set of statistical samples. Therefore, if parametric testing were completed to determine, refine or otherwise the improve emission estimates of one of these processes under the conditions of concern, another multiplier would be introduced. If you then assume some typical stack testing and analysis costs (of \$50,000 and upward), for the 10 to 20 pollutants likely to be of interest and then do the math, you can reasonably estimate that something on the order of \$6 Billion would be needed to test these facilities parametrically! This is on the order of the annual budget for all of the U.S. EPA! No way will such resources to be allocated to complete such a level of testing and to develop the needed better emission factors and bring us to the ideal level of emission factor accuracy and precision. Even these levels would not necessarily answer all the questions and needs and especially could not guarantee that the test methods used would provide precisely the same output as would compare with health and ambient data.

Pollutants

When emission inventory work first got started, there was one type of pollutants - "criteria." The pollutant definitions for criteria changed over the years and a specific list of hazardous air pollutants were added by the CAA. Consequently, the testing that was done (remember, emission factor development has depended upon scavenged data almost exclusively since the beginning of emission factor development) was usually for those pollutants which had been tested, which then helped define the pollutants for which standards were set. One can readily see that this soon leads to a circular situation where you can only (or at least frequently) develop good factors for pollutants which have been established as pollutants earlier. This has raised concern for those pollutants, which prompted development of better test methods and then, payment for testing to actually be done and reported in the literature. It thus has often been unproductive or against the perceived goals of companies and other organizations to test for something that does not already have a standard. If they tested for something else, the company might raise

attention to it, resulting in subsequent regulation. One might also take note that the current 187 pollutants do not constitute the population of pollutants that will likely cause harm to the human population or adverse welfare considerations. Many pollutants are on lists for other media where they have been determined to be unhealthful, toxic or otherwise of concern, but they are not on the Clean Air list. The Toxics Release Inventory (TRI) list for example, requires reporting a different list of substances directly to EPA from those the CAA requires states to regulate, for the same process. This leads to confusion for the regulators as well as to reporting facilities. It also likely leads to incomplete or incompatible interpretation of risk to a given situation as one set of rules may often require testing or reporting on a different basis than the other. For example, health investigations may be based on the levels of a metallic element (as part of a compound) in the ambient air and how much of that measure is associated with health issues and risk. However, emission reporting criteria may specify reporting the mass of the entire compound, and testing methods (and reporting) may not likely be compatible with both, or even one. This is then often ignored, or gross approximations made. If it were clear across the board as to what compatible form was to be used for health work and reporting, test methods could perhaps be required to be compatible or sufficiently complete to be responsive to the need.

Particulate Matter Example

Particulate matter (PM) provides an example of potential problems of this nature. PM was defined as total particulate or total suspended particulate (TSP) in the original National Ambient Air Quality Standards (NAAQS) and was further defined by the test method; the high volume air sampler. The original sampler's design did not make a precise differentiation of particle size but scientists had accepted approximately 30 micrometers particle size as the largest that would likely be picked up on the filter. However, rigorous studies later provided refinement to this value, and established a likely range from 50 up to even 100 micrometers, under various wind conditions and orientations as being a plausible cut-off. However, the samplers used in the laboratories and many of the health studies used in the development of the criteria documents and NAAQS were totally different.

In parallel with this ambient uncertainty, the process has been further complicated by the fact that it was impractical (or impossible) to put the same high volume air sampler into a stack and orient it in such a way to provide any meaningful relationship between stack emission measurements and those measured in the ambient air. Thus, the technical community came up with other ways to attempt to quantify the emissions from an emission source or stack. The method that gained acceptance for total particulate with the implication of being compatible with the emission standard, and perhaps ambient data, became known as Method 5¹⁴. It should also be noted that the method was primarily developed for measuring compliance with an emission standard which did not necessary have a direct relationship with the health standard. In essence, the emission test method is part of the definition of the emission standard, but that provides no solid connection or verification of compatibility with another independent set of data. Such are the considerations to be folded into the development and interpretation of emission factors and/or their interpretation.

