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A Screening Procedure for the Impacts of Air Pollution Sources on Plants, Soils, and Animals

by

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Publication No. EPA-450/2-81-078

CONTENTS

TABLES

TABLES (Cont'd)

FIGURES

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1 INTRODUCTION

1.1 BACKGROUND

Section 165 of the Clean Air Act[1] requires preconstruction review of major emitting facilities to provide for the prevention of significant deterioration (PSD) and charges Federal Land Managers (FLMs) with an affirmative responsibility to protect the air quality related values of Class I areas. Regulations[2] implementing these provisions require:

- An analysis of the impairment to visibility, soils, and vegetation (52.21 (o)) and
- A notice from the EPA Administrator to the appropriate FLM of any permit application from a source whose emissions would affect a Class I area (52.21 (p)).

For sources more than 10 km from any Class I areas, exemptions provide that no analysis of impairment need be done if emission increases are below specified limits.* The analysis should address the impairment due to general secondary growth associated with the source and need not address the impacts on vegetation having no significant commercial or recreational value. For impacts in Class I areas, consultation between EPA and the FLM is required.

1.2 SCOPE

The entire subject of air quality related values and impairment to these values is currently under investigation. For example, although some values related to plants, soils, and visibility are "air quality related values," the term itself remains to be defined in a fashion appropriate to the review of PSD permit applications and air quality reviews. Much of the data required to relate ambient concentrations of pollutants to impairment of these values is currently lacking. However, the requirements of 52.21 (o) and (p) need to be addressed now while additional investigations are being carried out.

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*The "de minimis" values are given in Sec. 52.21 (b)(23)(i) of the PSD regulations.[2]

The information and screening procedure presented here provide interim guidance:

- To aid in determining whether emissions are significant or whether there are significant air quality impacts under Sec. 52.21 (o) and
- To aid in flagging sources which should be brought to the attention of an FLM under Sec. 52.21 (p).

Impacts on vegetation and soils are the principal areas addressed by the procedure which thus takes a limited view of the possibly broad scope of air quality related values. A selected review of impacts on fauna has also been included and the odor potential of regulated pollutants is addressed.

This procedure is intended for use by air quality engineers and is not a manual for the assessment of impacts on plants, soils, and other air quality related values such as would be suitable for an ecologist. A handbook providing for such detailed assessments is being prepared for the FLMs. In keeping with the screening approach, the procedure provides conservative, not definitive results. However, a source which passes through the screen without being flagged for detailed analysis cannot necessarily be considered safe. Species more sensitive to particular pollutants than species considered in this study probably exist. Further research may indicate that averaging times different from those used here are controlling. When available, such information could be easily included in the screening procedure by changing the screening concentrations presented here.

Based on estimates of typical stack parameters, significant emission levels have been estimated. These estimates are not intended to replace source-specific screens, but do indicate what sizes of sources appear most likely to cause significant impacts on plants and soils.

2 OVERVIEW

The procedure presented here provides a simple method for assessing the potential a source has for adversely affecting some air quality related values. In particular, the potential for impacts on plants, soils, and animals is assessed. The approach taken is similar to the "de minimis" approach used by EPA in the PSD regulations.[3] In the procedure presented here, the minimum levels at which adverse effects have been reported in the literature are used as screening concentrations. These screening concentrations can be concentrations of pollutants in the ambient air, in soils, or in aerial plant tissues. They have been developed by searching the review literature; few original sources have been consulted. The analyst applying this procedure must read the material in Sec. 3 which lists these screening concentrations and provides background on them in order to apply and interpret them appropriately.

Section 5 describes a seven step process for screening a source. The procedure begins by estimating the maximum ambient concentrations caused by the source for the averaging times specified for the screening concentrations. For some pollutants these maxima are compared directly to the screening values. For other pollutants (trace elements) estimates of deposition in the soil and subsequent uptake by plants are made based on an estimate of the maximum annual concentration. The estimated concentrations of the pollutant in the soil and aerial plant parts are then compared to appropriate screening concentrations. Concentrations in excess of any of the screening concentrations would indicate that the source might have adverse impacts on plants, soils, or animals and that the actions required by 40 CFR 52.21 (o) and (p) need to be taken. For situations where modeling results are not available for the source, significant emission levels corresponding to the various screening concentrations are developed in Sec. 5.2. In these cases, emissions in excess of the significance levels would trigger the additional actions.

The estimation of potential impacts on plants, animals, and soils is extremely difficult. The screening concentrations provided here are not necessarily safe levels nor are they levels above which concentrations will necessarily cause harm in a particular situation. Effects data for plants, animals, and soils are under constant revision and reevaluation. There is good deal of controversy among experts. In addition, this procedure is based upon a simplistic view of extremely complex systems in which single value estimates are not possible and in which the number of variables is extremely large. Many simplifying assumptions have been involved in developing the procedure and are discussed in Sec. 3.

Ideally, the screening procedure should address the impacts of all the pollutants currently regulated under the Clean Air Act, but as shown in Table 2.1, screening concentrations were found for only half the regulated pollutants. Ozone and TSP are discussed in Sec. 3.1. Of the remaining substances for which screening concentrations were not found, methyl mercaptan, dimethyl sulfide, dimethyl disulfide, carbon disulfide, and carbonyl sulfide are regulated because of their odor potentials. Odor is an air quality related value and Sec. 52.21 (b)(23)(i) of the PSD regulations[2] gives "de minimis" emission levels for reduced sulfur (RS) and total reduced sulfur

Table 2.1 Regulated Pollutants

Screening Concentrations	
Available	Not Available
CO	TSP[a]
NO_2	Asbestos
SO_2	Sulfuric Acid Mist
O_3[b]	Vinyl chloride
Lead	Methyl Mercaptan[c]
Mercury	Dimethyl Sulfide[c]
Beryllium	Dimethyl Disulfide[c]
Fluoride	Carbon Disulfide[c]
Hydrogen Sulfide	Carbonyl Sulfide[c]

[a] Fraction of TSP present as trace elements treated through deposition and uptake by plants.

[b] Screening concentration available but no simple procedure for estimating the ozone impact of a single source is currently available.

[c] Regulated indirectly as constituents of reduced sulfur or total reduced sulfur.

(TRS) based on odor. RS and TRS include these sulfur compounds. Sources not emitting more than these "de minimis" levels (10 t/yr for both RS and TRS) are not expected to have a significant odor impact and hence should not require any additional review for impacts on air quality related values. If the 10 t/yr "de minimis" level is exceeded, the appropriate FLM might want to evaluate the potential for an odor problem. Whether or not these sulfur-containing compounds might adversely affect plants, soils, or animals could not be determined. There was one questionable indication that methyl mercaptan might be toxic to plants at concentrations near 150,000 $\mu g/m^3$, far above likely ambient concentrations.[4] Information for asbestos, sulfuric acid mist, and vinyl chloride was not available in the review literature consulted for this work.

Pollutants which can be screened by this procedure are listed in Table 2.2 according to whether they are screened for potential effects on plants or on animals and according to whether the potential effects are caused directly by concentrations of the pollutant in the ambient air or whether the potential effect is exerted indirectly through the soil or the diet. Absence of a pollutant from a particular column in the table does not necessarily mean that impacts can not result from the pollutant acting through the corresponding pathway. Such absence simply means that no data to provide a suitable screening concentration were found in the review literature consulted.

Table 2.2. Pollutants Screened

Potential Impacts on			
Plants		Animals	
Direct Ambient Impact	Indirect through Deposition and Uptake	Direct Ambient Impact	Indirect through Plants in Diet
SO_2	Arsenic		Arsenic
O_3	Boron	Beryllium	
NO_2	Cadmium		Cadmium
CO	Chromium		
H_2S	Cobalt		Cobalt
Ethylene	Copper		Copper
Fluoride	Fluoride		Fluoride
	Lead	Lead	Lead
	Manganese		Manganese
	Mercury		
	Nickel		Nickel
	Selenium		Selenium
	Vanadium		Vanadium
	Zinc		Zinc

[a] The other five sulfur-containing compounds are screened for odor impacts during the "de minimis" determinaion for RS and TRS.

3 AIR QUALITY RELATED IMPACT DATA

NOTE: In this chapter and throughout this work, a distinction is made between parts per million by volume (ppmv) and parts per million by weight (ppmw). The former, ppmv, is the unit more familiar to air quality analysts and is used, for example, to express ambient concentrations and standards. The latter, ppmw, or an equivalent (mg/kg, μg/g), is frequently used to express concentrations of elements in soils, plants, and animals. The air quality analyst should be aware of the difference, because the units are not equivalent. The unit ppmv is normally used only in expressing concentrations of components of gaseous mixtures.

3.1 GENERAL

Data to be used in screening impacts on three air quality related values (vegetation and crops, soils, and fauna) are discussed in this section. Vegetation and crops receive the greatest amount of attention, reflecting the availability of data. No direct impacts on soils are defined, such impacts being screened through the potential impacts on vegetation growing in soils which have become contaminated by the deposition of air pollutants. Impacts on fauna are also addressed indirectly with effects being related to the ingestion of plants containing toxic elements taken up from pollutants deposited on soils. Thus, the information presented here represents a preliminary definition of air quality related values and impacts.

Perhaps as important as the areas addressed are several areas not addressed in this procedure. These areas are visibility, acid precipitation, a screen for TSP, and a screen for ozone. Consideration of visibility as an air quality related value is required by regulations (40 CFR 52.21 (o) and (p)). Addressing visibility was beyond the scope of this work. However, EPA has prepared a report to Congress on visibility[6] and draft regulations[7] have been published.

No simple procedure is currently available to deal with the impact of a single source on acid precipitation. Acid precipitation presents a regional problem involving long-range transport which makes the impact of a single-source difficult to isolate. Various adverse effects on vegetation have been noted in areas with low soil buffering capacities and subject to heavy annual precipitation. Such areas appear to be most susceptible.[8,9,10,11] Observed effects include reduced growth, reduced germination of seeds and pollen, accelerated leaching of nutrients, decrease in soil calcium and other bases, and reduced microbial activity, particularly that of nitrifiers and nitrogen-fixers. A major EPA initiative to study acid precipitation is currently underway. Policy and guidance will be formulated as part of this initiative.

Total suspended particulates (TSP) are not considered here. No useable information other than that used to develop the ambient standards (NAAQS) was found in the review literature. Thus, EPA's current procedure for TSP[3] should suffice for the review of generic TSP. However, the trace metals in TSP may have greater impacts on vegetation and soils than the total amount of particulates. This section provides information related to specific trace metals.

No simple models are currently available to estimate the impacts on ozone concentrations of emissions of volatile organic compounds (VOC) from a single source. EPA is currently developing means other than modeling to deal with VOC emissions and ozone. It appears likely that an emission management approach will be taken. When this approach has been completed it could probably be used to review new sources for impacts on air quality related values. Meanwhile, the minimum reported concentrations at which vegetative damage occurs are presented here but no method for their use is given and no significance levels for VOC emissions have been developed.

3.2 NATURAL VEGETATION AND CROPS

3.2.1 General

Two pathways by which air pollutants can affect vegetation are considered here. The first is the direct exposure of a plant to a gaseous pollutant in the ambient air. The second involves indirect exposure to trace elements through deposition of the pollutant in the soil and later uptake by the plant. For each pathway certain qualifications and cautions should be kept in mind in order to avoid interpreting the values presented here either as absolutely safe levels for all plants or as levels which could never be exceeded without damaging vegetation. The following discussions are not intended to be exhaustive and details required by specialists are not given. The intent is to provide the air quality analyst with a feeling for the difficulty of estimating screening concentrations for plants and the complexity of making detailed assessments of impacts on vegetation. References 8, 9, 12, and 13 may be consulted for additional details and guidance to primary source material.

Effects of pollutants can be classified as acute or chronic. Acute effects result from short-term (e.g., 3-hr) exposures to relatively high concentrations. Chronic effects result from exposures to lower concentrations for times of from months to several years. Most of the effects data for plants comes from experiments conducted under acute conditions of exposure with some limited information on chronic exposures. Thus, the data may not adequately reflect impacts which take years or decades to develop.

The values presented here represent the ambient levels at which visible damage or growth retardation may occur or the observed minimum levels at which injury and mortality to plants have been reported. These numbers are generally the lowest values consistently reported in the literature on plant response to controlled exposures of single pollutants. Both field and greenhouse studies have been used in developing the data. Experiments which demonstrated only physiological changes (e.g., a change in respiration rate) without associated visible damage or effects on growth, weight, or yield were not considered in this compilation.

The majority of the studies were performed on crops and other economically important species; for lack of sufficient data, it is assumed here that native plant species are affected at similar concentrations. In addition, assessment of the data on crops is difficult because of the number of horticultural varieties available for many of the species tested. In the process of selecting desirable attributes in different varieties, the species' original sensitivity or resistance to the element being tested may have been inadvertently altered, making general conclusions about the sensitivity of the species as a whole difficult.

Effects from simultaneous exposure to two or more pollutants have been ignored in the majority of the studies. Exposure to a single pollutant at a time is not the usual situation. Particular combinations and concentrations of pollutants may act either synergistically or antagonistically under certain conditions. Such situations are seldom clearly predictable with current information and the screening procedure presented here does not deal with them. A limited discussion of synergisms is pesented in Sec. 3.2.3.

Each species exhibits a specific range of tolerance which may be higher, lower, broader, or narrower than another species'. In addition to the variation in tolerance between species, every individual of a given population has an intrinsic tolerance to environmental stress. Therefore, the population exhibits a characteristic range of tolerance so that all members of the population would not necessarily respond to pollutant levels that would adversely affect some members.

Species vary in the way they take up, metabolize, eliminate, and accumulate elements. Species also vary in the way they respond to different elemental forms. For example, As^{3+} is generally thought to be more toxic to plants than As^{5+}. The values presented here do not make such distinctions nor could they be made based on the review literature.

Finally, the response of species and individuals depends upon a number of uncontrolled variables. Changes in these variables might alter the sensitivity of the plant. These variables include: age (stage of development), health and vigor, season of year, temperature, light intensity, soil type, moisture content of soil, pH of soil, humidity, wind speed, and the presence of other elements.

3.2.2 Screening Concentrations for Ambient Exposures

Table 3.1 presents the suggested screening values for seven gaseous pollutants. These values represent the minimum concentrations at which adverse growth effects or tissue injury in exposed vegetation were reported in the literature. Data for some other gases could not be included because the critical specification of averaging time was missing. Where information was available, separate values are given for sensitive, intermediate, and resistant plants. Species belonging to each of these groupings are given in Appendix B for SO_2, NO_2, and ozone. Figure 3.1 displays graphically the variation in experimental determinations of the minimum SO_2 concentration at which effects occur. Figure 3.2 presents a similar display for NO_2. For both pollutants there is reasonable but not perfect agreement between the graphical data and the screening concentrations recommended in Table 3.1. The use of the data from the table rather than interpolation from the curves is

Table 3.1 Screening Concentrations for Exposure to Ambient Air Concentrations[a,b]

		Minimum Reported Level (ppmv)[c]			
		Vegetation Sensitivity			
Pollutant	Averaging Time	Sensitive[d]	Intermediate	Resistant	Reference
SO_2	1 hr	.35(917)	-	-	14
	3 hrs	.30(786)	.80(2096)	5.0(13100)	16
	1 yr	.007(18)			17
O_3[e]	1 hr	.20(392)	.35(686)	.55(1078)	18
	4 hrs	.10(196)	.15(294)	.35(686)	18
	8 hrs	.06(118)	.15(294)	.30(588)	18
NO_2	4 hrs	2.0(3760)	5.0(9400)	9.0(16920)	19
	8 hrs	2.0(3760)	4.0(7520)	8.0(15040)	19
	1 mo	.30(564)			f
	1 yr	.05-.10(94-188)			20
CO[g]	1 wk	1000 (1,800,000)	-	10,000 (18,000,000)	21
H_2S	4 hrs	20.0-60.0 (28,000-84,000)	-	400 (560,000)	22
Ethylene[h]	3-4 hrs	.04(47)			24
	24 hrs	.001(1.2)			25
Fluorine	10 days	(0.5-10)			26
Beryllium[i]	1 mo	(0.01)			27
Lead[j]	3 mo	(1.5)			28

[a] All values except beryllium and lead refer to effects on vegetation.

[b] Minimum reported levels at which visible damage or growth effects to vegetation may occur.

[c] Values in parentheses are $\mu g/m^3$ at 20°C and 1 atm.

[d] These values should be used in the screening procedure unless it is known that only intermediate or resistant plants will be affected.

[e] The values for 20% injury are reported here, since they correspond closely with other values in the literature.

[f] Based on generalization of results of a number of studies.

[g] Reversible decreases in photosynthetic rate have been shown to occur at significantly lower levels but effects on growth have not been demonstrated.

[h] Ethylene " ... is the only hydrocarbon that should have adverse effects on vegetation at ambient concentration of 1 ppm or less." (Ref. 23).

[i] NESHAP value to protect public health. Very toxic to humans and presumably to some animals also.

[j] NAAQS value to protect public health.

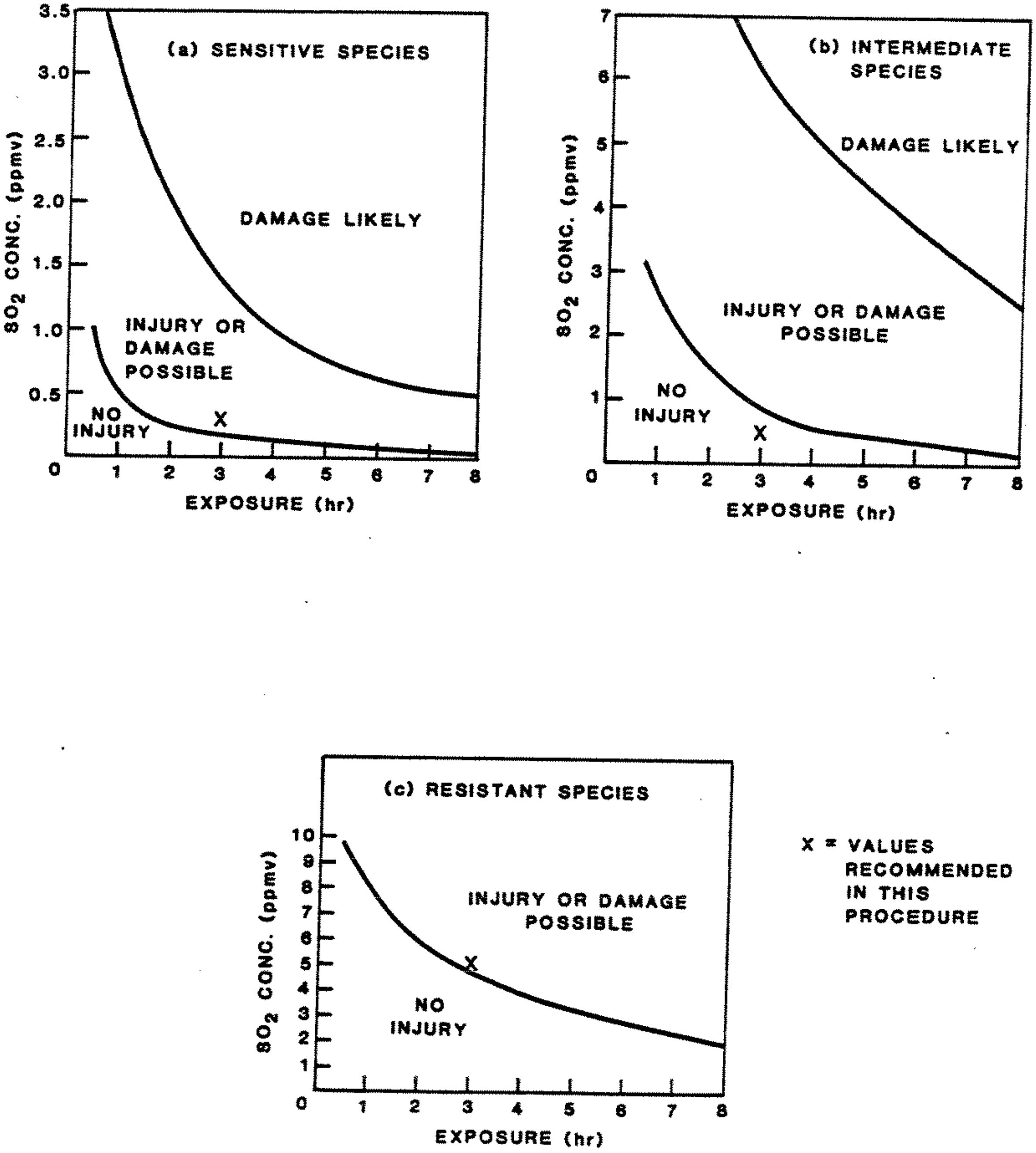

Fig. 3.1 SO$_2$ Dose-Injury Curves for Plant Species (From Ref. 8 as adapted from Ref. 29)

