INTRODUCTION

Emission factors and emission inventories have long been fundamental tools for air quality management. Emission estimates are important for developing emission control strategies, determining applicability of permitting and control programs, ascertaining the effects of sources and appropriate mitigation strategies, and other related applications by an array of users, including federal, state, and local agencies, consultants, and industry. Data from source-specific emission tests or continuous emission monitoring systems (CEMS) are usually preferred for estimating a source's emissions because those data provide the best representation of the tested source's emissions. However, test data from individual sources are not always available and, even then, may not reflect the variability of actual emissions over time. Thus, emission factors are frequently the best or only method available for estimating emissions, in spite of their limitations.

What Is An AP-42 Emission Factor?

An emission factor is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. These factors are usually expressed as the mass of the pollutant divided by a unit mass, volume, distance, or duration of the activity emitting the pollutant (*e.g.*, kilograms of particulate matter emitted per megagram of coal burned). Such factors facilitate estimation of emissions from various sources of air pollution. In most cases, these factors are simply averages of all available data of acceptable quality, and are generally assumed to be representative of long-term averages for all facilities in the source category (*i.e.*, a population average).

The general equation for emission estimation is:

$$E = A \times EF \times (1-ER/100)$$

where:

E = emissions,
A= activity rate,
EF = emission factor, and
ER = overall emission reduction efficiency, %.

ER is further defined as the product of the control device destruction or removal efficiency and the capture efficiency of the control system. When estimating emissions for a long time period (*e.g.*, one year), both the device and the capture efficiency terms should account for process upset periods (*e.g.*, startup, shutdown, and malfunction) as well as routine operations.

Emission factor ratings in AP-42 (discussed below) provide indications of the robustness, or appropriateness, of emission factors for estimating the average emissions for a source activity. Usually, data are insufficient to indicate the influence of various process parameters such as temperature and reactant concentrations. For a few cases, however, such as estimating emissions from petroleum storage tanks, this document contains empirical formulae (or emission models) that relate emissions to variables such as tank diameter, liquid temperature, and wind velocity. Emission factor formulae that account for the influence of such variables tend to yield more realistic

estimates than would factors that do not consider those parameters.

The extent of completeness and detail of the emissions information in AP-42 is determined by the information available from published references. Emissions from some processes are better documented than others. For example, several emission factors may be listed for the production of one substance: one factor for each of a number of steps in the production process such as neutralization, drying, distillation, and other operations. However, because of less extensive information, only one emission factor may be given for production facility releases for another substance, though emissions are probably produced during several intermediate steps. There may be more than one emission factor for the production of a certain substance because differing production processes may exist, or because different control devices may be used. Therefore, it is necessary to look at more than just the emission factor for a particular application and to observe details in the text and in table footnotes.

The fact that an emission factor for a pollutant or process is not available from EPA does not imply that the Agency believes the source does not emit that pollutant or that the source should not be inventoried – rather, it simply means that EPA does not have enough data to develop or provide an emission factor at this time.

Uses Of Emission Factors

Emission factors may be appropriate to use in various situations such as making source-specific emission estimates for area-wide inventories. These inventories have many purposes, including ambient dispersion modeling and analysis, control strategy development, and in-screening sources for compliance investigations. Emission factor use may also be appropriate in some permitting applications, such as in applicability determinations and in establishing operating permit fees.

Emission factors in AP-42 are **neither** EPA-recommended emission limits (*e.g.*, best available control technology or BACT, or lowest achievable emission rate or LAER) **nor** standards (*e.g.*, National Emission Standard for Hazardous Air Pollutants or NESHAP, or New Source Performance Standards or NSPS). Use of these factors as source-specific permit limits and/or as emission regulation compliance determinations is **NOT** recommended by EPA. Because emission factors essentially represent an average of a *range* of emission rates, approximately half of the subject sources will have emission rates greater than the emission factor and the other half will have emission rates less than the emission factor. As such, a permit limit using an AP-42 emission factor could result in approximately half of the sources being in noncompliance.