Ozone and Volatile Organic Matter (VOC) Example

Although there is a NAAQS for ozone, the emissions of volatile organic compounds (VOCs) and oxides of nitrogen are pollutants for which reductions are implicated in order to establish a program to meet the ozone ambient standards. Thus, the test methods for VOC and NOx are not even "apples and apples." VOC's are measured by methods designed to define the lowest emission level that is desired from a gas stream. The methods to measure VOC's typically rely on flame ionization detectors and are responsive to methane in the air or that is "created" by the method. The method does not accurately produce mass measurements 16, but responds differently to various carbon bonds and compounds to different degrees. In addition, these methods hardly respond to oxygenates and some other compounds at all. Therefore, we again find that a method that serves well for the purpose of assessing the performance of a piece of control equipment does not relate to quantifying (by calculation or estimation) the compound by compound emissions that come from the stack and serve in a one to one relationship between the emission control situation as related to ambient impacts.

The definition of VOC's as published in the Federal Register¹⁷ excludes several compounds such as methane, ethane and others. Therefore, these emissions are to be excluded from the emission inventories that facilities submit to an agency and which are then used to run photochemical simulation models. However, when the modelers prepare the data base for modeling, they speciate the inventory and then "re-inject" estimates for these missing compounds, which are then recognized by the model and used in the photochemical simulations. Though they are not "reactive," they do have a role in the results and have a discernable impact somewhere down wind.

Hazardous Air Pollutants Example

Most HAPS are also particulate matter or VOC's, and occasionally both. The list of HAPs in the Act includes several "families" of compounds, such as for several heavy metals (This does not necessarily imply that heavy metal should be included as a family activity.). A computer search on a few of these will turn up several such families that include 150 to 250 compounds that are in common usage and included in the definition of the HAPs. It is no small undertaking to even identify what the specific compounds are that should be included in HAPs. Glycol ethers, for example, are in the CAA, along with a lengthy footnote that is complex, except to a trained organic chemist. Even that footnote contains an error that has not been officially recognized and only Congress can make the technical correction.

Emission Inventory Conferences

Many have concluded that the latest consecutive string of successful emission inventory conferences is the only efforts done in this regard. However, the very first emission inventory conference was conducted in 1977 in Raleigh by the US EPA. The Proceedings of this meeting are titled Emission Inventory/Factor Workshop, appropriately enough. A second meeting followed the formation of an Emission Inventory and Factor Technical Committee within the Air Pollution Control Association, and was called the "Mickey Mouse" meeting as it was held at Disneyland in Anaheim, California in November 1978. The West Coast Section of the Air Pollution Control Association hosted that meeting. Following, in April 1982, was a similar APCA-

sponsored meeting held in Kansas City, Mo.²⁰ It is enlightening and almost humorous to look through the program and subject topics in those programs. They include (abbreviated):

Raleigh 1977 (out of a total of 25 papers of up to 80 pages long – each)

- "Analysis of Data for Hydrocarbon Sources in Non-Attainment Areas"
- "A Format for the Storage of Area Source Emission Data"
- "Commercial Bakeries as a Major VOC Source"
- "Hydrocarbon Emissions from Floating Roof Storage Tanks"
- "An Organic Specie Emission Inventory for Stationary Sources in LA"
- "Highway Motor Vehicle Emission Factors" (by MVMA)
- "Biogenic Hydrocarbon Emission Inventories"

Anaheim, 1978

- "Emissions from Vegetation, Asphalt, Bakeries, Oil Shale & Urban Solvents"
- "Fine Particle Emissions; Size Distributions and Chemical Composition"
- "Emission Inventory Requirements for Photochemical Simulation Models"
- "Reliability of Inventory Data"
- "Inventory Software"
- "Use of Inventories for Offsets and PSD Baselines"
- "RAPS Emission Inventory"
- "Emission Inventory Data for Acrylonitrile,Carbon Black, Synthetic Ammonia, Ammonium Nitrite...."

Kansas City, 1982

- "Emission Inventories for Photochemical Modeling"
- "Matching an Emission Inventory to an Air Quality Dispersion Model"
- "Data Adequacy, Uncertainties and Policy Implications" Coauthored by author
- "IF Not AP-42, What?"
- "Developing a Database for the Area Source Inventory"
- "Role of Receptor Models in Air Quality Management"
- "Emission Inventory Data for Acid Rain Studies:

Indeed it enlightening to see many of the same topics that are still on the "menu" today and to see the progress that has been made. Some of the authors of the time continue to be familiar and still active in the field. This time period helped them establish their role as pioneers or stalwarts in the field.