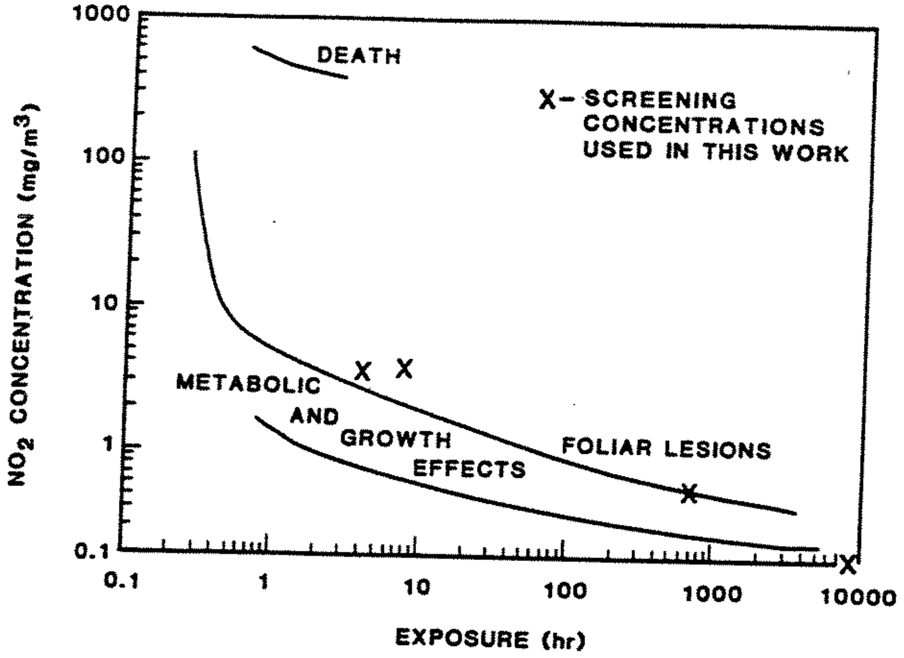

Fig. 3.2 NO$_2$ Dose-Injury Curves for Plant Species (From Ref. 8)

recommended, since the curves are based on attempts to fit theoretical dose-response curves to experimental data whereas the tabulated screening concentrations are based directly on experimental results.

Several points are worth noting about the chosen screening concentrations. First, the significant variation between the values for the various sensitivity groupings should be noted. With this large variation it appears unlikely that use of any values but those for sensitive vegetation could be justified in a screening procedure, given the large number of species for which information is not available.

Second, the tabulated concentrations should be compared to NAAQS, PSD increments, and likely ambient concentrations. Table 3.2 summarizes these comparisons for the cases where they can be made. For pollutant/averaging times not tabulated, either no corresponding NAAQS or PSD increment exists or it appears that the screening concentration could be exceeded under certain circumstances. For the criteria pollutants, the NAAQS appear to protect against vegetative damage except possibly for 3-hr and annual SO$_2$ exposures. For the 3-hr exposure, the screening concentration exceeds the applicable PSD

Table 3.2 Screening Concentrations of Gaseous Pollutants Compared to Ambient Criteria

<table>
<tr><th rowspan="2">Pollutant</th><th rowspan="2">Averaging Time</th><th colspan="3">Vegetation Sensitivity</th></tr>
<tr><th>Sensitive</th><th>Intermediate</th><th>Resistant</th></tr>
<tr><td>SO_2</td><td>3 hr</td><td>< NAAQS[a]
> PSD[b]</td><td>> NAAQS[a]
> PSD[b]</td><td>c
c</td></tr>
<tr><td></td><td>1 yr</td><td colspan="3">< NAAQS[d]
> PSD I[e]</td></tr>
<tr><td>O_3</td><td>1 hr</td><td>> NAAQS[f]</td><td>> NAAQS[f]</td><td>> NAAQS[f]</td></tr>
<tr><td>NO_2</td><td>4 hr</td><td>-</td><td>c</td><td>c</td></tr>
<tr><td></td><td>8 hr</td><td>-</td><td>c</td><td>c</td></tr>
<tr><td></td><td>1 yr</td><td colspan="3">≈ NAAQS[g]</td></tr>
<tr><td>CO</td><td>1 wk</td><td>c</td><td>-</td><td>c</td></tr>
</table>

[a] SO_2 3-hr NAAQS = .50ppmv (1300 $\mu g/m^3$).

[b] SO_2 3-hr PSD increments ($\mu g/m^3$) = 25(Class I), 512(Class II), 700(Class III), 325(Class I variance). These values do not include background.

[c] Screening concentration unlikely to be reached under ambient conditions.

[d] SO_2 annual NAAQS = .03 ppmv (80 $\mu g/m^3$).

[e] SO_2 annual PSD increments ($\mu g/m^3$) = 2(Class I), 20(Class II), 40(Class III), 20(Class I variance). These values do not include background.

[f] O_3 1-hr NAAQS = 0.12 ppmv (235 $\mu g/m^3$).

[g] NO_2 annual NAAQS = 0.05ppmv (100 $\mu g/m^3$).

increments and for the annual exposure, it exceeds the Class I increment. However, the screening concentration should be compared to the total SO_2 concentration including background whereas the PSD increment does not include background. Thus, a source could cause an SO_2 concentration less than the increment while the total SO_2 concentration (source plus background) could exceed the screening concentration. With the exception of the following it appears that possible adverse impacts to vegetation resulting from direct exposure to ambient concentrations of criteria pollutants are already covered by existing programs for NAAQS attainment:

- SO_2 exposures at 1 hour, 3 hours, and 1 year,
- Ozone exposures at 4 and 8 hours,

- NO_2 exposures of sensitive species at 4 and 8 hours, and
- Long-term NO_2 exposures at 1 month and 1 year.

This observation does not preclude doing a review for impacts on plants, particularly where the minimum values at which effects have been reported are close to being exceeded. It does, however, indicate that the vegetative impact review can be done along with the review for NAAQS or PSD increments. Even in cases where review for NAAQS and PSD increments covers exposures to plants, there may still be the necessity of dealing with trace metal exposures through deposition in the soil or through concentration in plant tissues.

3.2.3 Synergisms

Only a very limited amount of information was available in the review literature consulted regarding synergisms. Three indications of synergism were found:

- SO_2 and NO_2,
- SO_2 and O_3, and
- SO_2, O_3, and NO_2.

Table 3.3 presents values which could be used as screening concentrations based on the most restrictive values in the references. Where averaging times allow comparison, the screening concentrations for single pollutants in Table 3.1 are greater than the screening concentrations for mixed pollutants in Table 3.3. Given the problems with the data discussed in Secs. 3.1 and 3.2.1, this comparison should not be interpreted as clear evidence of synergism. An additional caution is also in order. Mixtures of gases may act synergistically on some species and antagonistically on others (see, for example, Ref. 18). Thus, the tabulated values should be used to indicate situations where the FLMs should be alerted so that the situation may be evaluated by them. There may be additional synergisms which are not noted in Table 3.3 but which could be added to the table and incorporated in the screening procedure at a later date.

Table 3.3 Synergisms of Gaseous Pollutants (Plants)[a]

Pollutants	Concentrations (ppmv)	Exposure	Reference
SO_2 NO_2	.05 .05	1 hr	30
SO_2[b] O_3	.30 .10	1 hr	31
SO_2[b] O_3	.05 .05	4 hr	32
SO_2 O_3 NO_2	.14 .05 .10	6 hr/day for 28 days	33

[a] The same criteria were used in selecting these values from Ref. 15 as were used in developing Table 3.1.

[b] Antagonism, as well as synergism, has been reported for mixutes of SO_2 and O_3 (Ref. 18).

3.2.4 Screening Concentrations for Soil and Plant Tissue Exposures

Table 3.4 presents suggested screening concentrations for trace elements found to adversely affect plants. Two types of data are presented. One gives a concentration which when present in the soil has been found harmful to plants. The other gives a concentration found to be present in the tissues of plants which had been harmed. In considering these values, it should be remembered that most elements and compounds are not deleterious until they have been complexed in the soil and become suitable for uptake by plants. In addition, many soil characteristics such as pH, composition (sand, clay, loam, organic matter, etc.), moisture content, and cation exchange capacity affect the amount of trace elements available for uptake. In developing the tabulated values, only data taken with the plants growing in soil were considered. Data developed in experiments in which plants were grown in aqueous nutrient solutions were ignored. Conditions of nutrient solution culture are likely to be sufficiently different from natural conditions as to render the results of the experiments misleading for the purposes of this work.

As with the ambient screening concentrations for gases, a great deal of variation is exhibited by the data as shown in Fig. 3.3. For comparison

Table 3.4 Screening Concentrations for Exposure of Vegetation to Pollutant Concentrations in Soil and Tissue

	Minimum Reported Level (ppmw)		
	Pollutant Source		
Pollutant	Soil	Tissue	Reference
Arsenic	3	0.25	9
Boron	0.5	11	9
Cadmium	2.5	3	9
Chromium	8.4	1	9,35
Cobalt[a]	-	19	9
Copper	40	0.73	9
Fluoride[a]	400	310	9
Lead[a]	1000	126	9
Manganese	2.5	400	9,36
Mercury	455	-	9
Nickel	500	60	9
Selenium[a]	13	100	9,37
Vanadium	2.5	-	38
Zinc	-	300	9

[a] Tissue concentrations may affect animals before affecting plants. Compare to toxic levels for animals in Table 3.7.

purposes, this figure includes results based on experiments in nutrient solutions and also shows the values chosen for screening concentrations in this work.

No standards or PSD increments currently apply to these trace elements so no comparisons with other review criteria can be made. It should be noted, however, that the heavy metals listed in Table 3.4 are emitted as particles and become TSP in the atmosphere. To the extent that they contribute to TSP levels, the NAAQS and PSD increments would apply to these trace elements. The connection between such ambient levels and the screening concentrations for soils and tissues is discussed in Sec. 5.

3.3 SOILS

In contrast to the amount of published information on the effects of atmospheric pollutants on plants and animals, very little has been reported on their effects on soils. Research on trace elements in soils, often the same

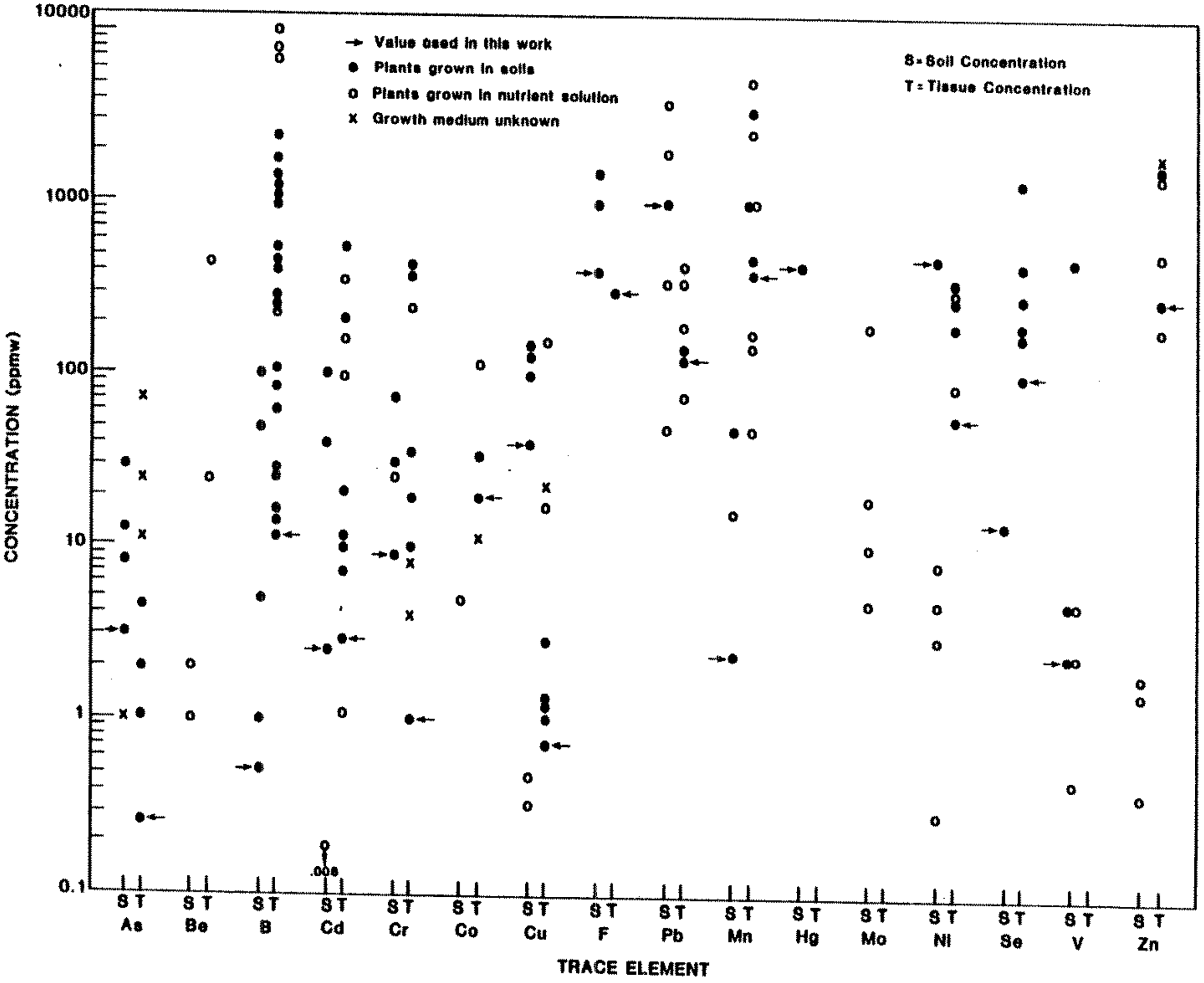

Fig. 3.3 Concentrations of Some Trace Elements Toxic to Terrestrial Plants

elements as atmospheric pollutants, has been directed to notable deficiencies or excesses that limit agricultural crop production. When the amount of an atmospheric pollutant entering a soil system is sufficiently small, the natural ecosystem can adapt to these small changes in much the same way as the ecosystem adapts to the natural weathering processes that occur in all soils. Cultural practices (e.g., liming, fertilization, use of insecticides and herbicides) add elements and modify a soil system more than a small amount of deposited atmospheric pollutant can. The secondary effects of the pollutant appear to impact the soil system more adversely than the addition of the pollutant itself to the soil. For instance, damaging or killing vegetative cover could lead to increased solar radiation, increased soil temperatures, and moisture stress. Increased runoff and erosion add to the problem. The indirect action of the pollutant, through changes to the stability of the system, thus may be more significant than the direct effects on soil invertebrates and soil microorganisms. However, the lack of long-term historical data on both the type and amount of atmospheric pollutants as well as the lack of baseline data on soils has made difficult the task of determining the effect of pollutants on soils by monitoring changes associated with exposure to pollutants. A limited number of studies have been carried out on trace element contamination of soils.[39,40] Plant and animal communities appear to be affected before noticeable accumulations occur in the soils. Thus, the approach used here in which the soil acts as an intermediary in the transfer of deposited trace elements to plants appears reasonable as a first attempt at identifying the air quality related values associated with soils.

When viewing soils in this way it is important to know the endogenous or background concentrations of elements already in the soil of interest, for these endogenous levels may be available for plant uptake. There is, however, a wide variation in the normal concentrations of various trace elements as shown in Table 3.5.[8] If extremes in the concentrations are considered, the range of endogenous concentrations becomes even larger (see Fig. 3.4).[41] Both references show relatively good agreement on the normal ranges. The tabulated values also provide "average concentrations" which can be used when specific information about the concentrations of trace elements in the region of interest is not available. One of the difficulties with screening for impacts on plants and soils becomes apparent when the endogenous concentrations in Table 3.5 are compared with the screening concentrations for soils in

Table 3.5 Range of Endogenous Soil Contentrations of Selected Elements[a]

Element	Range (ppmw)	Average Soil Concentration (ppmw)
Arsenic	0.1-40	6.0
Beryllium	1-40	6.0
Boron	2-100	10.0
Cadmium	0.01-7.0	0.06
Chromium	5-3000	100
Cobalt	1-40	8
Copper	2-100	20
Fluoride	30-300	200
Lead	2-100	10
Manganese	100-4000	850
Mercury	0.01-4.0(?)	-
Nickel	10-1000	40
Selenium	0.01-80	0.5
Vanadium	20-500	100
Zinc	10-300	50

[a]Based on Ref. 8.