Also, for some sources, emission factors may be presented for facilities having air pollution control equipment in place. Factors noted as being influenced by control technology do not necessarily reflect the best available or state-of-the-art controls, but rather reflect the level of (typical) control for which data were available at the time the information was published. Sources often are tested more frequently when they are new and when they are believed to be operating properly, and either situation may bias the results.

As stated, source-specific tests or CEMS can determine the actual pollutant contribution from an existing source better than emission factors. Even then, the results will be applicable only to the conditions existing at the time of the testing or monitoring. To provide the best estimate of longer-term (*e.g.*, yearly or typical day) emissions, these conditions should be representative of the source's routine operations.

A material balance approach may also provide reliable average emission estimates for specific sources. For some sources, a material balance may provide a better estimate of emissions than emission tests would. In general, material balances are appropriate for use in situations where a high percentage of material is lost to the atmosphere (*e.g.*, sulfur in fuel, or solvent loss in an uncontrolled coating process). In contrast, material balances may be inappropriate where material is consumed or chemically combined in the process, or where losses to the atmosphere are a small portion of the total process throughput (*e.g.,* UV curing technique in coating process). As the term implies, one needs to account for all the materials going into and coming out of the process for such an emission estimation to be credible.

If representative source-specific data cannot be obtained, emissions information from equipment vendors, particularly emission performance guarantees or actual test data from similar equipment, is a better source of information for permitting decisions than an AP-42 emission factor. When such information is not available, use of emission factors may be necessary as a last resort. Whenever factors are used, one should be aware of their limitations in accurately representing a particular facility, and the risks of using emission factors in such situations should be evaluated against the costs of further testing or analyses.

There are various approaches to emission estimation, in a hierarchy of requirements and levels of sophistication, that one should consider when analyzing the tradeoffs between cost of the estimates and the quality of the resulting estimates. Where risks of either adverse environmental effects or adverse regulatory outcomes are high, more sophisticated and more costly emission determination methods may be necessary. Where the risks of using a poor estimate are low, and the costs of more extensive methods are unattractive, then less expensive estimation methods such as emission factors and emission models may be both satisfactory and appropriate. In cases where no emission factors are available but adverse risk is low, it may even be acceptable to apply factors from similar source categories using engineering judgment. Selecting the method to be used to estimate source-specific emissions may warrant a case-by-case analysis considering the costs and risks in the specific situation. All sources and regulatory agencies should be aware of these risks and costs and should assess them accordingly.

Variability Of Emissions

Average emissions differ significantly from source to source and, therefore, emission factors frequently may not provide adequate estimates of the average emissions for a specific source. The extent of between-source variability that exists, even among similar individual sources, can be large depending on process, control system, and pollutant. Although the causes of this variability are considered in emission factor development, this type of information is seldom included in emission test reports used to develop AP-42 factors. As a result, some emission factors are derived from tests

that may vary by an order of magnitude or more. Even when the major process variables are accounted for, the emission factors developed may be the result of averaging source tests that differ by factors of five or more.

Air pollution control devices also may cause differing emission characteristics. The design criteria of air pollution control equipment affect the resulting emissions. Design criteria include such items as the type of wet scrubber used, the pressure drop across a scrubber, the plate area of an electrostatic precipitator, and the alkali feed rate to an acid gas scrubber. Often, design criteria are not included in emission test reports (at least not in a form conducive to detailed analysis of how varying process parameters can affect emissions) and therefore may not be accounted for in the resulting factors.

Before simply applying AP-42 emission factors to predict emissions from new or proposed sources or to make other source-specific emission assessments, the user should review the latest literature and technology to be aware of circumstances that might cause such sources to exhibit emission characteristics different from those of other, typically existing sources. Care should be taken to assure that the subject source type and design, controls, and raw material input are those of the source(s) analyzed to produce the emission factor. The similarity between the subject source and the sources used to develop the emission factor should be considered, as well as the age of the information and the user's knowledge of technological advances.