After these APCA specialty conferences, the intensity fell off for some years as the focus of the activities had moved to the annual meetings of the APCA, somewhat due to the formation of an Emission Factors and Inventories Committee as part of the Technical Council of the Association. The current continuous series of conferences started again in 1991 with a meeting in Raleigh, supported by the Air & Waste Management Association.

The **A&WMA** meetings were all were followed by bound proceedings.²¹ A list of these meetings follows:

Emission Inventories in the 1990's, Durham, NC, September 9-12, 1991 Emission Inventory Issues, Durham, NC, October 1992,

Emission Inventory: Perception and Reality, Pasadena, CA, October 18-20, 1993 The Emission Inventory: Applications and Improvement, Raleigh, NC, November

1-3, 1994,

The Emission Inventory: Programs and Progress, Research Triangle Park, NC, October 11-13, 1995,

The Emission Inventory: Key to Planning, Permits, Compliance and Reporting, New Orleans, Louisiana, September 4-6, 1996 (During Hurricane Fran in NC)

Emission Inventory: Planning for the Future, Research Triangle Park, NC, October 28-30, 1997,

Emission Inventory: Living in a Global Environment, New Orleans, LA, December 8-10, 1998

The Emission Inventory: Regional Strategies for the Future, Raleigh, NC, October 26-28, 1999

The tie with A&WMA was broken in 2000 and continues with this current conference. The list below conveys the meetings (from the web) that have been ably organized by Sally Dombrowski, and other associates, as a contractor-assisted in-house effort:

International Emission Inventory Conference, "One Atmosphere, One Inventory, Many Challenges." Denver, CO, April 30, 2001.

International Emission Inventory Conference "Emission Inventories - Partnering for the Future," Atlanta, GA, April 15-18, 2002.

International Emission Inventory Conference "Emission Inventories - Applying New Technologies," San Diego, CA, April 28 - May 1, 2003.

International Emission Inventory Conference, "Working for Clean Air in Clearwater," Clearwater, Florida, June 7 - 10, 2004.

Obviously, the Group has handled production of these conferences very well and the web pages with the papers and presentations is a very acceptable substitute for bound proceedings.

Conclusions

This author has presented several related evolving treatises²² ²³ ²⁴ on emission inventory, especially emission factor topics over the past 35 or so years. The intent has been to stimulate original and innovative thought and to encourage readers to evaluate the practical related issues and to work toward resolution. This historical perspective is intended to provide the newer generation (next wave) of professionals responsible for these topics, some insights into the past and how we got to where we are, where we went right and where wrong.

History not learned is history repeated!

The author is near the end of his formal career and wishes to help ignite the flames in this new generation to strive toward the pure truth, but to learn to use the information available and extract the greatest amount of use from it. I also express my personal apologies to the readers and audience for any "self-serving" nuances of this paper and its presentation. Sometimes it is necessary to get personal in order to express the feeling of having been there.

The author would also like to express personal appreciation to all the people who facilitated any insights included in this treatise. This especially includes supervisors and management who provided support and direction over the years, and especially to several co-workers who had a major role over these years in the emission factor world who are now deceased and have gone on to check their answers (emission factors) "in the back of the book." A special recognition and tribute to Carl Spangler, Frank Noonan, Tom Lahre and Arch MacQueen (the Original Emission Factor Curmudgeon), all of which were former close professional associates, and with whom the employee/employer relationship was more than a situation tolerated to get the next pay check.

Parting with a "corrupted" toast from North Carolina, my adopted home and the "Old North State!"

A Toast to North Carolina and David Mobley's Passion for BBQ

by Leonora Martin and Mary Burke Kerr, adapted/corrupted

Here's to the land of the long leaf pine,
The summer land where the sun doth shine,
Where the weak grow strong and the strong grow great,
Here's to "Down Home," the Old North State!
Home of the best BBQ!

Here's to the land of the cotton bloom white, Where the scuppernong perfumes the breeze at night, Where the soft southern moss and jessamine mate, 'Neath the murmuring pines of the Old North State! Home of the best BBQ!