Table 3.4: the screening values are exceeded for some part of the listed range for nine out of the twelve elements for which screening concentration are given. Fluorine, lead, and mercury are the only elements whose screening values lie above the corresponding endogenous ranges. The default average soil concentration exceeds the screening concentration for boron, manganese, vanadium, and chromium and, for the first three of these four, the entire listed normal range exceeds the screening value. In interpreting this indication, it must be remembered that the screening concentration value represents the lowest value found in the review literature (see Fig. 3.3) and that not all plant species are as sensitive as the one upon which the value is based. As outlined in Sec. 3.2.1, there are many additional reasons why there is no inherent conflict between screening concentrations and endogenous concentrations above these values. The chief among these are probably the variation in sensitivity between individuals, the variation in sensitivity between species, and the fraction of the endogenous concentration really available for uptake by plants. It should be noted, however, that endogenous concentrations of some elements can make soils toxic to some species. Thus, certain tolerant plants can act as indicator species for the element tolerated; they will be among the species present in soils where the endogenous concentrations of that element exceed levels toxic to more sensitive species.[12]

The problem associated with the amount of an element in the soil which is actually taken up into plant tissues can be handled in an approximate fashion by using a plant:soil concentration ratio. Table 3.6 provides two sets of concentration ratios (CR's). One set is recommended for use in this work; the other is based on nonstandard methods using solution cultures

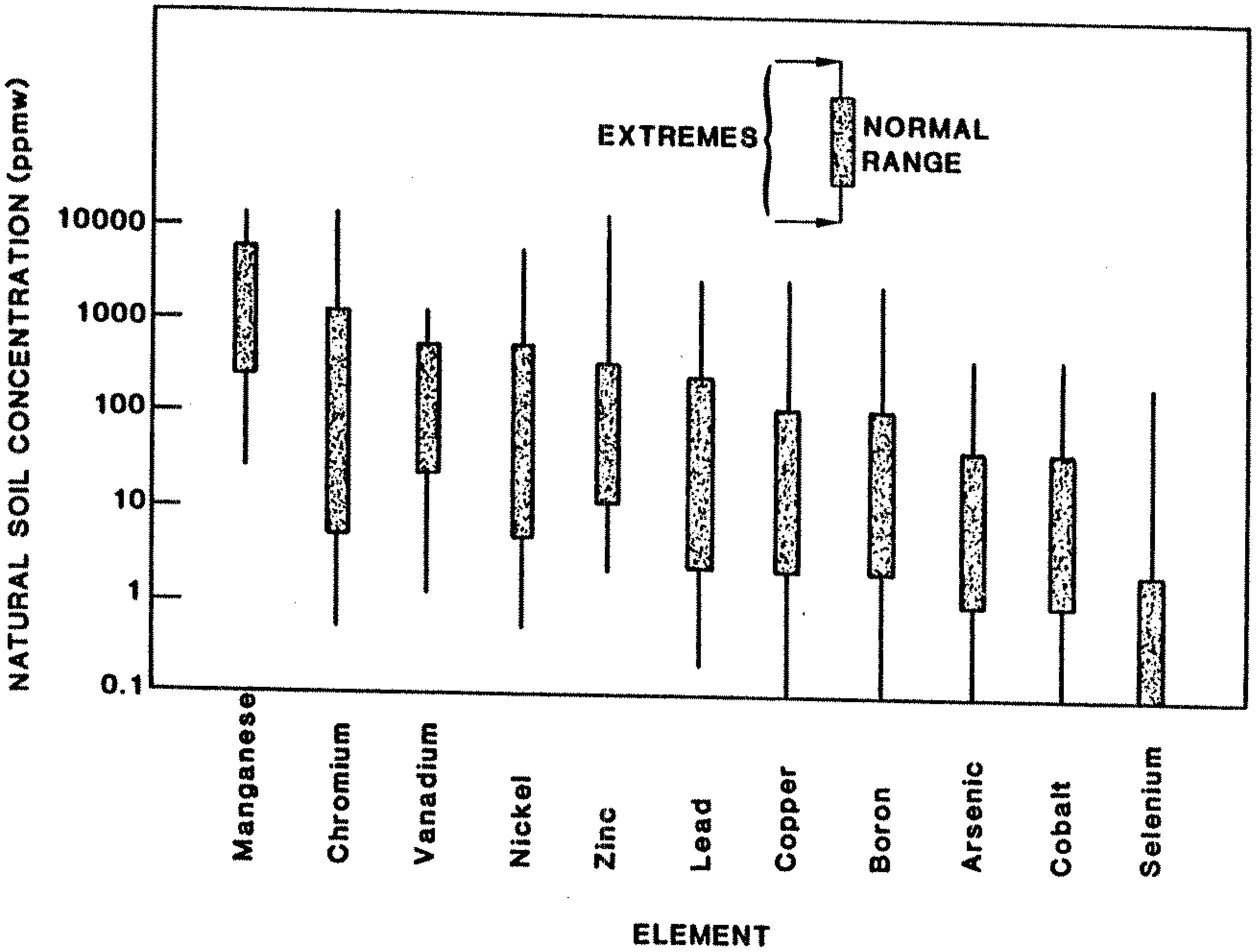

Fig. 3.4 Range of Endogenous Concentrations of Trace Elements (From Ref. 41)

but is given to provide some feeling for the large uncertainties associated with this type of work. The comparison set of concentration ratios could be used in the screening procedure presented here to provide very conservative estimates of potential impacts. Some elements (boron and cadmium) tend to be concentrated by plants (ratios > 1), that is, concentrations in plant tissues exceed those found in the soil whereas the concentrations of most of the listed elements tend to be less in plant tissue than in the surrounding soil. In any case, these CR's represent ratios of averages[9] and thus may give results quite different from the true ratio between plant and soil concentrations in a particular case. However, they appear to be the best means available for estimating uptakes of various elements from the soil.

Table 3.6. Plant: Soil Concentration Ratios

Element	Recommended Value[a]	Comparative Value[b]
Arsenic	0.14	4.2
Boron	5.3	-
Cadmium	10.7	222
Chromium	0.02	250
Cobalt	0.11	87
Copper	0.47	1000
Fluoride	0.03	-
Lead	0.45	2
Manganese	0.066	3000
Mercury	0.02-0.5	26
Nickel	0.045	331
Selenium	1.0	4
Vanadium	0.01	1
Zinc	0.64	40

[a]Based on Ref. 8.

[b]Based on Ref. 12. Based on non-standard methods involving solution cultures. See discussion in text.

3.4 FAUNA

The screening concentrations presented here are based on data for terrestrial vertebrates. Data for aquatic species, including fish, were not examined in the literature reviewed. Also, effects on aquatic and terrestrial microorganisms are not considered here. Table 3.7 presents the screening concentration values based on data summarized in Refs. 8 and 9. The tabulated values represent the lowest dietary concentrations found to be harmful. Several factors limited the usefulness of the available data. Some harmful levels were given in terms of average concentrations in the affected animals. Unfortunately no equivalents of the plant:soil CR's were available to go from dietary concentrations to concentrations per unit body weight. In addition, all the data on ambient exposures failed to give averaging times thus rendering it unuseable in this screening procedure. Even for the data upon which

Table 3.7 is based, there were no indications as to how long the element needed to be ingested in the given concentration before causing the harmful effect. Comparison of the screening concentrations for animal effects (Table 3.7) with the values for plant tissue concentrations (Table 3.4) shows that the values for animals generally exceed those for plant tissue concentrations. However, for cobalt, fluoride, lead, and selenium, it appears that plants could accumulate concentrations that would be toxic to some animals before the plants themselves were harmed.

Table 3.7. Dietary Trace-Element Concentrations Toxic to Animals[a]

Trace Element	Dietary Concentration (ppmw)
Arsenic[b]	3
Cadmium[b]	15
Cobalt	1-3
Copper[b]	20-30
Fluoride	100-300
Lead	80-150
Manganese[b]	500-5000
Nickel[b]	1000
Selenium	5-30
Vanadium	10-500
Zinc	500-1000

[a] Based on Ref. 8.

[b] Tissue concentrations in plants may affect plants before affecting animals. Compare to plant screening concentrations in Table 3.4.

For beryllium and lead, data on ambient air exposures were available in terms of the NESHAP and NAAQS, respectively (see Table 3.1). These values relate to human exposures. Without other indications these same levels have been assumed to be potentially hazardous to at least some animals as well.

4 TRACE ELEMENT AIR QUALITY DATA

EPA's Storage and Retrieval of Aerometric Data (SAROAD) system was used as a data base to develop air quality information for trace elements. The information was intended to serve primarily as an aid in estimating background concentrations so minimum concentrations were included. A secondary purpose of the information was to identify locations where high concentrations already exist. For this purpose, maximum concentrations were included. Compilation of available data for all the pollutants discussed here with estimates for all relevant averaging times would not have been feasible so the data search was limited to trace elements including lead. It was also felt that more complete data for the gaseous criteria pollutants would be available locally than could be found in SAROAD. On the other hand, many localities probably lack estimates of trace element concentrations. Since only annual averages are used in screening for trace element impacts, the data search emphasized annual average data. Maximum and minimum short-term observations have been included in the data compilations for informational purposes.

In order to improve coverage, data for 1975-77 inclusive were used. Many locations had data for only one of the three years. As expected, all the data were based on high volume sampler data with 24-hour averaging times. It was also frequently the case that insufficient data was available to allow the calculation of a valid annual average. The available data is presented in Appendix C. No data was found for mercury, boron, cobalt, copper, and nickel. The data is presented by state and county for each pollutant. As can be seen from the tables, the spatial coverage is poor. For counties with data, only the minimum and maximum annual averages from all reporting stations are given. With multiple stations, it is unlikely that both values come from the same location.

In order to avoid possible misinterpretation of the data, it should be kept in mind that SAROAD routinely stores values below the limit of detectability as one-half the minimum detectable limit. In some cases, this will be the value which is listed as the minimum observation. These situations are usually fairly obvious, since the same minimum value will be recorded at a large number of stations.

5 SCREENING PROCEDURE

5.1 METHODOLOGY

5.1.1 Description

A simplified view of the pathways between sources and receptors is presented in Fig. 5.1. This simple view is used here as the basis for screening a source for potential adverse impacts on plants, soils, and animals. Emissions from the source are assumed to disperse in the atmosphere and add to whatever local background concentrations might exist to provide an estimate of the maximum ambient concentration for the averaging times of interest. These ambient concentrations may act along four different pathways. The first two are routes in which the ambient concentrations affect animals or plants directly without any intervening mechanisms. In the third, animals can ingest substances deposited on plants before the substances have been washed off by rain or blown off onto the soil. Such ingestion is a critical pathway. Appendix D provides a referenced discussion of the literature related to toxicity resulting from this pathway and the potential for harm to animals exists whenever heavy metals are deposited on materials which they ingest. Some start on dealing with this issue was made here in terms of estimating the amount of deposited material but a complete methodology was not developed. However, reviewers should be aware of this potentially critical pathway and the material in Appendix D may be useful in flagging critical situations. In the fourth, a certain amount of the dispersed material is deposited on the soil. As noted in Sec. 3, only the deposition of trace elements is considered here. The deposited trace elements as well as any endogenous concentration of the element are then available for uptake by plants in quantities which may be toxic to the plants themselves or to animals which feed upon the plants.

It is important to realize that this simplified picture leaves out many potentially important pathways and natural processes. For example, there is no provision for the uptake and concentration of substances by plants directly from the air; all such concentration is assumed to be through the soil with uptake by plant roots. No account is taken of removal of deposited substances from the soil by runoff, leaching, or erosion and the

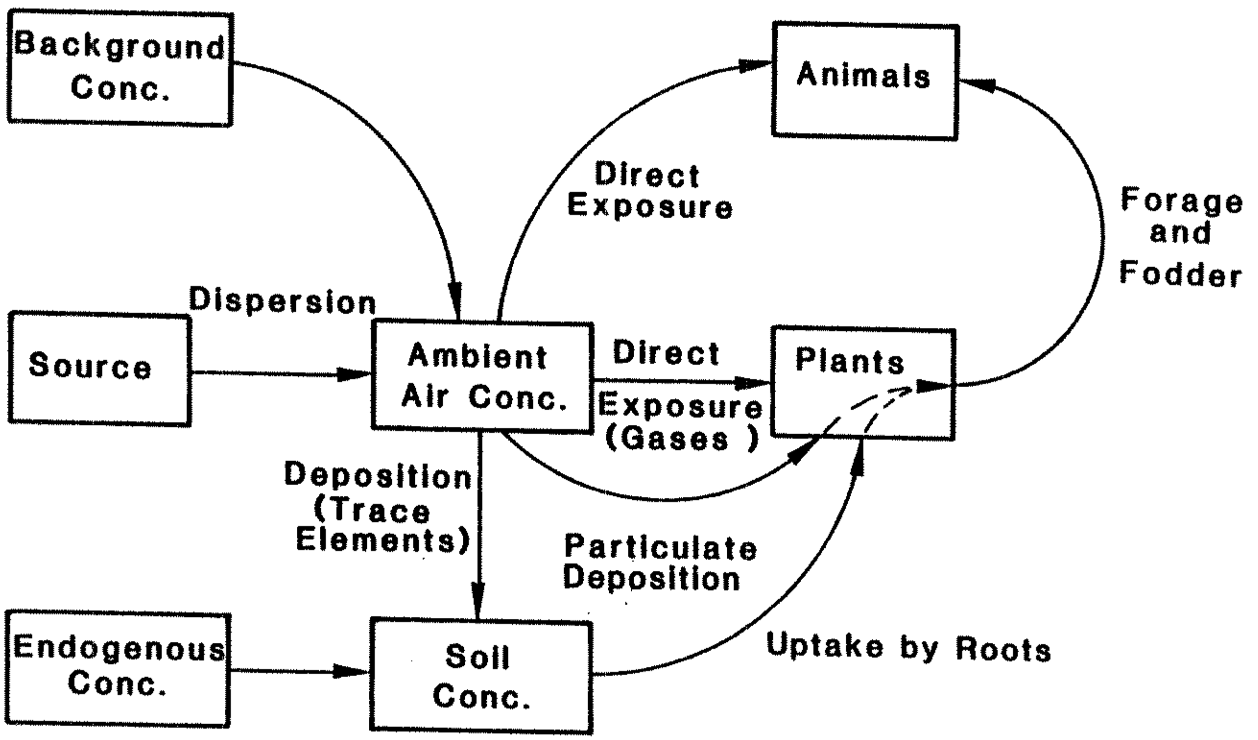

Fig. 5.1 Pollutant Pathways

subsequent deposition of such substances in bodies of water. Also, no account is taken of deposition directly from the air into water. Finally, the effects on animals of ingesting contaminated water have not been addressed.

Screening for a particular source is accomplished in a series of steps. Steps 1 and 2 apply to airborne pollutants; steps 1 and 3-7 apply for trace metals where deposition must be taken into account. Step 8 provides an alternative where modeling results for the source are unavailable.

1. Estimate the maximum ambient concentration for averaging times appropriate to the screening concentrations for pollutants emitted by the source and including any background concentrations.
2. For exposures to airborne pollutants, check the maxima from Step 1 against the corresponding screening concentrations in Table 3.1 or against the corresponding NAAQS, NESHAP or PSD increments, whichever applicable standard is most restrictive. In addition, the possibility of synergisms should be considered.
3. For trace metals, calculate the concentration deposited in the soil from the maximum annual average concentration assuming that all deposited material is soluable and available for uptake by plants.
4. Compare the increase in concentration in the soil to the existing endogenous concentration using the average values in Table 3.5 when local data is unavailable. (This provides a supportive indicator, not a primary decision parameter.)
5. Calculate the amount of trace element potentially taken up by plants using the CR's in Table 3.6.
6. Compare the concentrations from Steps 3 and 5 with the corresponding screening concentrations in Tables 3.4 and 3.7.
7. Reevaluate the results of the comparisons in Steps 4 and 6 using estimated solubilities of elements in the soil to provide supportive indications, recognizing that actual solubilities may vary significantly from the estimated values.
8. If modeling results are unavailable, the significance levels for emissions developed in Sec. 5.2 may be used to screen the source.

The discussion in Sec. 5.2 also provides an example of the application of the screening procedure. This example develops the significant emission levels for one of the trace elements from an estimate of a source's maximum annual average concentration. Table 5.1 summarizes these steps and indexes them to the relevant sections, tables, and equations in the text. Figure 5.2 provides a flowchart of the screening procedure showing the more commonly used tables and equations.

5.1.2 Estimating Maximum Concentrations (Step 1)

To estimate the maximum concentration, the maximum air quality impact of the new source must be estimated and added to an appropriate background concentration.

5.1.2.1 Air Quality Modeling

The first step in the screening procedure for air quality related values is to estimate the maximum ambient concentrations of pollutants emitted from the new source for appropriate averaging times. Table 5.2 gives the correspondence between pollutants and the averaging times to be considered for each. Two cases need to be considered. The first arises when the required source-specific concentration estimates are available and the second arises when they are not.

Concentration Estimates Available. When source-specific estimates made by an approved model are available they should be used directly in making the calculations and comparisons called for in Steps 2-7 of Table 5.1. Such a situation would be ideal but such estimates may frequently be unavailable, particularly during early discussions of a permit application.

Concentration Estimates Unavailable. When source-specific estimates of concentrations are unavailable or when they are lacking for some critical averaging times, there are two courses of action:

- Use of a screening technique for air quality impacts if the emission rates and stack parameters are available or
- Use of the significance levels for emissions presented in Sec. 5.2.

If stack parameters are available, some simple techniques of dispersion modeling can be used to screen the source for its air quality impact, remembering that only a screen and not a definitive demonstration is required. Reference 42 provides such techniques developed by EPA for use in new source

Table 5.1 Steps in Screening Procedure

Step	Description	Applicable Text		
		Section	Tables	Equation
1	Estimate ambient maxima			
	● Modeling	5.1.2	–	–
	● Background	5.1.2, Appendix C	C.1–C.10	–
2	Screen for direct exposure	5.1.3	3.1,3.3,5.3	–
3	Calculate deposited concentration of trace elements[a]	5.1.3	–	5.1
4	Calculate percentage increases over endogenous concentrations[b]	5.1.3	3.5	5.4
5	Calculate tissue concentrations in plants	5.1.3	3.6	5.5
6	Screen for potential adverse impacts of trace elements	5.1.3	3.4,3.7,5.5	–
7	Consider effects of trace element solubility[b]	5.1.3	3.4,3.7,5.4	5.7,5.8
8	Apply significance emission levels[c]	5.2	5.6,5.7	

[a] Reviewers may want to review the information in Appendix D to assess the potential for harm to animals from directly ingesting deposited materials.

[b] Supportive indication only, not primary decision parameter.

[c] Used only when source-specific modeling results are not available.

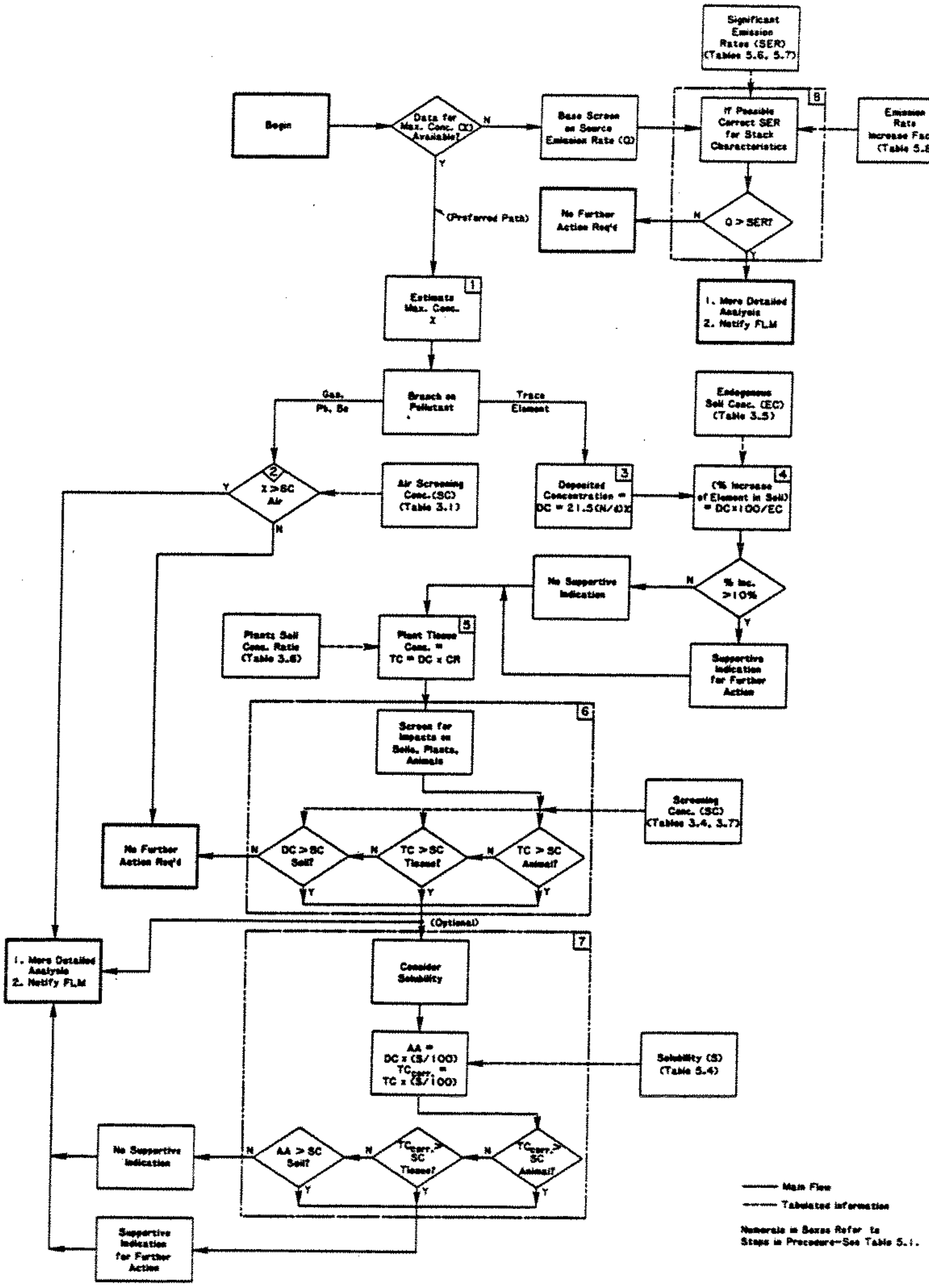

Fig. 5.2 Flowchart of Screening Procedure

Table 5.2 Pollutants and Averaging Times

Pollutant	Required Averaging Times									
	1 hr	3 hr	4 hr	8 hr	24 hr	1 wk	10 days	1 mo	3 mo	1 yr
SO_2	X	X			X[a]					X[b]
NO_2			X	X				X		X[b]
CO	X[a]			X[a]		X				
H_2S	X[a]		X							
Ethylene		X			X					
Fluoride					X[a]		X			
Be								X[a]		
Pb									X[b]	X[c]
Trace Elements[d]										X[e]

[a] For comparison with criteria not necessarily related to impacts on plants, animals, or soils (NAAQS, NESHAP's, PSD increments).