Estimates of short-term or peak (*e.g.*, daily or hourly) emissions for specific sources are often needed for regulatory purposes. Using emission factors to estimate short-term emissions will add further uncertainty to the emission estimate. Short-term emissions from a single specific source often vary significantly with time (*i.e.*, within-source variability) because of fluctuations in process operating conditions, control device operating conditions, raw materials, ambient conditions, and other such factors. Testing is usually conducted at normal operating conditions in order to demonstrate compliance with an emission limit. Therefore, the emission factors developed from these tests generally represent long-term, steady-state average emissions. Parameters that can cause short-term fluctuations in emissions are generally avoided in testing and are not taken into account in test evaluation. Thus, using emission factors to estimate short-term emissions will cause even greater uncertainty. The AP-42 user should be aware of this limitation and should evaluate the possible effects on the particular application.

To assess within-source variability and the range of short-term emissions from a source, one needs either a number of tests performed over an extended period of time or continuous monitoring data from an individual source. Generally, material balance data are not likely to be sufficient for assessing short-term emission variability because the accuracy of a material balance is greatly reduced for shorter time intervals. In fact, one of the advantages of a material balance approach is that it averages out all of the short-term fluctuations to provide a good long-term average.

Pollutant Terminology And Conventions

The factors in this document represent units of pollutants (or precursors for ozone) for which

there are National Ambient Air Quality Standards (NAAQS). These are often referred to as "criteria" pollutants. Factors may be presented also for hazardous air pollutants (HAPs) designated in section 112 of the Clean Air Act, and other regulated and unregulated pollutants. If the pollutants are organic compounds or particulate matter, additional species or analytical information may be needed for specific applications. It is often the case that the ideal measure of a pollutant for a specific application may not be available, or even possible, because of test method or data limitations, costs, or other problems. When such qualifications exist in AP-42, they will be noted in the document. If a pollutant is not mentioned in AP-42, that does not necessarily mean that the pollutant is not emitted, but that EPA does not have sufficient data to create an emission factor.

Many pollutants are defined by their chemical names, which often may have synonyms and trade names. Trade names are often given to mixtures to obscure proprietary information, and the same components may have several trade names. For assurance of the use of the proper chemical identification, the Chemical Abstract Service (CAS) number for the chemical should be consulted along with the list of synonyms. Some pollutants, however, follow particular conventions when used in air quality management practices. The pollutant terminology and conventions currently used in AP-42 are discussed below.

Particulate Matter

Terms commonly associated with the general pollutant, "particulate matter" (PM), include PM-10, PM-X, total particulate, total suspended particulate (TSP), primary particulate, secondary particulate, filterable particulate, and condensable particulate. TSP consists of matter emitted in solid, liquid, and vapor forms, but exists in the ambient air as particulate solids or liquids. Primary particulate matter includes solid, liquid, or gaseous material at the pressure and temperature in the process or stack that would be expected to become a particulate at ambient temperature and pressure. AP-42 contains emission factors for pollutants that are expected to be primary particulate matter. Primary particulate matter includes matter that may eventually revert to a gaseous condition in the ambient air, but it does not include secondary particulate matter. Secondary particulate matter is gaseous matter that may eventually convert to particulate matter through atmospheric chemical reactions. The term "total particulate" is used in AP-42 only to describe the emissions that are primary particulate matter. The term "total PM-X" is used in AP-42 to describe those emissions expected to become primary particulate matter smaller than "X" micrometers (μm) in aerodynamic diameter. For example, "PM-10" is emitted particulate matter less than 10 μm in diameter. In AP-42, "Total Particulate" and "Total PM-X" may be divided into "Filterable Particulate," "Filterable PM-X," "Condensable Organic Particulate," and "Condensable Inorganic Particulate." The filterable portions include the material that is smaller than the stated size and is collected on the filter of the particulate sampling train.