Here's to the land where the galax grows, Where the rhododendron's rosette glows, Where soars Mount Mitchell's summit great, In the "Land of the Sky," in the Old North State! *Home of the best BBQ!*

Here's to the land where maidens are fair, Where friends are true and cold hearts rare, The near land, the dear land, whatever fate, Home of the best BBQ!

References

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³ Southerland, James H., <u>Introduction: Proceedings, Emission Inventories and Air Quality Management,</u> Specialty Conference, Air Pollution Control Association, Kansas City, MO, April 1982 (Now, A&WMA). ⁴ Bromberg, Steven M., <u>The Underappreciated Emission Inventory; Foundation for Pollution Control Decisions, EM, pp 17 - 20, August 1997.</u>

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⁶ S. Smith Griswold, "Air Pollution Control Field Operations Manual, - A Guide for Inspection and Enforcement," County of Los Angeles, published by US DHEW, Public Health Service, Division of Air Pollution, Washington, D.C., 1962.

¹³ Compilation of Air Pollutant Emission Factors, 5th Edition, 1995, U.S. Environmental Protection Agency, Research Triangle Park, NC, December 1995

⁸ Adapted from definition of an engineer; Civil Engineer Magazine, University of Tennessee, 1966.

⁹ Rapid Survey Techniques, Volume temporarily misplaced – correct later

¹⁰ Clean Air Act, Public Law 91-604, December 31 1970, as signed by Richard Nixon

¹¹ James H Southerland, Myers, Ronald and Wallace, Dennis: "Developing Improved Emission Factors and Assessment of Uncertainties," Air and Waste Management Association, <u>Proceedings</u>, Emission Inventory Conference: Pasadena, CA, October 1993

¹².National Incinerator Testing and evaluation Program, (NITEP), Volume 4, Detailed Results, A Report to Environment Canada, June 1985

¹³"Are Inaccurate Emission Measurements Clouding Pollution Control Planning?" EM, pp 16-17, September 1997

¹⁴ 40 CFR Part 60, Appendix A, Method 5

¹⁵.40 CFR Part 60, Appendix A, Methods 18, 24, 24A, 25, 25A, and 25B

¹⁶Michael Pjetraj, "VOC Emissions; Influence of VOC Measurement and Reporting Methods on Regulatory Policy and Emissions Estimation," NC State University (CE589W), December 6 1996 ¹⁷·40 CFR Part 51, Revision to Definition of Volatile Organic Compounds, with revisions through November 29, 2004.

¹⁸ Emission Inventory/Factor Workshop, Volumes I and II; James Southerland, Moderator; Air Pollution Training Institute and Air Management Technology Branch, 450/3-78-042a&b; US EPA, Raleigh, NC, September 13-15, 1977.

¹⁹ Proceedings, A Specialty Conference on: Emission Factors and Inventories; E. Richard Davis - General Chairman, James H. Southerland – Honorary Chairman; Sponsored by the West Coast Section and the Technical Council of the Air Pollution Control Association, Anaheim, CA, November 13-16, 1978.

²⁰ Proceedings, Emission Inventories & Air Quality Management, Specialty Conference, Midwest Section Air Pollution Control Association, Kansas City, Missouri; General Chairman - Ralph Keller, Technical Program Chairman - James Southerland, April 27-30, 1982.

²¹ List of A&WMA EI Conferences & Proceedings: 1991 – Durham, NC, VIP 22; 1992 – Durham, NC, VIP-27; 1993 – Pasadena, CA, VIP 38; 1994 – Raleigh, NC, VIP 45; 1995 – Research Triangle Park, NC, VIP 56; 1996 – New Orleans, LA, VIP 65, 1997 – Research Triangle Park, NC, VIP 77; 1998 – New Orleans, LA, VIP 88; 1999 – Raleigh, NC, VIP 93.

²² Southerland, James H. <u>Some Common Sense Aspects of Emission Estimates</u>, The Emission Inventory: Key to Planning, Permits, Compliance and Reporting, Proceedings of a Specialty Conference, (New Orleans) Air & Waste Management Association, VIP-65, 1996.

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²⁴ Southerland, James H., <u>Incongruities in Terminology and Actions: From the Clean Air Act to Reality</u>, The Emission Inventory: Regional Strategies for the Future, Proceedings of a Specialty Conference (Raleigh, NC) Air & Waste Management Association, VIP-93, Pittsburgh, October 1999, pp 41-48.