[b] Applies to both impacts on plants, animals, soils and other criteria.

[c] Also included in trace element analysis.

[d] Trace elements: As, B, Cd, Cr, Co, Cu, F (as fluoride), Pb, Mn, Hg, Ni, Se, V, Zn.

[e] Required for use in estimating amount of deposition.

review. These methods were used to develop EPA's significance levels for emissions[42] published as part of the proposed PSD regulations.[43,44]

As an alternative, the procedure used in Ref. 45 to estimate air quality impacts can be used as presented in Appendix A. Some expansion of the original procedure was required to cover the range of averaging times needed for this screening procedure. The equations presented in Appendix A are suitable for hand calculation or the development of a simple computer code. The significance levels presented in Sec. 5.2 are based on this procedure.

5.1.2.2 Background Concentrations

The estimation of background concentrations is one of the perennially difficult problems of air quality analysis. Development of new approaches was beyond the scope of this work. The analyst should consult Ref. 46 for guidance on this subject. No attempt was made here to develop information for the gaseous criteria pollutants. For these gases, it was felt that local records would be likely to provide more timely and complete information. In addition, the sheer volume of data available precluded its inclusion in this procedure. No attempt was made to develop background estimates for other than annual averaging times.

For the 14 trace elements (including lead), EPA's SAROAD files were searched as described in Sec. 4. No information was found for mercury, boron, cobalt, copper, and nickel. The tables in Appendix C summarize the information found by state and county. To estimate a background value, the concentrations in the county of interest or nearby counties should be used and the minimum geometric mean picked. This minimum can then be added to the estimated maximum annual concentration from the source being screened. Values of the minimum geometric mean from other areas should be compared with the value chosen. It is possible that some of the tabulated minima may be too high to represent background levels because the monitor providing the data is impacted by a large source and thus is not representative of general background conditions.

It will not be possible to estimate background levels by this method for many locations. In such a situation, the minimum geometric mean may be selected from among those tabulated in Appendix C and used in a sensitivity analysis to determine if the addition of a background level is likely to raise the predicted concentration above the screening concentration. If it does, then a determination of background will be necessary to allow a clear determination of the source's potential to cause adverse impacts due to trace element deposition.

5.1.3 Screening and Deposition (Steps 2-7)

Screening for Direct Impacts (Step 2). This screen applies to the pollutants listed in Table 3.1 for which data was available on direct impacts of airborne concentrations on plants and animals: SO_2, NO_2, CO, H_2S, ethylene, flourides, Be, and Pb. After the maximum concentrations both with and without background have been calculated, screening is simple. The appropriate maxima are compared to the values given in Table 5.3. Values in excess of the screening concentrations indicate that additional detailed review is required and that the appropriate FLM should be notified. The possibility of synergisms should also be checked at this point. Consideration should be given to the synergisms listed in Table 3.3 but no screen on the values listed there is recommended here. Rather, the information could be used to alert the appropriate FLM to the possibility of a problem arising from synergisms.

Also included in Table 5.3 are the values used in reviewing new sources under other criteria. The value expected to be controlling for each pollutant has been circled in the table under the following assumptions:

- No background,
- Long averaging times result in lower concentrations than short averaging times, and
- For short averaging times, the concentration is proportional to averaging time raised to the power -0.17.

This observation is made only to give some feeling for what might be expected. It is possible, for example, for a new SO_2 source in a Class III area to be controlled by the 700 $\mu g/m^3$ PSD increment and still need to do a review for plant, soil, and animal impacts if 3-hour background levels are high enough to make the predicted ambient concentration likely to exceed 786 $\mu g/m^3$. Completion of Step 2 would complete the screening for direct impacts from airborne pollutants.

Table 5.3 Ambient Screening Concentrations

Screening Criterion	Ambient Concentration ($\mu g/m^3$)																
	Pollutant and Averaging Time^a																
	SO_2				NO_2				CO			H_2S	Ethylene		Fluoride	Beryllium	Lead
	1	3	24	A	4	8	M	A	1	8	W	4	3	24	240	M	3M
AQRV																	
Screening Concentration^b	917	786	-	18	3,760^b	3760^b	564	100	-	-	1,800,000^b	28,000^b	47	1.2	0.5	.01	1.5
NAAQS^{c,d}	-	1,300	365	80	-	-	-	100	40,000	10,000	-	-	-	-	-	-	1.5
PSD Increment																	
I^{e,f}	-	25	5	2	-	-	-	-	-	-	-	-	-	-	-	-	-
II^{e,f}	-	512	91	20	-	-	-	-	-	-	-	-	-	-	-	-	-
III^{e,f}	-	700	182	40	-	-	-	-	-	-	-	-	-	-	-	-	-
Variance^{e,g}	-	325	91	20	-	-	-	-	-	-	-	-	-	-	-	-	-
NESHAP^{f,h}	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.01	-

Note: Circled values expected to be controlling; see text.

[a] Numerals: hours
W: 1 week
M: 1 month
A: Annual

[b] Ambient concentrations this high are unlikely.

[c] 40 CFR 50.

[d] Based on maximum impact of source <u>plus</u> background.

[e] Ref. 1.

[f] Based on maximum impact of source alone.

[g] Includes the source together with all other sources.

[h] 40 CFR 61.

Calculating Deposited Soil Concentrations (Step 3). Deposition of trace elements is a long-term process extending over the lifetime of the source. The simple procedure used here depends upon an estimate of the maximum annual average concentration from the source as corrected by the addition of a background concentration if known. Reviewers may also want to review Appendix D at this point to assess the potential for harm to animals from direct ingestion of deposited heavy metals (see Sec 5.1.1). The following equation can be used to estimate the maximum concentration in the soil:

$$DC(\text{ppmw}) = 21.5\ (N/d)X \qquad (5.1)$$

where:

DC = deposited concentration (ppmw),

N = expected lifetime of source (yr),

d = depth of soil through which deposited material is distributed (cm), and

X = maximum annual average ambient concentration from the source ($\mu g/m^3$).

The value generally recommended for d is 3 cm.[8,9,12] Some work[13] has assumed 20 cm for d, but the more conservative value of 3 should be adopted for use in this screening procedure unless site-specific data indicate that greater penetrations of deposited substances are more representative of local conditions. It should also be noted that an estimate of the source's lifetime must be made in order to use Eq. 5.1. In the absence of contrary indications, a value of $N = 40$ years should provide a reasonable and generally conservative estimate of source lifetimes based on lifetimes equal to twice the time allowed by the Internal Revenue Service for equipment depreciation.[45,47] If the source is tied to a resource, the estimated resource lifetime might be used instead of 40 years. For example, a mine-mouth power plant might have a lifetime of $N = 100$ years based on the life expectancy of the mine or a gas plant might have a lifetime $N = 15$ years, the expected useful life of the gas field.

Equation 5.1 is simply derived. Consider a volume of soil 1 m^2 in area and d cm deep at the location of the source's annual maximum. The weight of material deposited on this area of 1 m^2 can be calculated as:

$$\begin{pmatrix}\text{Weight}\\ \text{Deposited}\end{pmatrix} = \begin{pmatrix}\text{Ambient}\\ \text{Concentration}\end{pmatrix} \times \begin{pmatrix}\text{Deposition}\\ \text{Velocity}\end{pmatrix} \times (1\ \text{m}^2) \times (\text{Time}). \qquad (5.2)$$

The weight of the soil in the volume of interest is

$$\begin{aligned}\begin{pmatrix}\text{Weight}\\ \text{of soil}\end{pmatrix} &= \begin{pmatrix}\text{Volume}\\ \text{of soil}\end{pmatrix} \times \begin{pmatrix}\text{Bulk Density}\\ \text{of soil}\end{pmatrix}\\ &= (1\ \text{m}^2) \times (d) \times \begin{pmatrix}\text{Bulk Density}\\ \text{of soil}\end{pmatrix}. \qquad (5.3)\end{aligned}$$

Then the ratio of the weight deposited to the weight of the soil can be used to find the concentration of the deposited material by weight in the soil. Soil densities range from 1-2 gm/cm^3 and a value of 1.47 g/cm^3 is assumed here as a good average value.[12] If an average value of 1 cm/sec is assumed for the deposition velocity, Eqs. 5.2 and 5.3 can be combined to give

$$\begin{aligned}\text{DC} &= (\text{Weight deposited})/(\text{Weight of soil})\\ &= X\left(\frac{\mu\text{g}}{\text{m}^3}\right) \times 1\ \text{m}^2 \times 1\ \frac{\text{cm}}{\text{sec}} \times \frac{1\ \text{m}}{.01\ \text{cm}} \times 3.1558 \times 10^7 \left(\frac{\text{sec}}{\text{yr}}\right)\\ &\quad \times N(\text{yr}) \times \frac{1}{d(\text{cm})} \times \frac{.01\ \text{cm}}{\text{m}} \times \frac{1}{1\ \text{m}^2} \times \frac{1}{1.47}\left(\frac{\text{cm}^3}{\text{g}}\right) \times \frac{1}{10^6}\left(\frac{\text{m}^3}{\text{cm}^3}\right)\\ &= 21.5\ (N/d)\ X \left(\frac{\mu\text{g}}{\text{g}}\right)\\ &= 21.5\ (N/d)\ X\ (\text{ppmw})\end{aligned}$$

(21.5)(30/3)

where conversion factors have been used as appropriate to give consistent units. This result is simply Eq. 5.1. The principal assumptions in this derivation are:

- Deposition velocity of 1 cm/sec,
- Average bulk density of soil = 1.47 gm/cm^3,
- Uniform distribution of deposited material throughout the soil volume, and
- All deposited material is retained by the soil, that is, no leaching, surface runoff, or erosion.

Calculate Increase over Endogenous Soil Concentration (Step 4). The purpose of this simple calculation is to provide a supportive indication for the primary screen for deposition to be carried out in Step 6. As suggested in Ref. 13, an increase over the endogenous concentration of more than 10% over the lifetime of the source could be taken as a possible cause for concern. The percentage increase is simply calculated from

$$(\%\ \text{Increase}) = [\text{DC(ppmw)} \times 100)]/[\text{Endogenous Concentration (ppmw)}] \quad (5.4)$$

where the deposited concentration (DC) was calculated in Step 3. The average endogenous concentrations from Table 3.5 can be used but data for the area of interest is preferable given the wide range in natural concentrations.

It is not recommended at this time that a source be flagged for further actions based solely on the results of this calculation. The results of the screens in Step 6 are appropriate for that purpose. However, an indicated increase of more than 10% in this step would increase the assurance with which a finding that additional action was necessary could be made.

Calculate Potential Concentrations in Plant Tissue (Step 5). Once the deposited concentration in the soil has been calculated using Eq. 5.1, straightforward application of the plant:soil concentration ratios in Table 3.6 can be used to estimate the concentration in aerial plant parts (tissue concentration)

$$[\text{Tissue concentration (ppmw)}] = [\text{Deposited concentration (ppmw)}] \times [\text{Concentration ratio}]$$

or

$$\text{TC (ppmw)} = \text{DC (ppmw)} \times \text{CR} \quad (5.5)$$

using TC for tissue concentration and other symbols introduced earlier. Equation 5.5 requires an additional conservative assumption:

- All the deposited material is soluable and available for uptake by plants.

This assumption is almost always violated in practice. Table 5.4 gives the solubilities of some trace elements based on extraction of these elements from endogenous concentrations in the soil.[13] Of course, the solubilities of exogenous deposited elements could differ markedly from these values as could the solubilities of endogenous concentrations in different soils. The solubility of a trace element in the soil depends upon many factors. Among these

Table 5.4 Solubilities of Endogenous Trace Elements[a,b]

Element	Solubility (%)[c]	Emission Rate Increase Factor[d]
Arsenic	9	11
Boron	—	—
Cadmium	40	2.5
Chromium	0.004	25,000
Cobalt	0.4	250
Copper	0.1	1,000
Fluoride	—	—
Lead	—	—
Manganese	37	2.7
Mercury	0.8	120
Nickel	0.1	1,000
Selenium	21	4.8
Vanadium	—	—
Zinc	8	12

[a] Based on Ref. 13.

[b] Used in Step 7.

[c] Only soluable fraction would be available for uptake by plants.

[d] Used when Step 8 is required.

are chemical form, temperature, presence of other elements, selective uptake by plants, soil pH, and soil moisture content. The composition of the soil is also an important determinant of solubility, especially the presence of organic matter and clays which can bind trace elements. The point is that a significant portion of the exogenous concentration may be unavailable for uptake by plants, making Eq. 5.5 a conservative estimator.

Screen for Potential Adverse Impacts from Trace Elements (Step 6). At this point the screen for adverse impacts from the deposition of trace elements is straightforward. The process is similar to that used in Step 2, that is, the comparison of calculated concentrations to tabulated screening concentrations. In this step, however, three comparisons need to be made:

1. The deposited concentration (DC) is compared to the soil screening concentration in Table 3.4,
2. The tissue concentration (TC) is compared to the tissue screening concentration in Table 3.4, and
3. The tissue concentration (TC) is compared to the dietary screening concentration for animals in Table 3.7.

A calculated concentration in excess of any one of the three screening concentrations is an indication that a more detailed evaluation may be required for the new source and/or that the FLM should be notified, since there are indications of potential adverse impacts to plant, soils, or animals. In making these three comparisons, the following additional assumptions have been made:

- All deposited forms of an element have the same toxicity,
- The feeding or grazing range of animals is limited to the area exposed to the estimated maximum annual concentration, and
- Most importantly, it is the exogenous incremental burden which should be compared with the screening concentration values, not the burden which would result from both the exogenous and endogenous concentrations.

This last assumption is critical and follows the procedure used in Refs. 12 and 13. The assumption is implicit in Eq. 5.5 where only the deposited concentration (DC) is used to calculate the tissue concentration (TC) and in the three screens as defined above.

The three screens can be compared to see which is the most restrictive. The screening value for concentrations in aerial plant tissues and for concentrations toxic to animals can be converted into equivalent soil concentration values by use of the plant:soil concentration ratios. The dietary concentration potentially toxic to animals can be thought of as the concentration in aerial plant parts that may be toxic to animals. Thus, Eq. 5.5 can be rearranged to give the equivalent deposited concentration (EDC) corresponding to a particular screening tissue concentration (STC):

$$\text{EDC (ppmw)} = \text{STC (ppmw)}/\text{CR} \qquad (5.6)$$

where the STC is either the plant tissue screening concentration from Table 3.4 or the animal screening concentration from Table 3.7. In fact, Eq. 5.6 provides an alternative approach to the screening procedure that is equivalent to the one presented here. Table 5.5 gives the equivalent deposited concentrations (EDCs) for the trace elements. Based on the CR's and assumptions used here, animals appear to be the critical receptor for cobalt, lead, and selenium while tissue concentrations in plants appear to be critical for arsenic, cadmium, copper, and zinc. For the remaining seven elements, the soil concentration appears to be critical. As long as the screening concentrations and concentration ratios given here are used, Table 5.5 can be used to reduce the number of comparisons required for a screen. For example, cadmium sources need only be screened against the single screening value for plant tissue concentrations, since this screening concentration is shown to be controlling in the table.

Table 5.5 Equivalent Exogenous Soil Screening Concentrations

	Equivalent Deposited Concentration (ppmw)		
Trace Element	Soil[a]	Plant Tissue[b]	Animals[c]
Arsenic	3	1.8[d]	21
Boron	0.5[d]	2.1	-
Cadmium	2.5	0.28[d]	1.4
Chromium	8.4[d]	50	-
Cobalt	-	170	9.1[d]
Copper	40	1.6[d]	43
Fluoride	400[d]	10,300	3,300
Lead	1000	280	180[d]
Manganese	2.5[d]	6,100	7,600
Mercury	455[d]	-	-
Nickel	500[d]	1,300	22,000
Selenium	13	100	5[d]
Vanadium	2.5[d]	-	1,000
Zinc	-	470[d]	780

[a] Same as soil value in Table 3.4.

[b] EDC = (STC for plants from Table 3.4)/CR.

[c] EDC = (STC for animals from Table 3.7)/CR.

[d] Controlling value.

Since acute fluoride poisoning in various species of cattle has been well documated,[48] it is surprising that animals do not appear to be critical for fluorides. This may be due to the omission of the critical pollutant pathway involving ingestion by animals of materials deposited on plants prior to these materials being washed off or blown off the plants and carried into the soil. The same indication could be given of course, if the screening concentration value for the effects of soil fluorides on plants were based upon a very sensitive species. Further detailed investigation and more data would be required to determine whether the latter explanation is true or whether there is a deficiency in the procedure outlined here. In either case, the fluoride example serves to illustrate the potential problems involved in screening for impacts on air quality related values.

Consider Effects of Solubilities (Step 7). The assumption that all deposited material is soluable and available for uptake by plants is unlikely ever to be met in practice. If a screen indicates that a further action is needed on a source because its emissions will cause a trace element screening concentration to be exceeded, an attempt may be made to look at the possible effect of reduced solubility on that indication by considering the solubility of the deposited material. This additional consideration should only be used as a supportive indicator; it can only increase confidence in the decision to take further action; it can never reverse such a decision based on the screens in Step 6. That is, the conservative assumption of 100% solubility should be used in making the decision for further action on the source.

If the solubility of a particular trace element is S%, the amount actually available for uptake (AA) by plants is

$$\begin{pmatrix}\text{Amount}\\ \text{available}\\ \text{for uptake}\end{pmatrix} = DC \times (S/100)$$

or

$$AA = DC \times (S/100). \tag{5.7}$$

This value for AA should be compared with the soil screening concentrations in Table 3.4. An equation similar to Eq. 5.5 can now be written reflecting the assumption that only the fraction AA of the deposited concentration is available for uptake.

$$TC_{corr.} = AA \times CR = DC \times (S/100) \times CR = TC \times (S/100) \qquad (5.8)$$

where $TC_{corr.}$ stands for the tissue concentration corrected for the solubility of the deposited material. The new values of $TC_{corr.}$ could be compared with the screening concentrations for plant tissues and animals given in Tables 3.4 and 3.7, respectively.

5.2 EXAMPLE SCREEN AND SIGNIFICANT EMISSION RATES

Section 5.2.1 illustrates the use of Steps 1-7 of the screening procedure through application to a source of nitrogen dioxide and arsenic. Whenever source-specific estimates of maximum concentrations are available or can be generated, Steps 1-7 should be used. Step 8 provides an alternative screening procedure based on the concept of significant emission rates (SER). Section 5.2.2 illustrates the derivation of the SER for arsenic from the results for the example source and describes the use of the SER's for screening. Use of the SER's precludes any consideration of the emission characteristics of the source other than emission rate. Local conditions including background also cannot be taken into account. Application of Steps 1-7 is the preferred procedure.

5.2.1 Example Screen

The example source is assumed to have a plume release height of 30 m (physical stack plus plume rise). It is assumed that the source is subject to PSD review and that it is desired to screen the source for arsenic and nitrogen dioxide among other pollutants. An emission rate of 1 T/yr of arsenic is assumed for this example and estimates of maximum concentrations of NO_2 are available for 4-hour and 8-hour averaging times. Following Table 5.1 or Fig. 5.2, the first step in the procedure is to estimate maximum concentrations for the times listed in Table 5.2. For arsenic, these estimates need to be made. Using the simple modeling procedure outlined in Appendix A, the maximum annual average ground level concentration is found to be $X = 0.1051\ \mu g/m^3$. Other appropriate models or techniques could also be used. If an insignificant background is assumed for the example, this result completes Step 1 of the screening procedure for arsenic. For NO_2, the available results show maximum ground level concentrations (including background) of $\chi_4 = 51\ \mu g/m^3$ and $\chi_8 = 45\ \mu g/m^3$ for averaging times of 4 and 8 hours, respectively. (A little foresight will show that estimates need not be made for 1 mo and 1 yr.) These results complete Step 1.