Unless noted, it is reasonable to assume that the emission factors in AP-42 for processes that operate above ambient temperatures are for filterable particulate, as defined by EPA Method 5 or its equivalent (*i.e.*, a filter temperature of 120°C (248°F)) or under certain circumstances as defined by EPA Method 5B (*i.e.*, a filter temperature of 160°C (320°F)). The condensable portions of the particulate matter consist of vaporous matter at the filter temperature that is collected in the sampling train impingers and is analyzed by EPA Method 202 or its equivalent. AP-42 follows conventions in attempts to define total particulate and its subcomponents, filterable particulate,

condensable particulate, and PM-10 and their interrelationships. Because of test method and data limitations, this attempt may not always be successful, and some sources may not generate such components.

Because emission factors in AP-42 are usually based upon the results of emission test reports, in the past AP-42 emission factors were not specific for designating the "type" of PM and often may adequately characterize only the in-stack filterable PM-10. Updated parts of the AP-42 series have used a clearer nomenclature for the various particulate fractions (*e.g.*, filterable PM, filterable PM-10, filterable PM-2.5, total PM, total PM-10, and total PM-2.5). It is reasonable to assume that, where AP-42 does not define the components of particulate clearly and specifically, the PM-10 factor includes only the filterable portion of the total PM-10. Therefore, an evaluation of potential condensable particulate emissions should be based upon additional data or engineering judgment.

As an additional convention, users should note that many hazardous or toxic compounds may be emitted in particulate form. In such cases, AP-42 factors for particulate matter represent the total, and factors for such compounds or elements are reported as mass of that compound or element.

Organic Compounds

Precursors of the criteria pollutant ozone include organic compounds. "Volatile organic compounds" (VOC) are required in a State Implementation Plan (SIP) emission inventory. VOCs have been defined by EPA (40 CFR 51.100, February 3, 1992) as "any compound of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate, which participates in atmospheric chemical reactions." There are a number of compounds deemed to have "negligible photochemical reactivity," and these are therefore exempt from the definition of VOC. These exempt compounds include methane, ethane, methylene chloride, methyl chloroform, many chlorofluorocarbons, and certain classes of perfluorocarbons. Additional compounds may be added to the exempt list in the future.

Though the regulatory definition of VOC is followed in ozone control programs, the exempt organic compounds are of concern when developing the complete emission inventory that is needed for broader applications. Therefore, this document strives to report the total organic emissions and component species, so that the user may choose those that are necessary for a particular application. In many cases, data are not available to identify and quantify either all the components (such as some oxygenated compounds that are not completely measured by many common test methods), the total organics, or other variations of the quantities desired. In such cases, the available information is annotated in an effort to provide the data to the user in a clear and unambiguous manner. It is not always possible to present a complete picture with the data that are available.

The term "total organic compounds" (TOC) or "total hydrocarbons" (THC) is used in AP-42 to indicate all VOCs and all exempted organic compounds including methane, ethane, chlorofluorocarbons, toxics and HAPs, aldehydes, and semivolatile compounds. Component species are separately identified and quantified, if data are available, and these component species are included in TOCs. Often, a test method will produce a data set that excludes methane. In such cases, the term total nonmethane organic compound (TNMOC) may be used. Here, methane will be

separately quantified if the data are available. Factors are nominally given in terms of actual weight of the emitted substance. However, in some cases where data do not allow calculation of the result in this form, factors may be given "as methane," "as propane," etc. Once the species distribution is determined, actual mass can be calculated based on molecular weight of each compound represented.

Many organic compounds are also HAPs. Where such species can be quantified, an emission factor representing their individual mass will be presented. This quantity will also be included in the total VOC and/or TOC factors, as appropriate. To avoid double counting regarding permit fees, etc., this fact should be taken into consideration.

Sulfur Dioxide

The primary product from combustion of sulfur is sulfur dioxide (SO_2). However, other oxidation states are usually formed. When reported in this document, these compounds are jointly referred to as SO_x, or oxides of sulfur. Hence, SO_2 means sulfur dioxide, and SO_x means the combination of all such emissions reported on the basis of the molecular weight of SO_2.