Then in Step 2 of the screening procedure, these maximum concentrations for NO_2 would be compared to the appropriate screening concentrations in Table 3.1 or Table 5.3. For NO_2, the screening concentration at both 4 and 8 hours is 3760 $\mu g/m^3$. The estimated maxima are for below this value. No calculation need be done for the one month and annual averaging times, since the modeled 4- and 8-hour maxima are already below the corresponding screening concentrations. There would thus be no indication that a more detailed review would be required for NO_2 impacts on plants, soils, and animals.

Since the screen also involves a trace element, the next step is Step 3. If a 10-year lifetime (N=10) is assumed and the recommended value of 3 cm is used for the depth of soil throughout which the deposited arsenic is mixed, Eq. 5.1 gives

$$DC = 21.5\ (N/d)\chi$$
$$= 21.5\ (10/3) \times (.1051) = 7.53$$ ppmw as the concentration of arsenic in the soil.

Following with Step 4 and Eq. 5.4,

$$[\%\ \text{Increase}] = 7.53 \times 100/6 = 126\%$$

where 6.0 ppmw has been used as the average endogenous soil concentration of arsenic from Table 3.5. Thus, there is a supportive indication that the source should receive further review if Step 6 shows the potential for adverse impacts because the source may increase concentrations of arsenic in the soil by more than 10%. In Step 5, the plant tissue concentration would be calculated from Eq. 5.5:

$$TC = DC \times CR = 7.53 \times 0.14 = 1.05 \text{ ppmw}.$$

Next the screening comparisons are made in Step 6. The DC (=7.53 ppmw) exceeds the soil screening concentration of 3 ppmw for arsenic given in Table 3.4. Similarly, the TC (1.05 ppmw) exceeds the tissue screening concentration of 0.25 ppmw given in Table 3.4. The TC does not exceed the animal-related screening concentration of 3 ppmw given in Table 3.7. There are thus two indications that this source might adversely affect plants and that further actions need to be taken.

To look at the possible effect of arsenic solubility on these indications, the calculations in Step 7 can be done. For arsenic, Table 5.4 gives a solubility of 9% to account for the limited solubility of arsenic compounds. Equations 5.7 and 5.8 give $AA = 7.53 \times .09 = 0.68$ ppmw and $TC_{corr} = 1.05 \times .09 = 0.0945$ ppmw. AA does not exceed the soil screening concentration of 3 ppmw and TC_{corr} does not exceed the tissue screening concentrations for plants and animals, 0.25 ppmw and 3 ppmw, respectively. Thus, no supportive indication has been found but the original indication that additional detailed work is required on the source is not altered and it is known that solubility effects might be important.

5.2.2 Significant Emission Rates

Basic Levels. This subsection discusses the development of a significant emission rate (SER) for arsenic based on the generic source discussed in Sec. 5.2.1 with a release height of 30 m and an expected lifetime of 10 years. An SER is defined as the minimum emission rate which would cause the source's impact to just equal the screening concentration. That is,

$$\begin{pmatrix}\text{Significant}\\ \text{emission}\\ \text{rate}\end{pmatrix} = [(\text{Screening concentration})/(\text{Concentration from source})] \times (\text{Source's emission rate}).$$

For arsenic in soils and the example source,

$$\text{SER(Soils)} = [3/7.53] \times (1\ \text{T/yr}) = 0.40\ \text{T/yr}.$$

Arsenic emissions from this source in excess of 0.40 T/yr might be expected to cause a soil concentration in excess of the screening concentration. Similarly, significant emission rates based on plant tissues (TC = 1.05 ppmw) and animal ingestion (TC = 3 ppmw) can also be calculated:

$$\text{SER(Tissue)} = [0.25/1.05] \times (1\ \text{T/yr}) = 0.24\ \text{T/yr and}$$

$$\text{SER(Animals)} = [3/1.05] \times (1\ \text{T/yr}) = 2.8\ \text{T/yr}.$$

Such significant emission rates were calculated assuming a 30 m release height as in Ref. 43, a 10-year source lifetime, and the air quality model presented in Appendix A. For pollutants acting along the direct pathways, Table 5.6 presents the significant emission rates. Table 5.7 presents such rates for trace elements. When no modeling results or stack parameters such as are required by simple air quality screening procedures are available, the source's emission rates can be compared directly with those given in these two tables. As already noted in the discussion of Table 5.3, other criteria may be controlling particularly when background is considered. Still, the significant emission rates presented in Table 5.6 can be used to screen for potential adverse impacts to plants, animals, and soils. Other criteria may apply to different stages of the new source review process. When applying the significant emission rates in Table 5.7, only the smallest value need be considered for each pollutant. The values based on exceeding ten percent of the average endogenous soil concentration should again only be used as supportive indicators; the primary decision is based upon exceeding the values based on the criteria for soils, plant tissues, and animals.

The values tabulated in Table 5.7 assume a source lifetime of 10 years. Significant emission rates for other lifetimes for trace elements acting through the deposition pathway are easily calculated:

$$\begin{pmatrix}\text{Significant}\\ \text{emission}\\ \text{rate for}\\ \text{N year}\\ \text{lifetime}\end{pmatrix} = \begin{pmatrix}\text{Tabulated}\\ \text{significant}\\ \text{emission rate}\end{pmatrix} \times (10/N). \tag{5.9}$$

Thus, for example, if the lifetime of the arsenic source in the above example had been 40 years instead of 10 years, the associated significant emission rate based on the plant tissue screening concentration would have been changed from 0.24 T/yr to

$$(0.24) \times (10/40) = 0.06 \text{ T/yr}.$$

<u>Solubility</u>. As in Step 7, additional supportive indications can be sought by considering the effects of solubility. A corrected significant emission rate can be found from

$$\begin{pmatrix}\text{Significant}\\ \text{emission}\\ \text{rate corrected}\\ \text{for solubility}\end{pmatrix} = \begin{pmatrix}\text{Significant}\\ \text{emission rate}\\ \text{from Table 5.7}\end{pmatrix} \times \begin{pmatrix}\text{Emission rate}\\ \text{increase factor}\\ \text{from Table 5.4}\end{pmatrix} \tag{5.10}$$

Table 5.6 Significant Emission Rates for Direct Acting Pollutants[a]

Screening Criterion	Significant Emission Rate (T/yr)																
	Pollutant and Averaging Time[b]																
	SO_2				NO_2				CO			H_2S	Ethylene		Fluoride	Beryllium	Lead
	1	3	24	A	4	8	M	A	1	8	W	4	3	24	240	M	3M
AQRV Screening Concentration	160	170	-	171	840	950	3,200	950	-	-	760,000	6,400	10.0	0.36	0.23	0.057	11
NAAQS	-	290	110	760	-	-	-	950	7,000	2,500	-	-	-	-	-	-	11
PSD Increment I	-	5.3	1.5	19	-	-	-	-	-	-	-	-	-	-	-	-	-
II	-	110	28	190	-	-	-	-	-	-	-	-	-	-	-	-	-
III	-	150	55	380	-	-	-	-	-	-	-	-	-	-	-	-	-
Variance	-	69	28	190	-	-	-	-	-	-	-	-	-	-	-	-	-
NESHAP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.057	-

[a] Based on 30 m release height and no background.

[b] Numerals: hours
W: 1 week
M: 1 month
A: Annual

Table 5.7 Significant Emission Rates for Trace Elements[a]

	Significant Emission Rate (T/yr)			
	Criterion			
Trace Element	Soils	Plant Tissue	Animals	10% of Endogenous Soil Concentration[b]
Arsenic	.40	.24	2.8	.08
Boron	.067	.28	-	.13
Cadmium	.33	.037	.19	.00080
Chromium	1.1	6.7	-	1.3
Cobalt	-	23[c]	1.2	.11
Copper	5.3	.21	5.7	.27
Fluoride	53[c]	1400[c]	440[c]	2.7
Lead	130[d]	37[d]	24[d]	.13
Manganese	.33	810[c]	1000[c]	11[c]
Mercury	61[c]	-	-	-
Nickel	67[c]	170[c]	3000[c]	.53
Selenium	1.7	13[c]	.67	.0067
Vanadium	.33	-	130[c]	1.3
Zinc	-	63[c]	100[c]	.67

[a] Based on a 30 m release height, no background, and a source lifetime of 10 years. For a lifetime of N years, divide the tabulated values by (N/10).

[b] For use as a supportive indicator only; based on a 10% increase over the average values in Table 3.5.

[c] Exceeds the significant emission level for TSP of 10 T/yr established for PSD (Ref. 3).

[d] Exceeds the significant emission level for lead of 1 T/yr established for PSD (Ref. 3).

These emission rate increase factors are simply (100/S), the reciprocals of the solubilities in percent.

Other Stacks. Even though the stack parameters may not be known exactly, it may be known that the stack is hot or cold. Table 5.8 gives stack parameters for four stacks which might be useful if they are closer to the source's expected stack parameters than the 30 m release height assumed

Table 5.8. Summary of Representative Stacks

	Stack Parameters			
Stack	Height (m)	Temperature (°K)	Flow (m^3/sec)	Emission Rate Increase Factor
30 m release	30	293	0	1.00
10 m cold	10	350	4	0.96
10 m hot	10	550	4	4.07
30 m cold	30	350	4	3.43
30 m hot	30	550	4	8.93

in Tables 5.6 and 5.7. The volume flow rate of 4 m^3/sec is felt to be conservative for major sources unless a large number of stacks are used. Also given in the table are emission rate increase factors for each model stack. A particular factor would be used to adjust the tabulated significant emission rates in Tables 5.6 and 5.7 to correspond more closely to concentrations expected from the proposed source:

$$\left(\begin{array}{l}\text{Significant}\\ \text{emission rate}\\ \text{corrected}\\ \text{for stack}\end{array}\right) = \left(\begin{array}{l}\text{Significant}\\ \text{emission rate}\\ \text{from Tables}\\ \text{5.6 or 5.7}\end{array}\right) \times \left(\begin{array}{l}\text{Emission rate}\\ \text{increase factor}\\ \text{from Table 5.8}\end{array}\right) \tag{5.11}$$

APPENDIX A

Estimates of Maximum Ground Level Concentrations

APPENDIX A

ESTIMATES OF MAXIMUM GROUND-LEVEL CONCENTRATIONS

This appendix develops the procedure used to estimate maximum ground-level concentrations (mglc's) from a single source for averaging times ranging from one hour to one year. The developments presented here follow the presentation in Ref. 45 which can be consulted for additional details. The procedure is useful for screening because the calculations can be done by hand or implemented in a simple computer program. The procedure accounts for stack parameters, plume rise, and meteorological conditions.

A.1 SHORT-TERM ESTIMATES

The familiar Gaussian plume model is the basis for estimating short-term ground level concentrations.[49] According to this model the plume center-line concentration is given by

$$\chi(x) = \frac{Q \times 10^6}{\pi u \sigma_y(x) \sigma_z(x)} \exp\left[-1/2\left(\frac{H}{\sigma_z(x)}\right)^2\right] \qquad (A.1)$$

where:

x = Downwind distance from source (m),
$\chi(x)$ = Ground-level centerline concentration at x ($\mu g/m^3$),
Q = Source emission rate (g/sec),
u = Wind speed (m/sec),
$\sigma_y(x)$ = Horizontal dispersion coefficient (m)
$\sigma_z(x)$ = Vertical dispersion coefficient (m), and
H = Effective stack height (m) = $h_s + \Delta h$ = (Physical stack height) + (Plume rise).

To derive an analytic expression for the mglc, the following commonly used representatives of the two dispersion coefficients are used:

$$\sigma_y(x) = ax^b \qquad (A.2)$$

and

$$\sigma_z(x) = cx^d. \qquad (A.3)$$

The parameters a, b, c, and d depend upon atmospheric stability class and, for σ_z, the downwind distance x. The following expressions for the estimated mglc (χ_m) and the corresponding downwind distance x_m may be derived.[50]

$$\chi_m = \frac{AQ \times 10^6}{\pi u} \times \frac{1}{H^{2\alpha}} \tag{A.4}$$

and

$$x_m = \left[\left(\frac{H^2}{c}\right)\frac{1}{2\alpha}\right]^{1/2d} \tag{A.5}$$

where:

$$\alpha = (b+d)/(2d) \tag{A.6}$$

and

$$A = \frac{c^{2\alpha-1}}{a}(2\alpha)^{\alpha}\exp(-\alpha) \tag{A.7}$$

Values for a, b, c, d, and A are presented in Table A.1.

Both χ_m and x_m depend on stability class and wind speed. To estimate these quantities, the plume rise must be estimated because both depend upon the effective stack height H. Plume rise can be estimated using the formulas of Briggs.[52,53]

Setting

$$F = g\left(\frac{T-Ta}{T}\right)V \tag{A.8}$$

where:

g = Acceleration of gravity (9.8 m/sec^2),
T = Exit gas temperature (°K),
T_a = Ambient temperature (°K), and
V = Exist gas flow rate at temperature T (m^3/sec),

it can be shown that

$$\Delta h(n/u) = C/u \text{ for neutral/unstable conditions} \tag{A.9}$$

and

$$\Delta h(s) = D/u^{1/3} \text{ for stable conditions.} \tag{A.10}$$

Table A.1 Dispersion Coefficient Parameters and Maximum Concentration Coefficient

Atmospheric Stability	Moderately Unstable	Neutral	Moderately Stable
Corresponding Pasquill-Gifford Stability Class	B	D	E-F (intermediate)
a*	0.351	0.150	0.0853
b*	0.867	0.889	0.894
c**,†	0.139, 0.0494, 0.0494	0.0856, 0.259, 0.737	0.0682, 0.227, 1.437
d**,†	0.947, 1.114, 1.114	0.865, 0.687, 0.564	0.814, 0.618, 0.401
A†	0.335, 0.188, 0.188	0.396, 0.955, 3.85	0.468, 1.21, 34.7

*Estimated from Fig. 3.2, Ref. 49.

**Taken from Table 5, Ref. 51.

†The first numbers given for each stability are appropriate at distances between 100 and 500 m, the second numbers at distances between 500 and 5000 m, and the third numbers at distances greater than 5000 m.

Assuming an ambient temperature of 293°K (20°C) and an ambient potential temperature lapse rate ($\partial\theta/\partial z$) of 0.5°K/100 m, representative of moderately stable conditions,

$$F = 9.8 \left(\frac{T-293}{T}\right) V, \tag{A.11}$$

$$C = 21.4F^{0.75}\ m^2/sec \text{ for } F<55\ m^4/sec^3, \tag{A.12}$$

$$C = 38.7F^{0.6}\ m^2/sec \text{ for } F>55\ m^4/sec^3, \text{ and} \tag{A.13}$$

$$D = 47.2F^{1/3}\ m^{4/3}\ sec^{-1/3}. \tag{A.14}$$

A wind speed corresponding to the mglc can now be found. For neutral and unstable conditions,

$$u_{worst}(n/u) = \frac{b}{d}\frac{C}{h_s}, \tag{A.15}$$

with a corresponding mglc

$$\chi_{worst}(n/u) = \frac{AQ \times 10^6}{\pi} \cdot \frac{1}{Ch_s^{b/d}} \cdot \frac{(b/d)^{b/d}}{(1+b/d)^{1+b/d}} . \tag{A.16}$$

For stable conditions

$$\chi_{worst}(s) = \frac{AQ \times 10^6}{\pi} \cdot \frac{u^{(b-2d)/3d}}{(u^{1/3}h_s + D)^{1+b/d}}. \tag{A.17}$$

Equation A.17 has no maximum unless b/d is greater than 2. Operationally, this difficulty is solved by setting u = 2 m/sec for the stable case in which case Eqs. A.10 and A.17 become

$$\Delta h(s) = 0.794\ D \tag{A.18}$$

and

$$\chi_{worst}(s) = \frac{AQ \times 10^6}{\pi} \cdot \frac{2^{(b-2d)/3d}}{(1.26\ h_s+D)^{1+b/d}} . \tag{A.19}$$

Equations A.15, A.16, and A.19 are the basic equations used to calculate the short-term mglc. The calculations need to be done separately for unstable, neutral, and stable conditions and the maximum value selected for the mglc. In addition, for each stability class, the calculations need to be done for three ranges of downwind distance because of the dependence of c, d, and A on x (see Table A.1). The value chosen for each stability class is the maximum self-consistent value, that is, the maximum of the values for which the calculated x_m falls within the range of downwind distances over which the particular c, d, and A values apply.

In implementing this procedure, high worst-case wind speeds are occasionally found which are unlikely to persist for periods of time on the order of hours to one day. On the other hand, low worst-case wind speeds are found which are small enough to render the Gaussian plume formulation inapplicable. To avoid both extremes and still retain a conservative estimate of the mglc, limits are placed on the worst-case wind speed for neutral/unstable conditions such that $0.8 \leq u_w \leq 30$ m/sec.

Estimates made in this way are appropriate for averaging times of one hour. For averaging times out to about 24 hours, the one-hour estimates can be multiplied by an appropriate conversion factor from Table A.2. These factors represent a power law dependence of concentration on averaging time with an exponent of -0.17:

$$\chi(t) = \chi(1)t^{-0.17}. \tag{A.20}$$

For averaging times between 24 hours and about one month, a recognized simple procedure for estimating the concentration from a single source at one averaging time given the concentration at another averaging time appears to be lacking. Larsen[54] has developed a method which can be used in multi-source applications. For averaging times less than one month, he finds that for a year's data

$$\chi_{max}(t) = \chi_{max}(1\ hr)t^q \tag{A.21}$$

where q depends upon the geometric standard deviation of the concentration values. The form of Eq. A.21 with $q = -0.17$ is exactly the same as that of Eq. A.20. On the basis of this equivalence of mathematical form, the use of Eq. A.20 was extended beyond 24 hours to estimate conversion factors for 4 and 10 days as shown in Table A.2.

A.2 LONG-TERM ESTIMATES

Expected monthly and annual mglc's from a single source are based upon the "sector-averaged" form of Eq. A.1:[49,55]

Table A.2 Averaging Time Conversion Factors

Averaging Time (hrs)	Conversion Factor
1	1.00[a]
3	0.83[a]
4	0.79[a]
8	0.70[a]
24	0.58[a]
96 (4 da)	0.46[b]
240 (10 da)	0.39[b]

[a] Based on Ref. 49.

[b] See discussion in text.

$$\chi(x) = \left(\frac{2}{\pi}\right)^{1/2} \frac{fQ \times 10^6}{u\sigma_z(x)\left(\frac{2\pi x}{n}\right)} \exp\left[-1/2\left(\frac{H}{\sigma_z(x)}\right)^2\right] \tag{A.22}$$

where:

n = the number of sectors into which the entire 360° range of wind directions is divided and

f = the fraction of the time during which the wind direction lies in the sector of interest.

Using the same parameterization as above (Eq. A.3),

$$\chi_m = \frac{BfQ \times 10^6}{uh^{2\beta}} \tag{A.23}$$

where:

$$\beta = (1+d)/2d \tag{A.24}$$

and

$$B = \left(\frac{2}{\pi}\right)^{1/2} \frac{n}{2\pi} c^{2\beta-1} (2\beta)^{\beta} \exp(-\beta). \tag{A.25}$$

To estimate the expected long-term mglc, values of c and d for neutral atmospheric stability and distances between 500 and 5000 m are used and the plume rise is calculated using Eq. A.9. With these assumptions,

$B = 0.256$ and

$\beta = 1.23$.

Examination of annual wind roses in Ref. 56 indicated that the maximum expected wind direction in a single 22.5° sector ($n=16$) is about 27% ($f=0.27$). For monthly wind roses, this maximum persistence is about 45% ($f=0.45$). The wind speed u used for both the annual and monthly calculations is $u = 4.4$ m/sec, corresponding to the nationwide annual mean wind speed based upon the speeds listed with the annual wind roses. For these conditions Eq. A.23 gives

$$\chi_m(yr) = \frac{0.0157\ Q \times 10^6}{H^{2.46}} \text{ for annual mglc's} \tag{A.26}$$

and

$$\chi_m(mo) = \frac{0.0262\ Q \times 10^6}{H^{2.46}} \text{ for monthly mglc's.} \tag{A.27}$$

APPENDIX B

Pollutant Sensitivities of Plant Species

Table B.1. Sulfur Dioxide Sensitivity of Crop Species[a]

Sensitivity			
Sensitive		Intermediate	Resistant
Alfalfa	Leek	Cotton	Corn
Apple	Lettuce		Sorghum
Barley	Oats		Cantaloupe
Bean, field	Okra		Citrus spp.
, lima	Onion		
Beet, sugar	Parsley		
, table	Parsnip		
Blackberry	Pea		
Blueberry	Peach		
Broccoli	Pear		
Brussels Sprouts	Pepper		
Cabbage	Plum, prune		
Carrot	Potato, Irish		
Celery	Potato, sweet		
Chard, Swiss	Pumpkin		
Cherry, sour	Radish		
, sweet	Raspberry		
Clover	Rye		
Clover, sweet	Safflower		
Cucumber	Soybean		
Currant, red	Spinach		
Eggplant	Squash		
Endive	Tobacco		
Gooseberry	Turnip		
Grapes	Wheat		
Kale			

[a] Compiled from data in Ref. 16.

Table B.2. Sulfur Dioxide Sensitivity of Natural Vegetation[a]

Common Name	Scientific Name
Sensitive	
Alder, mountain	*Alnus tenuifolia*
Aspen, large-toothed	*Populus grandidentata*
, trembling	*Populus tremuloides*
Ash, red (green)	*Fraxinus pennsylvanica*
, white	*Fraxinus americana*
Birch, gray	*Betula populifolia*
, western paper	*Betula papyrifera commutata*
, white(paper)	*Betula papyrifera*
, yellow	*Betula allegheniensis*
Blueberry, lowbush	*Vaccinium angustifolium*
Cherry, bitter	*Prunus emarginata*
Fir, subalpine	*Abies lasiocarpa*
Grasses-bentgrass	*Agrostis palustris*
-bluegrass	*Poa annua*
-desert grass	*Oryzopsis hymenoides*
-Ky. bluegrass	*Poa pratensis*
-orchard grass	*Dactylis glomerata*
-red fescue	*Festuca rubra*
Hazel, beaked	*Corylus cornuta*
, California	*Corylus cornuta californica*
Hemlock, mountain	*Tsuga mertensia*
Larch, western	*Larix occidentalis*
Maple, Manitoba	*Acer negundo interius*
, Rocky Mt.	*Acer glabrum*
Mulberry, Texas	*Morus microphylla*
Pine, eastern white	*Pinus strobus*
, jack	*Pinus banksiana*
, red	*Pinus resinosa*
, Virginia	*Pinus virginiana*
Rockspirea, creambush	*Holodiscus discolor*
Serviceberry, low	*Amelanchier stolonifera*
, Saskatoon	*Amelanchier alnifolia*
, Utah	*Amelanchier utahensis*
Sumac, staghorn	*Rhus typhina*
Tulip tree	*Liriodendron tulipifera*
Willow, black	*Salix nigra*

Table B.2. (Cont'd)

Common Name	Scientific Name
Intermediate	
Basswood	*Tilia americana*
Birch, water	*Betula occidentalis*
Boxelder	*Acer negundo*
Chokecherry	*Prunus virginiana*
Cottonwood, black	*Populus trichocarpa*
, eastern	*Populus deltoides*
, narrowleaf	*Populus angustifolia*
Dogwood, red osier	*Cornus stolonifera*
Elm, American	*Ulmus americana*
Fir, blasam	*Abies balsamea*
, Douglas	*Pseudotsuga menziesii*
, grand	*Abies grandis*
Grape, wild	*Vitis riparia*
Hemlock, western	*Tsuga heterophylla*
Mahogany, mountain	*Cercocarpus montanus*
Maple, Douglas	*Acer glabrum douglasii*
, red	*Acer rubrum*
Mountain-ash, western	*Sorbus scopulina*
Oak, white	*Quercus alba*
Pine, lodgepole	*Pinus contorta*
, ponderosa	*Pinus ponderosa*
, shortleaf	*Pinus echinata*
, western white	*Pinus monticola*
Poplar, balsam	*Populus balsamifera*
Sagebrush, big	*Artemisia tridentata*
Snowberry, mountain	*Symphoricarpos oreophilus*
, Columbia	*Symphoricarpos rivularis*
Spruce, Engelmann	*Picea engelmannii*
, white	*Picea, glauca*
Witch hazel	*Hamamelis virginiana*
Resistant	
Black gum	*Nyssa sylvatica*
Buck-brush	*Ceanothus velutinus*
Buffalo-berry	*Shepherdia canadensis*
Ceanothus, redstem	*Ceanothus sanguineus*
Cedar, western red	*Thuja plicata*
, white(arborvitae)	*Thuja occidentalis*
Dogwood, flowering	*Cornus florida*
Fir, silver	*Abies amabilis*
, white	*Abies concolor*
Hawthorn, black	*Crataegus douglasii*

Table B.2. (Cont'd)

Common Name	Scientific Name
Resistant (cont'd)	
Grape, Oregon	*Odostemon aquifolium*
Grasses-blue grama	*Bouteloua gracilis*
-needle grass	*Stipa comata*
-western wheatgrass	*Agropyron smithii*
Juniper, common	*Juniperus communis*
, Rocky Mt.	*Juniperus scopulorum*
, Utah	*Juniperus osteosperma*
, Western	*Juniperus occidentalis*
Kinnikinnick	*Arctostaphylos uva-ursi*
Locust, black	*Robinia pseudoacacia*
Mahogany, curl-leaf mt.	*Cercocarpus ledifolius*
Maple, mountain	*Acer spicatum*
, silver	*Acer saccharinum*
, sugar	*Acer saccharum*
Oak, gambel	*Quercus gambelii*
, live	*Quercus virginiana*
, northern red	*Quercus rubra*
, pin	*Quercus palustris*
Pine, limber	*Pinus flexilis*
, pinyon	*Pinus edulis*
Poplar, Carolina	*Populus canadensis*
Sourwood	*Oxydendron arboreum*
Spruce, blue	*Picea pungens*
Squawbush	*Rhus trilobata*
Sumac, smooth	*Rhus glabra*
Sycamore, American	*Platanus occidentalis*
Willow, shrubby	*Salix tristis*
Yew, Pacific	*Taxus brevifolia*

[a] Compiled from lists in Refs. 9 and 16.

Table B.3. Ozone Sensitivity of Crop Species[a]

Sensitivity		
Sensitive	Intermediate	Resistant
Alfalfa[b]	Bean, bush	Cotton
bean, pinto	, lima	Lettuce
, white	Beet, table	Onion
Broccoli	Cabbage	
Clover[b]	Chard, swiss[d]	
Corn, sweet	Clover, white sweet	
Oats[b]	Corn, field	
Radish[c]	Cucumber[d]	
Safflower[c]	Potato, Irish	
Soybean[b]	Sorghum	
Spinach[b]	Squash, summer	
Tobacco		
Tomato[b]		

[a] Compiled from data in Ref. 18.

[b] Some cultivars intermediate or resistant.

[c] Some cultivars intermediate.

[d] Some cultivars resistant.

Table B.4. Ozone Sensitivity of Natural Vegetation[a]

Common Name	Scientific Name
Sensitive	
Aspen, trembling	*Populus tremuloides*
Ash, red(green)	*Fraxinus pennsylvanica*
, white	*Fraxinus americana*
Cottonwood, black	*Populus trichocarpa*
Grasses-bent grass	*Agrostis palustris*
-blue grass	*Poa annua*
-brome grass	*Bromus tectorum*
Oak, gambel	*Quercus gambelii*
, white	*Quercus alba*
Pine, Coulter	*Pinus coulteri*
, eastern white	*Pinus strobus*
, jack	*Pinus banksiana*
, jeffrey	*Pinus jeffreyi*
, loblolly	*Pinus taeda*
, Monterey	*Pinus radiata*
, ponderosa	*Pinus ponderosa*
, Virginia	*Pinus virginiana*
Serviceberry, Saskatoon	*Amelanchier alnifolia*
Sycamore, American	*Platanus occidentalis*
Tulip tree	*Liriodendron tulipifera*
Intermediate	
Boxelder	*Acer negundo*
Cedar, incense	*Libocedrus decurrens*
Grasses-Ky. bluegrass	*Poa pratensis*
-perennial rye	*Lolium perenne*
-red fescue	*Festuca rubsa*
Oak, black	*Quercus velutina*
, pin	*Quercus palustris*
, scarlet	*Quercus coccinea*
Pine, lodgepole	*Pinus contorta*
, pitch	*Pinus rigida*
, shortleaf	*Pinus echinata*
, slash	*Pinus elliottii*
, sugar	*Pinus lambertiana*
, Torrey	*Pinus torreyana*
Redbud	*Cercis canadensis*
Sweetgum	*Liquidambar styraciflua*

Table B.4. (Cont'd)

Common Name	Scientific Name
Resistant	
Basswood	*Tilia americana*
Birch, white (paper)	*Betula papyrifera*
Black gum	*Nyssa sylvatica*
Cedar, white (arborvitae)	*Thuja occidentalis*
Dogwood, flowering	*Cornus florida*
Fir, balsalm	*Abies balsamea*
, Douglas	*Pseudotsuga menziesii*
, white	*Abies concolor*
Grasses-orchard grass	*Dactylis glomerata*
Hemlock	*Tsuga canadensis*
Juniper, western	*Juniperus occidentalis*
Locust, black	*Robinia pseudoacacia*
Maple, red	*Acer rubrum*
, sugar	*Acer saccharum*
Oak, mossy-cup	*Quercus macrocarpa*
, northern red	*Quercus rubra*
, shingle	*Quercus imbricaria*
Pine, digger,	*Pinus sabiniana*
, red	*Pinus resinosa*
Redwood	*Sequoia sempervirens*
Sequoia	*Sequoiadendron giganteum*
Spruce, black	*Picea mariana*
, blue	*Picea pungens*
, white	*Picea glaucaa*
Walnut, black	*Juglans nigra*

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[a] Compiled from lists in Refs. 18 and 57.

Table B.5. Nitrogen Dioxide Sensitivity of Crop Species[a]

	Sensitivity	
Sensitive	Intermediate	Resistant
Alfalfa	Bean, bush	Asparagus
Barley	Celery	Cabbage, red
Bean, pinto	Citrus spp.	, white
Broccoli	Corn, sweet	Corn, field
Carrot	Cotton	Cucumber
Clover, crimson	Endive	Kale
, red	Potato, Irish	Kohlrabi
Leek	Rye	Onion
Lettuce	Strawberry, pine	Sorghum
Lucerne	Tomato	
Mustard, white	Wheat	
Oats		
Parsley		
Peas		
Radish		
Rhubarb		
Tobacco[b]		

[a] Compiled from lists in Refs. 19, 20, and 58.

[b] Some cultivars intermediate or resistant.

Table B.6. Nitrogen Dioxide Sensitivity of Natural Vegetation[a]

Common Name	Scientific Name
Sensitive	
Grasses-Viper's grass	*Scorzonera hispanica*
Intermediate	
Fir, common silver	*Abies pectinata*
, white	*Abies alba*
Grasses-bluegrass	*Poa annua*
Spruce, blue	*Picea pungens*
, white	*Picea glauca*
Resistant	
Grasses-Ky. bluegrass	*Poa pratensis*

[a] Compiled from tables in Refs. 20 and 58.

APPENDIX C

Trace Element Air Quality Data

TABLE C-2. AIR QUALITY DATA FOR CADMIUM

STATE	COUNTY	MINIMUM (UG/M3) OBS	MINIMUM (UG/M3) ARITH MEAN	MINIMUM (UG/M3) GEO MEAN	MAXIMUM (UG/M3) OBS	MAXIMUM (UG/M3) ARITH MEAN	MAXIMUM (UG/M3) GEO MEAN
	ITASCA	0.0010	---	---	0.0010	---	---
	KANDIYOHI	0.0010	---	---	0.0020	---	---
	KOOCHICHING	0.0010	---	---	0.0110	---	---
	LYON	0.0010	---	---	0.0040	---	---
	MCLEOD	0.0010	---	---	0.0010	---	---
	MILLE LACS	0.0010	---	---	0.0010	---	---
	MOWER	0.0010	---	---	0.0020	---	---
	NOBLES	0.0010	---	---	0.0020	---	---
	OLMSTED	0.0010	---	---	0.0450	---	---
	OTTERTAIL	0.0010	---	---	0.0020	---	---
	POLK	0.0010	---	---	0.0050	---	---
	ST. LOUIS	0.0010	---	---	0.0030	---	---
	SCOTT	0.0010	---	---	0.0020	---	---
	STEARNS	0.0010	---	---	0.0180	---	---
	WASHINGTON	0.0010	---	---	0.0040	---	---
	WINONA	0.0010	---	---	0.0020	---	---
MO	ADAIR	0.0010	---	---	0.0042	---	---
	AUDRAIN	0.0016	---	---	0.0028	---	---
	BOONE	0.0007	---	---	0.0140	---	---
	BUCHANAN	0.0016	---	---	0.0440	---	---
	BUTLER	0.0003	---	---	0.0062	---	---
	CALLAWAY	0.0012	---	---	0.0055	---	---
	CAMDEN	0.0003	---	---	0.0046	---	---
	CAPE GIRARDEAU	0.0020	---	---	0.0050	---	---
	CLAY	0.0016	---	---	0.0150	---	---
	COLE	0.0012	---	---	0.0066	---	---
	JASPER	0.0024	---	---	0.0079	---	---
	JEFFERSON	0.0027	---	---	1.4350	---	---
	LIVINGSTON	0.0010	---	---	0.0052	---	---
	MARION	0.0012	---	---	0.0050	---	---
	NEW MADRID	0.0003	---	---	0.0045	---	---
	NODAWAY	0.0010	---	---	0.0052	---	---
	PETTIS	0.0008	---	---	0.0125	---	---
	PHELPS	0.0011	---	---	0.0053	---	---
	PLATTE	0.0010	---	---	0.0109	---	---
	ST. CHARLES	0.0050	---	---	0.0060	---	---
	STE. GENEVIEVE	0.0031	---	---	0.0030	---	---
	SCOTT	0.0010	---	---	0.0074	---	---
	VERNON	0.0015	---	---	0.0041	---	---
MT	DEER LODGE	0.0100	---	---	0.0500	---	---
NM	RIO ARRIBA	0.0001	0.0001	0.0001	0.0100	0.0002	0.0001

A INDICATES ONLY ONE STATION REPORTING

TABLE C-2. AIR QUALITY DATA FOR CADMIUM

STATE	COUNTY	MINIMUM (UG/M3)			MAXIMUM (UG/M3)		
		OBS	ARITH MEAN	GEO MEAN	OBS	ARITH MEAN	GEO MEAN
	SAN JUAN	0.0001	0.0002	0.0001	0.2000	0.0002	0.0001
OK	OKLAHOMA	0.0001	0.0008	0.0006	5.0000	0.2739	0.0012
SC	CHARLESTON	0.0020	---	---	0.0020	---	---
TN	ANDERSON	0.0010	---	---	0.0030	---	---
	BEDFORD	0.0010	---	---	0.0010	---	---
	BLOUNT	0.0010	---	---	0.0040	---	---
	BRADLEY	0.0010	---	---	0.0010	---	---
	CAMPBELL	0.0010	---	---	0.0040	---	---
	CARTER	0.0010	---	---	0.0010	---	---
	COFFEE	0.0010	---	---	0.0050	---	---
	CUMBERLAND	0.0010	---	---	0.0020	---	---
	DYER	0.0010	---	---	0.0030	---	---
	GIBSON	0.0010	---	---	0.0070	---	---
	GREENE	0.0010	---	---	0.0010	---	---
	HAMBLEN	0.0010	---	---	0.0090	---	---
	HENRY	0.0010	---	---	0.0030	---	---
	HUMPHREYS	0.0010	---	---	0.0040	---	---
	LINCOLN	0.0010	---	---	0.0010	---	---
	MCMINN	0.0040	---	---	0.0040	---	---
	MADISON	0.0010	---	---	0.0030	---	---
	MARION	0.0010	---	---	0.0030	---	---
	MAURY	0.0010	---	---	0.0030	---	---
	MONTGOMERY	0.0010	---	---	0.0100	---	---
	OBION	0.0010	---	---	0.0030	---	---
	POLK	0.0010	---	---	0.0370	---	---
	PUTNAM	0.0010	---	---	0.0010	---	---
	ROANE	0.0010	---	---	0.0090	---	---
	ROBERTSON	0.0010	---	---	0.0050	---	---
	RUTHERFORD	0.0010	---	---	0.0010	---	---
	SULLIVAN	0.0010	---	---	0.0050	---	---
	SUMNER	0.0010	---	---	0.0020	---	---
	WARREN	0.0010	---	---	0.0010	---	---
	WASHINGTON	0.0010	---	---	0.0010	---	---
	WILLIAMSON	0.0010	---	---	0.0010	---	---
	WILSON	0.0010	---	---	0.0010	---	---
TX	BEE	0.0300	---	---	0.0300	---	---
	BEXAR	0.0300	0.0300A	0.0300A	0.0300	0.0300A	0.0300A
	BOWIE	0.0300	0.0300A	0.0300A	0.0300	0.0300A	0.0300A
	BRAZORIE	0.0300	0.0300	0.0300	0.0300	0.0300	0.0300

A INDICATES ONLY ONE STATION REPORTING

TABLE C-2. AIR QUALITY DATA FOR CADMIUM

STATE	COUNTY	MINIMUM (UG/M3) OBS	MINIMUM (UG/M3) ARITH MEAN	MINIMUM (UG/M3) GEO MEAN	MAXIMUM (UG/M3) OBS	MAXIMUM (UG/M3) ARITH MEAN	MAXIMUM (UG/M3) GEO MEAN
	BRAZOS	0.0300	0.0300A	0.0300A	0.0300	0.0300A	0.0300A
	BROWN	0.0300	---	---	0.0300	---	---
	CALHOUN	0.0300	---	---	0.0300	---	---
	CAMERON	0.0300	0.0300	0.0300	0.0300	0.0300	0.0300
	CHAMBERS	0.0300	---	---	0.0300	---	---
	DALLAS	0.0300	0.0300	0.0300	0.1000	0.0300	0.0300
	DENTON	0.0300	---	---	0.0300	---	---
	ECTOR	0.0300	0.0300A	0.0300A	0.0300	0.0300A	0.0300A
	ELLIS	0.0300	---	---	0.0300	---	---
	EL PASO	0.0300	0.0300	0.0300	0.1000	0.0300	0.0300
	GALVESTON	0.0300	0.0300A	0.0300A	0.1000	0.0300A	0.0300A
	GRAY	0.0300	---	---	0.0300	---	---
	GRAYSON	0.0300	---	---	0.0300	---	---
	HALE	0.0300	---	---	0.0300	---	---
	HARRIS	0.0001	0.0300	0.0300	0.0300	0.0300	0.0300
	HAYS	0.0300	---	---	0.0300	---	---
	HIDALGO	0.0300	0.0300	0.0300	0.0300	0.0300	0.0300
	HOWARD	0.0300	0.0300A	0.0300A	0.0300	0.0300A	0.0300A
	JEFF DAVIS	0.0300	---	---	0.0300	---	---
	JEFFERSON	0.0300	0.0300A	0.0300A	0.0300	0.0300A	0.0300A
	LUBBOCK	0.0300	---	---	0.0300	---	---
	MCLENNAN	0.0300	---	---	0.0300	---	---
	MCMULLEN	0.0300	---	---	0.0300	---	---
	MATAGORDA	0.0300	---	---	0.0300	---	---
	MAVERICK	0.0300	0.0300A	0.0300A	0.0300	0.0300A	0.0300A
	MIDLAND	0.0300	0.0300A	0.0300A	0.0300	0.0300A	0.0300A
	MONTGOMERY	0.0300	---	---	0.0300	---	---
	MOORE	0.0300	---	---	0.0300	---	---
	NACOGDOCHES	0.0300	---	---	0.0300	---	---
	NUECES	0.0300	0.0300	0.0300	0.2000	0.0300	0.0300
	ORANGE	0.0300	0.0300A	0.0300A	0.0300	0.0300A	0.0300A
	POTTER	0.0300	---	---	0.0300	---	---
	SAN PATRICIO	0.0300	---	---	0.0300	---	---
	SCURRY	0.0300	---	---	0.0300	---	---
	SMITH	0.0300	0.0300A	0.0300A	0.0300	0.0300A	0.0300A
	TARRANT	0.0300	---	---	0.0300	---	---
	TAYLOR	0.0300	0.0300A	0.0300A	0.0300	0.0300A	0.0300A
	TITUS	0.0300	0.0300A	0.0300A	0.0300	0.0300A	0.0300A
	TOM GREEN	0.0300	---	---	0.0300	---	---
	TRAVIS	0.0300	0.0300	0.0300	0.0300	0.0300	0.0300
	VAL VERDE	0.0300	---	---	0.0300	---	---
	VICTORIA	0.0300	---	---	0.0300	---	---
	WALKER	0.0300	---	---	0.0300	---	---