Oxides Of Nitrogen

The primary combustion product of nitrogen is nitrogen dioxide (NO_2). However, several other nitrogen compounds are usually emitted at the same time (*e.g.*, nitric oxide or NO, nitrous oxide or N_2O, etc.), and these may or may not be distinguishable in the available test data. They are usually in a rapid state of flux, with NO_2 being, in the short term, the ultimate nitrogen product emitted or formed shortly downstream of the stack. The convention followed in AP-42 is to report the distinctions wherever possible, but to report total NO_x on the basis of the molecular weight of NO_2.

Lead

Lead is emitted and measured as particulate and often will be reported for a process both separately and as a component of the particulate matter emission factor. Lead may exist as pure metal or as compounds. The convention followed in AP-42 is that all emissions of lead are expressed as the weight of elemental lead. Lead compounds will also be reported on the basis of the weight of those compounds, if the information is available.

Toxic, Hazardous, And Other Noncriteria Pollutants

Hazardous Air Pollutants (HAP) are defined for EPA regulatory purposes in Title III of the 1990 Clean Air Act Amendments (CAAA). However, many states and other authorities designate additional toxic or hazardous compounds, organic or inorganic, that can exist in gaseous or particulate form. Also, as mentioned, compounds emitted as VOCs may be of interest for their participation in photochemical reactivity. Few EPA Reference Test Methods exist for these compounds, which may come from the myriad sources covered in this document. However, test methods are available to allow reasonably reliable quantification of many compounds, and

adequate test results are available to yield estimates of sufficient quality to be included in this document. Where such compounds are quantified herein with emission factors, they represent the actual mass of that compound emitted. Totals for PM or VOC, as appropriate, are inclusive of the component species unless otherwise noted. There are a limited number of gaseous hazardous or toxic compounds that may not be VOCs, and whenever they occur they will be identified separately.

Examples Of Emission Factor Application -

Calculating carbon monoxide (CO) emissions from distillate oil combustion serves as an example of the simplest use of emission factors.

Consider an industrial boiler that burns 90,000 liters of distillate oil per day. In Section 1.3 of AP-42, "Fuel Oil Combustion," the CO emission factor for industrial boilers burning distillate oil is 0.6 kilograms (kg) CO per 10^3 liters of oil burned.

Then CO emissions

= CO emission factor x distillate oil burned/day
= 0.6 x 90
= 54 kg/day

In a more complex case, suppose a sulfuric acid (H_2SO_4) plant produces 200 Mg of 100 percent H_2SO_4 per day by converting sulfur dioxide (SO_2) into sulfur trioxide (SO_3) at 97.5 percent efficiency. In Section 8.10 of AP-42, "Sulfuric Acid," the SO_2 emission factors are listed according to the SO_2-to-SO_3 conversion efficiencies in whole numbers. The reader is then directed by footnote to an interpolation formula that may be used to obtain the emission factor for 97.5 percent SO_2-to-SO_3 conversion.

The emission factor for kg SO_2/Mg 100% H_2SO_4

= 682 - [(6.82)(% SO_2-to-SO_3 conversion)]
= 682 - [6.82)(97.5)]
= 682 - 665
= 17 kg

In the production of 200 Mg of 100 percent H_2SO_4 per day, SO_2 emissions are calculated:

SO_2 emissions
= 17 kg SO_2 emissions/Mg 100 percent H_2SO_4 x 200 Mg 100 percent H_2SO_4/day
= 3400 kg/day

Emission Factor Ratings

A factor's rating is a general indication of the reliability, or robustness, of that factor. Historically, each AP-42 emission factor was given a rating from A through E, with A being the best.

These ratings were assigned based on the estimated reliability of the tests used to develop the factor and on both the amount and the representative characteristics of those data. In general, factors based on many observations, or on more widely accepted test procedures, were assigned higher (*i.e.*, better) rankings. Conversely, a factor based on a single observation of questionable quality, or one extrapolated from another factor for a similar process, was rated much lower. Because the older emission factors were based on source tests, modeling, mass balance, or other information, factor ratings varied greatly.