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TABLE C-2. AIR QUALITY DATA FOR CADMIUM

STATE	COUNTY	MINIMUM (UG/M3) OBS	MINIMUM (UG/M3) ARITH MEAN	MINIMUM (UG/M3) GEO MEAN	MAXIMUM (UG/M3) OBS	MAXIMUM (UG/M3) ARITH MEAN	MAXIMUM (UG/M3) GEO MEAN
	WEBB	0.0300	---	---	0.0300	---	---
	WICHITA	0.0300	---	---	0.0300	---	---
	WISE	0.0300	---	---	0.0300	---	---
UT	EMERY	0.0001	---	---	0.0001	---	---
	GARFIELD	0.0001	0.0001	0.0001	0.0200	0.0003	0.0001
	KANE	0.0001	0.0002A	0.0001A	0.0100	0.0002A	0.0001A
	SAN JUAN	0.0001	0.0001	0.0001	0.0100	0.0020	0.0001
	WASHINGTON	0.0001	0.0001	0.0001	0.0100	0.0002	0.0001

TABLE C-3. AIR QUALITY DATA FOR CHROMIUM

		MINIMUM (UG/M3)			MAXIMUM (UG/M3)		
STATE	COUNTY	OBS	ARITH MEAN	GEO MEAN	OBS	ARITH MEAN	GEO MEAN
AZ	APACHE	0.0010	0.0020	0.0010	0.0500	0.0030	0.0010
	COCONINO	0.0010	0.0020	0.0010	0.0700	0.0050	0.0020
	MARICOPA	0.0010	---	---	0.0010	---	---
	MOHAVE	0.0010	0.0010	0.0010	0.0300	0.0040	0.0020
	NAVAJO	0.0010	0.0030A	0.0010A	0.0500	0.0030A	0.0010A
CO	LA PLATA	0.0010	0.0020A	0.0010A	0.0500	0.0040A	0.0020A
	MONTEZUMA	0.0010	0.0030A	0.0010A	0.0400	0.0030A	0.0010A
MO	ADAIR	0.0060	---	---	0.0980	---	---
	AUDRAIN	0.0060	---	---	0.0920	---	---
	BOONE	0.0040	---	---	0.0170	---	---
	BUCHANAN	0.0060	---	---	0.0860	---	---
	BUTLER	0.0050	---	---	0.0130	---	---
	CALLAWAY	0.0050	---	---	0.0670	---	---
	CAMDEN	0.0040	---	---	0.0310	---	---
	CAPE GIRARDEAU	0.0050	---	---	0.0180	---	---
	CLAY	0.0070	---	---	0.0600	---	---
	COLE	0.0060	---	---	0.0640	---	---
	JASPER	0.0070	---	---	0.0150	---	---
	JEFFERSON	0.0030	---	---	0.0640	---	---
	LIVINGSTON	0.0040	---	---	0.0680	---	---
	MARION	0.0060	---	---	0.0670	---	---
	NEW MADRID	0.0050	---	---	0.2370	---	---
	NODAWAY	0.0060	---	---	0.0610	---	---
	PETTIS	0.0070	---	---	0.0110	---	---
	PHELPS	0.0050	---	---	0.0840	---	---
	PLATTE	0.0050	---	---	0.0620	---	---
	ST. CHARLES	0.0050	---	---	0.0080	---	---
	STE. GENEVIEVE	0.0090	---	---	0.0090	---	---
	SCOTT	0.0050	---	---	0.0780	---	---
	VERNON	0.0070	---	---	0.0130	---	---
IN	ALLEN	0.0050	---	---	0.0270	---	---
	BARTHOLOMEW	0.0010	---	---	0.0140	---	---
	ELKHART	0.0020	---	---	0.0090	---	---
	LAKE	0.0060	---	---	0.0160	---	---
	MONROE	0.0050	---	---	0.0110	---	---
	VANDERBURGH	0.0040	---	---	0.0100	---	---
NM	RIO ARRIBA	0.0010	0.0020A	0.0010A	0.0500	0.0030A	0.0010A
	SAN JUAN	0.0010	0.0020	0.0010	0.0500	0.0030	0.0010

A INDICATES ONLY ONE STATION REPORTING

TABLE C-3. AIR QUALITY DATA FOR CHROMIUM

STATE	COUNTY	MINIMUM (UG/M3) OBS	MINIMUM (UG/M3) ARITH MEAN	MINIMUM (UG/M3) GEO MEAN	MAXIMUM (UG/M3) OBS	MAXIMUM (UG/M3) ARITH MEAN	MAXIMUM (UG/M3) GEO MEAN
SC	CHARLESTON	0.1530	---	---	0.1530	---	---
TN	ANDERSON	0.0010	---	---	99.0000	---	---
	BEDFORD	0.0010	---	---	0.0050	---	---
	BLOUNT	0.0010	---	---	0.0050	---	---
	BRADLEY	0.0010	---	---	0.0050	---	---
	CAMPBELL	0.0010	---	---	0.0050	---	---
	CARTER	0.0010	---	---	0.0010	---	---
	COFFEE	0.0010	---	---	0.0050	---	---
	CUMBERLAND	0.0010	---	---	0.0090	---	---
	DYER	0.0010	---	---	0.0050	---	---
	GIBSON	0.0010	---	---	0.0050	---	---
	GREENE	0.0010	---	---	0.0010	---	---
	HAMBLEN	0.0010	---	---	0.0050	---	---
	HENRY	0.0010	---	---	0.0050	---	---
	HUMPHREYS	0.0010	---	---	0.0050	---	---
	LINCOLN	0.0010	---	---	0.0010	---	---
	MCMINN	0.0050	---	---	0.0050	---	---
	MADISON	0.0010	---	---	0.0050	---	---
	MARION	0.0010	---	---	0.0050	---	---
	MAURY	0.0010	---	---	0.0050	---	---
	MONTGOMERY	0.0010	---	---	0.0090	---	---
	OBION	0.0010	---	---	0.0050	---	---
	POLK	0.0010	---	---	0.0050	---	---
	PUTNAM	0.0010	---	---	0.0020	---	---
	ROANE	0.0010	---	---	0.0050	---	---
	ROBERTSON	0.0010	---	---	0.0050	---	---
	RUTHERFORD	0.0010	---	---	0.0050	---	---
	SULLIVAN	0.0010	---	---	0.0050	---	---
	SUMNER	0.0010	---	---	0.0050	---	---
	WARREN	0.0010	---	---	0.0050	---	---
	WASHINGTON	0.0010	---	---	0.0010	---	---
	WILLIAMSON	0.0010	---	---	0.0010	---	---
	WILSON	0.0010	---	---	0.0050	---	---
TX	BEE	0.0200	---	---	0.0200	---	---
	BEXAR	0.0200	---	---	0.0900	---	---
	BOWIE	0.0200	---	---	0.0900	---	---
	BRAZORIA	0.0200	---	---	0.0300	---	---
	BRAZOS	0.0200	---	---	0.0200	---	---
	BROWN	0.0200	---	---	0.0200	---	---
	CALHOUN	0.0200	---	---	0.0200	---	---

A INDICATES ONLY ONE STATION REPORTING

TABLE C-3. AIR QUALITY DATA FOR CHROMIUM

STATE	COUNTY	MINIMUM (UG/M3)			MAXIMUM (UG/M3)		
		OBS	ARITH MEAN	GEO MEAN	OBS	ARITH MEAN	GEO MEAN
	CAMERON	0.0200	---	---	0.2400	---	---
	CHAMBERS	0.0200	---	---	0.0200	---	---
	DALLAS	0.0200	---	---	0.0500	---	---
	DENTON	0.0200	---	---	0.0200	---	---
	ECTOR	0.0200	---	---	0.0500	---	---
	ELLIS	0.0200	---	---	0.0200	---	---
	EL PASO	0.0200	---	---	0.1400	---	---
	GALVESTON	0.0200	---	---	0.1000	---	---
	GRAY	0.0200	---	---	0.0200	---	---
	GRAYSON	0.0200	---	---	0.0200	---	---
	HALE	0.0200	---	---	0.0200	---	---
	HARRIS	0.0010	---	---	0.5600	---	---
	HAYS	0.0200	---	---	0.0200	---	---
	HIDALGO	0.0200	---	---	0.0200	---	---
	HOWARD	0.0200	---	---	0.0500	---	---
	JEFF DAVIS	0.0200	---	---	0.0500	---	---
	JEFFERSON	0.0200	---	---	0.0700	---	---
	LUBBOCK	0.0200	---	---	0.0200	---	---
	MCLENNAN	0.0200	---	---	0.0200	---	---
	MCMULLEN	0.0200	---	---	0.0200	---	---
	MATAGORDA	0.0200	---	---	0.0200	---	---
	MAVERICK	0.0200	---	---	0.0200	---	---
	MIDLAND	0.0200	---	---	0.0200	---	---
	MONTGOMERY	0.0200	---	---	0.0200	---	---
	MOORE	0.0200	---	---	0.0200	---	---
	NACOGDOCHES	0.0200	---	---	0.0200	---	---
	NUECES	0.0200	---	---	0.3100	---	---
	ORANGE	0.0200	---	---	0.0200	---	---
	POTTER	0.0200	---	---	0.0800	---	---
	SAN PATRICIO	0.0200	---	---	0.0700	---	---
	SCURRY	0.0200	---	---	0.0200	---	---
	SMITH	0.0200	---	---	0.0700	---	---
	TARRANT	0.0200	---	---	0.0700	---	---
	TAYLOR	0.0200	---	---	0.0700	---	---
	TAYLOR	0.0200	---	---	0.0200	---	---
	TOM GREEN	0.0200	---	---	0.0200	---	---
	TRAVIS	0.0200	---	---	0.0700	---	---
	VAL VERDE	0.0200	---	---	0.0200	---	---
	VICTORIA	0.0200	---	---	0.0200	---	---
	WALKER	0.0200	---	---	0.0200	---	---
	WEBB	0.0200	---	---	0.0200	---	---
	WICHITA	0.0200	---	---	0.0200	---	---
	WISE	0.0200	---	---	0.0200	---	---

A INDICATES ONLY ONE STATION REPORTING

TABLE C-3. AIR QUALITY DATA FOR CHROMIUM

STATE	COUNTY	MINIMUM (UG/M3) OBS	MINIMUM (UG/M3) ARITH MEAN	MINIMUM (UG/M3) GEO MEAN	MAXIMUM (UG/M3) OBS	MAXIMUM (UG/M3) ARITH MEAN	MAXIMUM (UG/M3) GEO MEAN
UT	EMERY	0.0010	---	---	0.0300	---	---
	GARFIELD	0.0010	0.0020	0.0010	0.0500	0.0040	0.0010
	KANE	0.0010	0.0030A	0.0010A	0.0300	0.0030A	0.0010A
	SAN JUAN	0.0010	0.0010	0.0010	0.0400	0.0040	0.0020
	WASHINGTON	0.0010	0.0020	0.0010	0.0400	0.0030	0.0010

TABLE C-4. AIR QUALITY DATA FOR FLUORIDE ION

STATE	COUNTY	MINIMUM (UG/M3)			MAXIMUM (UG/M3)		
		OBS	ARITH MEAN	GEO MEAN	OBS	ARITH MEAN	GEO MEAN
AZ	MARICOPA	0.0200	0.0300	0.0300	0.3700	0.0500	0.0400
ND	BARNES	0.0200	0.0200A	0.0300A	0.0500	0.0200A	0.0300A
	BILLINGS	0.0200	0.0200A	0.0300A	0.0800	0.0300A	0.0300A
	BOWMAN	0.0200	0.0200A	0.0300A	0.0200	0.0200A	0.0300A
	BURLEIGH	0.0200	0.0300A	0.0300A	0.3500	0.0400A	0.0300A
	CASS	0.0200	0.0200	0.0300	0.0300	0.0300	0.0300
	DUNN	0.0200	0.0200	0.0300	0.0200	0.0200	0.0300
	GRAND FORKS	0.0200	0.0200	0.0300	0.1900	0.0300	0.0300
	GRANT	0.0200	0.0300A	0.0300A	0.1200	0.0300A	0.0300A
	HETTINGER	0.0200	0.0200	0.0300	0.0200	0.0200	0.0300
	MCKENZIE	0.0200	0.0200A	0.0300A	0.0200	0.0200A	0.0300A
	MCLEAN	0.0200	0.0200A	0.0300A	0.1600	0.0200A	0.0300A
	MERCER	0.0200	0.0200	0.0300	0.3000	0.0600	0.0400
	MORTON	0.0200	0.0200	0.0300	0.0600	0.0300	0.0300
	MOUNTRAIL	0.0200	0.0200	0.0300	0.0200	0.0200	0.0300
	OLIVER	0.0200	0.0200	0.0300	0.1100	0.0300	0.0300
	RAMSEY	0.0200	0.0200A	0.0300A	0.0200	0.0200A	0.0300A
	RICHLAND	0.0200	0.0200	0.0300	0.0200	0.0200	0.0300
	SHERIDAN	0.0200	0.0200	0.0300	0.0200	0.0200	0.0300
	STARK	0.0200	0.0200	0.0300	0.0200	0.0200	0.0300
	STUTSMAN	0.0200	0.0200	0.0300	0.1400	0.0300	0.0300
	WARD	0.0200	0.0200A	0.0300A	0.0200	0.0200A	0.0300A
	WILLIAMS	0.0200	0.0200	0.0300	0.0200	0.0200	0.0300

TABLE C-5. AIR QUALITY DATA FOR LEAD

STATE	COUNTY	MINIMUM (UG/M3) OBS	MINIMUM (UG/M3) ARITH MEAN	MINIMUM (UG/M3) GEO MEAN	MAXIMUM (UG/M3) OBS	MAXIMUM (UG/M3) ARITH MEAN	MAXIMUM (UG/M3) GEO MEAN
AL	ETOWAH	0.1700	0.5300A	0.4400A	2.0600	0.5300A	0.4400A
	JEFFERSON	0.2000	0.9400A	0.8400A	4.2300	0.9400A	0.8400A
	MADISON	0.2200	0.6500A	0.5500A	1.9600	0.6500A	0.5500A
	MOBILE	0.3500	---	---	2.9400	---	---
	MONTGOMERY	0.2300	---	---	3.0900	---	---
AZ	APACHE	0.0010	0.0140	0.0010	0.2000	0.0320	0.0160
	COCHISE	0.0010	0.0190A	0.0090A	0.9300	0.0190A	0.0090A
	COCONINO	0.0010	0.0120	0.0060	0.6200	0.0260	0.0130
	GILA	0.0010	---	---	0.4000	---	---
	GRAHAM	0.1000	---	---	0.4000	---	---
	GREENLEE	0.0010	---	---	0.4000	---	---
	MARICOPA	0.0010	0.5530	0.0220	9.3670	2.3240	1.7560
	MOHAVE	0.0010	0.0130	0.0050	0.3000	0.0180	0.0070
	NAVAJO	0.0010	0.0150	0.0070	0.3000	0.0150	0.0070
	PIMA	0.0010	0.3600	0.3210	2.1870	1.0010	0.8470
	PINAL	0.1000	---	---	0.5000	---	---
	YAVAPAI	0.0010	---	---	0.2000	---	---
	YUMA	0.1000	---	---	0.4000	---	---
AR	CRITTENDEN	0.3800	---	---	2.8700	---	---
	MILLER	0.2300	---	---	1.0500	---	---
	MONTGOMERY	0.0500	---	---	0.1500	---	---
	PULASKI	0.3000	0.9100A	0.8390A	1.6300	0.9100A	0.8390A
CA	ALAMEDA	1.4900	0.7210	0.6110	6.1100	1.2150	0.8800
	FRESNO	0.2900	1.5100A	1.1200A	5.1300	1.5100A	1.1200A
	KERN	0.1960	1.4310A	1.0960A	5.5320	1.4310A	1.0960A
	LOS ANGELES	0.5200	1.9100	1.6100	8.9400	2.5900	2.6500
	MADERA	0.2450	---	---	2.0610	---	---
	MERCED	0.2110	---	---	0.8700	---	---
	MODOC	0.1860	---	---	0.1860	---	---
	MONTEREY	0.0450	0.5020A	0.4160A	1.5120	0.5020A	0.4160A
	NAPA	0.0600	0.7290A	0.5460A	4.0500	0.7290A	0.5460A
	ORANGE	0.4400	1.8000A	1.4200A	6.4900	1.8000A	1.4200A
	RIVERSIDE	0.0900	0.6120	0.5310	4.5490	1.8390	1.6740
	SACRAMENTO	0.2600	0.6310	0.7900	8.5000	1.1000	0.5150
	SAN BERNARDINO	0.4100	1.5600	1.4000	4.5500	1.6550	1.4820
	SAN DIEGO	0.2500	0.9680	0.9900	6.2600	1.5930	1.1040
	SAN FRANCISCO	0.3400	0.9000A	0.8000A	6.9100	1.0290A	0.8890A
	SAN JOAQUIN	0.2880	---	---	0.4630	---	---
	SAN MATEO	0.0100	0.6580A	0.4610A	4.2600	0.6580A	0.4610A