From 1995 to 2018, the quality rating of AP-42 was letter based. The quality rating of AP-42 data helped identify good data, even when it was not possible to extract a factor representative of a typical source in the category from those data. For example, the data from a given test may be good enough for a data quality rating of "A," but the test may be for a unique feed material, or the production specifications may be either more or less stringent than at the typical facility. Hence, the AP-42 emission factor rating is an overall assessment of how good a factor is, based on both the quality of the test(s) or information that is the source of the factor and on how well the factor represents the emission source. Higher ratings are for factors based on many unbiased observations, or on widely accepted test procedures. For example, ten or more source tests on different randomly selected plants would likely be assigned an "A" rating if all tests are conducted using a single valid reference measurement method. Likewise, a single observation based on questionable methods of testing would be assigned an "E," and a factor extrapolated from higher-rated factors for similar processes would be assigned a "D" or an "E."

AP-42 emission factor quality ratings from 1995-2018 were thus assigned:

A — Excellent. Factor is developed from A- and B-rated source test data taken from many randomly chosen facilities in the industry population. The source category population is sufficiently specific to minimize variability.

B — Above Average. Factor is developed from A- or B-rated test data from a "reasonable number" of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industry. As with an A rating, the source category population is sufficiently specific to minimize variability.

C — Average. Factor is developed from A-, B-, and/or C-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industry. As with the A rating, the source category population is sufficiently specific to minimize variability.

D — Below Average. Factor is developed from A-, B- and/or C-rated test data from a small number of facilities, and there may be reason to suspect that these facilities do not represent a random sample of the industry. There also may be evidence of variability within the source population.

E — Poor. Factor is developed from C- and D-rated test data, and there may be reason to suspect that the facilities tested do not represent a random sample of the industry. There also may be evidence of variability within the source category population.

Since 2018, to reduce the subjectivity of AP-42 emission factors, a more objective rating system

for test reports was developed (see Appendix A of the Recommended Procedures for Development of Emissions Factors and Use of the WebFIRE Database). The rating system is intended to produce unbiased and consistent assessments of the information included in test reports which, in turn, will help us to better characterize the process and the quality of emissions values.

The rating system consists of a set of objective review questions developed for the EPA's manual and instrumental test methods that assess the quality of the process, control device, and measurement data collected during an emissions test in the following 8 criteria areas:

- General information,
- Process and control device information,
- Sampling locations,
- Test methods and reporting requirements,
- Sampling equipment calibrations,
- Sample recovery,
- Laboratory analysis, and
- Documentation.

Each factor is given a Factor Quality Index (FQI) number that represents the derived emission factor's ability to estimate emissions for the entire national population. The FQI is dependent upon the composite test rating (CTR), which is a weighted average quality indicator for a group of test reports, as well as the number of tests used to develop the emission factor. The FQI is used to create the three quality indicators used to characterize the calculated emission factor:

- ***Highly representative*** is assigned to emission factors having the lowest FQI rating.
- ***Moderately representative*** is assigned to emission factors having an intermediate FQI rating.
- ***Minimally representative*** is assigned to emission factors having the highest FQI rating.

For more information on the new rating system for emission factors, please see Appendix A of the Recommended Procedures for Development of Emissions Factors and Use of the WebFIRE Database.

Public Review Of Emission Factors

Since AP-42 emission factors may have effects on most aspects of air pollution control and air quality management (*e.g.*, operating permit fees, and SIP attainment emission inventories), these factors are always made available for public review and comment before publication. Announcements for new draft factors are posted on the AP-42 website and an email is sent out through the CHIEF Listserv. To subscribe to the CHIEF Listserv, send an email to *join-chief@lists.epa.gov*. The Agency encourages all interested parties to take every opportunity to review factors and to provide information for factor quality improvement. Toward this objective, EPA invites comments and questions about AP-42, and users are invited to submit any data or other information in accordance with this procedures document. Comments and questions can be

submitted to efcomments@epa.gov.