A INDICATES ONLY ONE STATION REPORTING

TABLE C-5. AIR QUALITY DATA FOR LEAD

STATE	COUNTY	MINIMUM (UG/M3) OBS	MINIMUM (UG/M3) ARITH MEAN	MINIMUM (UG/M3) GEO MEAN	MAXIMUM (UG/M3) OBS	MAXIMUM (UG/M3) ARITH MEAN	MAXIMUM (UG/M3) GEO MEAN
	SANTA BARBARA	0.0870	1.1050A	0.7940A	5.2470	1.1050A	0.7940A
	SANTA CLARA	0.3100	1.6200	0.8460	8.5000	1.4280	1.1180
	SISKIYOU	0.0620	0.2600A	0.2050A	0.8430	0.2600A	0.2050A
	SOLANO	0.0300	---	---	1.3000	---	---
	SONOMA	0.0800	0.4840	0.3480	2.0000	0.4840	0.3480
	TEHAMA	0.0670	---	---	0.3460	---	---
	VENTURA	0.1980	---	---	1.9870	---	---
CO	DENVER	0.4000	---	---	3.6400	---	---
	LA PLATA	0.0010	0.0170	0.0060	0.1700	0.0220	0.0100
	MONTEZUMA	0.0	0.0250A	0.0120A	0.1100	0.0250A	0.0120A
CT	FAIRFIELD	0.6300	1.3020A	1.2060A	2.4600	1.3020A	1.2060A
	HARTFORD	0.3400	1.0650A	0.9890A	2.2500	1.0650A	0.9890A
	NEW HAVEN	0.4600	1.1220	1.0100	4.1900	1.9160	1.7340
DE	KENT	0.0500	0.1600A	0.1300A	0.5200	0.1600A	0.1300A
	NEW CASTLE	0.0700	0.5300	0.3900	3.0700	1.5000	1.4200
DC	WASHINGTON	0.4600	---	---	3.1800	---	---
FL	DADE	0.1000	0.3460	0.2590	6.9000	2.0270	1.7460
	DUVAL	0.3000	0.8900A	0.8000A	2.7200	0.0390A	0.8000A
	HARDEE	0.0400	---	---	0.5200	---	---
	HIGHLANDS	0.0	---	---	0.1100	---	---
	HILLSBOROUGH	0.1500	---	---	2.5200	---	---
	PINELLAS	0.1100	---	---	1.3100	---	---
GA	CHATHAM	0.1000	0.5590A	0.4600A	1.3700	0.5590A	0.4600A
	FULTON	0.4100	1.2000A	1.0700A	3.2800	1.2000A	1.0700A
	MUSCOGEE	0.1900	0.6100A	0.5500A	2.9400	0.6140A	0.4870A
ID	ADA	0.2800	0.7800A	0.7000A	2.6200	0.7800A	0.7000A
	BANNOCK	0.1200	---	---	1.0500	---	---
	BUTTE	0.0	---	---	0.1300	---	---
	NEZ PERCE	0.2000	---	---	1.8800	---	---
	SHOSHONE	0.0200	0.5170	0.4390	82.0900	15.7250	11.7850
IL	COOK	0.1500	---	---	4.3800	---	---
	LAKE	0.1500	---	---	1.9200	---	---
	PEORIA	0.2800	---	---	3.9000	---	---
	ROCK ISLAND	0.1600	---	---	1.9900	---	---
	ST. CLAIR	0.0300	---	---	1.4400	---	---

A INDICATES ONLY ONE STATION REPORTING

TABLE C-5. AIR QUALITY DATA FOR LEAD

STATE	COUNTY	MINIMUM (UG/M3)			MAXIMUM (UG/M3)		
		OBS	ARITH MEAN	GEO MEAN	OBS	ARITH MEAN	GEO MEAN
	SANGAMON	0.1800	---	---	0.8300	---	---
	WILL	0.3100	---	---	1.2100	---	---
	WINNEBAGO	0.2000	---	---	2.0500	---	---
IN	ALLEN	0.2940	0.6810A	0.6130A	1.8200	0.6810A	0.6130A
	BARTHOLOMEW	0.1290	0.4300A	0.3660A	1.0460	0.4300A	0.3660A
	CLARK	0.3850	1.3370A	1.1770A	3.4040	1.3370A	1.1770A
	DELAWARE	0.3300	---	---	2.2900	---	---
	DUBOIS	0.1630	0.4870A	0.4440A	1.0780	0.4870A	0.4440A
	ELKHART	0.2560	0.5080A	0.4770A	1.1020	0.5080A	0.4770A
	FLOYD	0.4600	---	---	2.0600	---	---
	GRANT	0.1940	0.4850A	0.4420A	0.9970	0.4850A	0.4420A
	HOWARD	0.1400	0.5150A	0.4550A	1.5180	0.5150A	0.4580A
	JASPER	0.0310	0.1210A	0.1070A	0.2720	0.1210A	0.1070A
	JEFFERSON	0.1300	0.3770A	0.3330A	1.0410	0.3770A	0.3380A
	KNOX	0.2060	0.4990A	0.4620A	1.2810	0.4990A	0.4620A
	LAKE	0.1080	0.5910	0.4910	6.8700	0.7320	0.6440
	LA PORTE	0.2380	0.4400A	0.4160A	0.7700	0.4400A	0.4160A
	MARION	0.0560	0.8300A	0.7070A	5.2550	0.8300A	0.7070A
	MONROE	0.0400	0.7280A	0.6360A	1.8610	0.7280A	0.6360A
	PARKE	0.0600	---	---	0.2800	---	---
	ST. JOSEPH	0.2350	0.6000A	0.5190A	1.3500	0.6000A	0.5190A
	STEUBEN	0.0440	0.1780A	0.1640A	0.3760	0.1780A	0.1640A
	TIPPECANOE	0.2220	0.5300A	0.4930A	1.0500	0.5300A	0.4930A
	VANDERBURGH	0.1720	0.5250A	0.4670A	1.3620	0.5250A	0.4670A
	VIGO	0.1930	0.5120A	0.4420A	1.5840	0.5120A	0.4420A
	WAYNE	0.1960	0.5280	0.4600	1.6340	0.6270	0.5840
IA	BLACKHAWK	0.1700	0.4300A	0.3900A	2.0100	0.5840A	0.5090A
	DELAWARE	0.0520	---	---	0.2800	---	---
	DUBUQUE	0.0200	---	---	99.0000	---	---
	LEE	0.1100	---	---	0.3200	---	---
	LINN	0.1500	0.5400A	0.4500A	1.8300	0.5180A	0.4680A
	POLK	0.3400	1.0070A	0.9030A	2.7500	1.0070A	0.9030A
	POTTAWATAMIE	0.4500	---	---	0.6500	---	---
	SCOTT	0.3000	---	---	2.6700	---	---
KS	SEDGWICK	0.2000	---	---	1.1400	---	---
	SHAWNEE	0.1600	---	---	1.6400	---	---
	WYANDOTTE	0.0900	0.5100	0.4600	3.0200	0.4280	0.3840
KY	BOYD	0.1300	---	---	3.8900	---	---
	FAYETTE	0.2900	---	---	3.5600	---	---

A INDICATES ONLY ONE STATION REPORTING

TABLE C-5. AIR QUALITY DATA FOR LEAD

STATE	COUNTY	MINIMUM (UG/M3) OBS	MINIMUM (UG/M3) ARITH MEAN	MINIMUM (UG/M3) GEO MEAN	MAXIMUM (UG/M3) OBS	MAXIMUM (UG/M3) ARITH MEAN	MAXIMUM (UG/M3) GEO MEAN
	JEFFERSON	0.2700	0.9760A	0.9400A	3.3600	1.1800A	0.8910A
	KENTON	0.3200	0.7100A	0.6800A	1.2200	0.7100A	0.6800A
	WARREN	0.1900	0.4800A	0.4100A	1.1500	0.4800A	0.4100A
LA	CADDO PARRISH	0.2000	0.6720A	0.6100A	1.4400	0.6720A	0.6100A
	EAST BATON ROUGE PARRISH	0.2600	1.1500A	0.9000A	4.2600	1.1500A	0.9000A
	IBERVILLE PARRISH	0.0300	0.1300A	0.1100A	0.3800	0.1300A	0.1100A
	ORLEANS PARRISH	0.3900	0.8000	0.7700	1.6400	1.0300	0.9830
ME	CUMBERLAND	0.1000	0.4500A	0.4000A	1.4700	0.4500A	0.4000A
	HANCOCK	0.0	0.0600A	0.0400A	0.3900	0.0600A	0.0400A
MD	BALTIMORE (CITY)	0.4400	1.0700A	0.9800A	2.5000	1.0700A	0.9800A
	CALVERT	0.0300	0.1700A	0.1400A	0.3900	0.1700A	0.1400A
MA	CENTRAL MA. APCO	0.3000	0.8400A	0.7400A	1.8600	0.8400A	0.7400A
	METROPOLITAN BOSTON APCO	0.4000	---	---	1.3900	---	---
	PIONEER VALLEY APCO	0.6500	---	---	2.9000	---	---
	SOUTHEASTERN MA. APCO	0.1900	---	---	1.1700	---	---
MI	GENESEE	0.3800	---	---	1.3400	---	---
	INGHAM	0.2100	---	---	1.7100	---	---
	KENT	0.2700	---	---	2.2500	---	---
	SAGINAW	0.1400	0.4000A	0.3700A	0.9100	0.4000A	0.3700A
	WAYNE	0.1800	---	---	2.7100	---	---
MN	BELTRAMI	0.0860	---	---	0.1560	---	---
	BIG STONE	0.0060	---	---	0.1130	---	---
	BLUE EARTH	0.2690	---	---	0.7580	---	---
	CARLTON	0.0530	---	---	0.2280	---	---
	CLAY	0.0530	---	---	0.1150	---	---
	CROW WING	0.0130	---	---	0.2790	---	---
	DAKOTA	0.0550	---	---	0.4750	---	---
	GOODHUE	0.3130	---	---	1.2540	---	---
	HENNEPIN	0.1800	1.2700A	0.9400A	8.8100	1.2700A	0.9400A
	ITASCA	0.0220	---	---	0.1190	---	---
	KANDIYOHI	0.1120	---	---	0.2040	---	---
	KOOCHICHING	0.0320	---	---	0.4450	---	---
	LYON	0.1730	---	---	0.3670	---	---
	MCLEOD	0.1180	---	---	0.3200	---	---
	MILLE LACS	0.3330	---	---	1.2220	---	---
	MOWER	0.2190	---	---	0.3910	---	---
	NOBLES	0.0520	---	---	0.1720	---	---

A INDICATES ONLY ONE STATION REPORTING

TABLE C-5. AIR QUALITY DATA FOR LEAD

STATE	COUNTY	MINIMUM (UG/M3) OBS	MINIMUM (UG/M3) ARITH MEAN	MINIMUM (UG/M3) GEO MEAN	MAXIMUM (UG/M3) OBS	MAXIMUM (UG/M3) ARITH MEAN	MAXIMUM (UG/M3) GEO MEAN
	OLMSTED	0.2150	---	---	2.3930	---	---
	OTTERTAIL	0.0840	---	---	0.3140	---	---
	POLK	0.0530	---	---	0.1320	---	---
	RAMSEY	0.0720	---	---	3.8600	---	---
	ST. LOUIS	0.0010	---	---	2.3100	---	---
	SCOTT	0.0320	---	---	0.3430	---	---
	STEARNS	0.0100	---	---	1.1350	---	---
	WASHINGTON	0.2180	---	---	0.5610	---	---
	WINONA	0.1110	---	---	0.5770	---	---
MS	HINDS	0.1400	0.7500A	0.6700A	2.7600	0.7500A	0.6700A
	JACKSON	0.0020	---	---	0.4200	---	---
MO	ST. LOUIS (CITY)	0.2900	0.8900A	0.8100A	2.9200	0.8900A	0.8100A
	ADAIR	0.1200	---	---	0.5540	---	---
	AUDRAIN	0.1100	---	---	4.2300	---	---
	BOONE	0.1100	---	---	2.9400	---	---
	BUCHANAN	0.0500	---	---	2.8100	---	---
	BUTLER	0.0190	---	---	4.0600	---	---
	CALLAWAY	0.1150	---	---	0.3920	---	---
	CAMDEN	0.0100	---	---	0.7280	---	---
	CAPE GIRARDEAU	0.0680	---	---	0.3100	---	---
	CLAY	0.0010	---	---	2.1790	---	---
	COLE	0.0900	---	---	0.7300	---	---
	JACKSON	0.3500	---	---	1.3900	---	---
	JASPER	0.1600	---	---	0.9600	---	---
	JEFFERSON	0.2340	---	---	37.5300	---	---
	LIVINGSTON	0.0900	---	---	0.6120	---	---
	MARION	0.1700	---	---	1.0800	---	---
	NEW MADRID	0.1000	---	---	0.6360	---	---
	NODAWAY	0.0460	---	---	0.3150	---	---
	PETTIS	0.1970	---	---	0.3500	---	---
	PHELPS	0.0690	---	---	0.2300	---	---
	PLATTE	0.0900	---	---	1.1420	---	---
	ST. CHARLES	0.2400	---	---	0.6510	---	---
	STE GENEVIEVE	0.1400	---	---	0.3700	---	---
	SCOTT	0.1400	---	---	2.1900	---	---
	SHANNON	0.0300	0.0790A	0.0710A	0.1900	0.0790A	0.0710A
	VERNON	0.1490	---	---	0.3130	---	---
MT	GLACIER	0.0	---	---	0.0600	---	---
	JEFFERSON	0.0600	---	---	10.9700	---	---
	LEWIS AND CLARK	0.3300	---	---	24.6200	---	---

A INDICATES ONLY ONE STATION REPORTING

TABLE C-5. AIR QUALITY DATA FOR LEAD

STATE	COUNTY	MINIMUM (UG/M3) OBS	MINIMUM (UG/M3) ARITH MEAN	MINIMUM (UG/M3) GEO MEAN	MAXIMUM (UG/M3) OBS	MAXIMUM (UG/M3) ARITH MEAN	MAXIMUM (UG/M3) GEO MEAN
	POWDER RIVER	0.0	---	---	0.0400	---	---
	ROSEBUD	0.0	---	---	0.0300	---	---
NB	DOUGLAS	0.2400	---	---	1.9900	---	---
	LANCASTER	0.1200	0.3800A	0.3400A	0.9500	0.3800A	0.3400A
	THOMAS	0.0020	---	---	0.0500	---	---
NV	CLARK	0.5300	---	---	6.5200	---	---
	WASHOE	0.3100	---	---	5.2200	---	---
	WHITE PINE	0.0	---	---	0.0400	---	---
NH	COOS	0.0020	---	---	0.1600	---	---
	MERRIMACK	0.2000	---	---	1.5300	---	---
NJ	CAMDEN	0.3100	---	---	2.5200	---	---
	ESSEX	0.2200	---	---	2.1100	---	---
	GLOUCESTER	0.1300	---	---	1.1200	---	---
	HUDSON	0.2600	---	---	2.4900	---	---
	MERCER	0.4000	---	---	4.4200	---	---
	MIDDLESEX	0.4800	---	---	1.4400	---	---
	PASSAIC	0.6100	---	---	3.0500	---	---
	UNION	0.6500	---	---	4.8600	---	---
NM	BERNALILLO	0.4800	1.2700A	1.0600A	4.3200	1.2700A	1.0600A
	RIO ARRIBA	0.0010	0.0130A	0.0040A	0.1600	0.0140A	0.0070A
	SAN JUAN	0.0010	0.0130	0.0060	0.1100	0.0230	0.0120
NY	ALBANY	0.1700	---	---	1.2700	---	---
	ERIE	0.4300	---	---	1.3800	---	---
	JEFFERSON	0.0100	---	---	0.2600	---	---
	MONROE	0.5700	---	---	1.2700	---	---
	NEW YORK	0.2700	---	---	2.3700	---	---
	NIAGARA	0.2300	---	---	0.7500	---	---
	ONEIDA	0.4600	---	---	1.9000	---	---
	ONONDAGA	0.2700	---	---	2.7000	---	---
	WESTCHESTER	0.4100	---	---	2.1400	---	---
NC	DARE	0.0200	---	---	0.2500	---	---
	DURHAM	0.3600	---	---	4.0300	---	---
	FORSYTH	0.2900	0.8000	0.7400	2.2200	0.9230	0.8300
	GUILFORD	0.3300	---	---	3.0600	---	---
	MECKLENBURG	0.2300	0.6900	0.5900	3.8100	0.7550	0.6270
ND	BURLEIGH	0.3500	---	---	0.5700	---	---

A INDICATES ONLY ONE STATION REPORTING

TABLE C-5. AIR QUALITY DATA FOR LEAD

STATE	COUNTY	MINIMUM (UG/M3)			MAXIMUM (UG/M3)		
		OBS	ARITH MEAN	GEO MEAN	OBS	ARITH MEAN	GEO MEAN
OH	CUYAHOGA	0.4300	---	---	1.8700	---	---
	FRANKLIN	0.2700	0.7900A	0.7100A	2.3100	0.7900A	0.7100A
	HAMILTON	0.3600	0.8200A	0.7500A	1.8000	0.8200A	0.7500A
	JEFFERSON	0.1300	---	---	1.4200	---	---
	LUCAS	0.2600	---	---	1.7200	---	---
	MAHONING	0.2500	0.6100	0.5500	1.4700	0.6100	0.5500
	MONTGOMERY	0.4300	0.9800	0.8600	2.7500	0.9800	0.8600
	SCIOTO	0.1300	0.4100	0.3600	1.0400	0.4100	0.3600
	SUMMIT	0.2800	0.5700A	0.5500A	1.2000	0.5700A	0.5500A
OK	CHEROKEE	0.0500	---	---	0.2100	---	---
	OKLAHOMA	0.0100	0.1810	0.0850	30.0000	1.9120	1.5170
	TULSA	0.0005	0.5300A	0.4700A	1.4200	0.5300A	0.4700A
OR	CURRY	0.0020	0.0300A	0.0100A	0.0700	0.0300A	0.0100A
	MULTNOMAH	0.0020	0.8300A	0.6600A	4.2300	0.8300A	0.6600A
PA	ALLEGHENY	0.5200	---	---	3.1100	---	---
	BEAVER	0.5860	---	---	2.8020	---	---
	BERKS	0.2900	0.8100A	0.7400A	6.4350	0.8100A	0.7400A
	BLAIR	0.0010	---	---	2.8250	---	---
	BUCKS	0.1600	---	---	2.2600	---	---
	CAMBRIA	0.0020	---	---	3.2430	---	---
	CHESTER	0.1600	0.5100	0.4700	1.3300	0.5670	0.4860
	CLARION	0.0300	---	---	0.4400	---	---
	DAUPHIN	0.2400	1.0400	0.9000	2.6000	1.0400	0.9000
	ERIE	0.0200	0.6000A	0.3000A	2.1630	0.6000A	0.3000A
	INDIANA	0.1600	---	---	0.9600	---	---
	LACKAWANNA	0.6500	2.0500A	1.8500A	6.6100	2.0500A	1.8500A
	LANCASTER	0.1170	---	---	2.7500	---	---
	LEHIGH	0.0700	0.7900A	0.7100A	2.6600	0.7900A	0.7100A
	LUZERNE	0.2800	0.7900	0.7200	2.6200	0.8270	0.7820
	LYCOMING	0.3280	---	---	1.7820	---	---
	MERCER	0.2340	---	---	1.5640	---	---
	MONTGOMERY	0.2500	---	---	2.1700	---	---
	NORTHAMPTON	0.1680	---	---	1.4550	---	---
	NORTHUMBERLAND	0.2400	0.6600A	0.6100A	0.3300	0.6600A	0.6100A
	PHILADELPHIA	0.4600	1.2480	1.1790	2.7200	1.3200	1.2100
	WESTMORELAND	0.1670	---	---	2.5590	---	---
	YORK	0.2900	0.7200A	0.6600A	2.2630	0.7200A	0.6600A
RI	PROVIDENCE	0.3800	---	---	2.0300	---	---

A INDICATES ONLY ONE STATION REPORTING

TABLE C-5. AIR QUALITY DATA FOR LEAD

STATE	COUNTY	MINIMUM (UG/M3)			MAXIMUM (UG/M3)		
		OBS	ARITH MEAN	GEO MEAN	OBS	ARITH MEAN	GEO MEAN
	WASHINGTON	0.0300	---	---	0.6900	---	---
SC	CHARLESTON	0.8450	---	---	0.8450	---	---
	GREENVILLE	0.3500	1.0500	0.8600	3.4500	1.1320	0.9380
	RICHLAND	0.0500	---	---	4.1500	---	---
SD	CUSTER	0.0	---	---	0.0500	---	---
	MINNEHAHA	0.0200	---	---	1.6200	---	---
TN	ANDERSON	0.5800	---	---	1.3100	---	---
	BEDFORD	0.2800	---	---	0.6400	---	---
	BLOUNT	0.6500	---	---	1.5000	---	---
	BRADLEY	0.2000	---	---	0.4900	---	---
	CAMPBELL	0.4500	---	---	0.8100	---	---
	CARTER	0.5300	---	---	0.5300	---	---
	COFFEE	0.1600	---	---	1.6200	---	---
	CUMBERLAND	0.0100	0.0900A	0.0800A	0.5000	0.0900A	0.0800A
	DAVIDSON	0.2500	---	---	2.4600	---	---
	DYER	0.1600	---	---	0.7700	---	---
	GIBSON	0.1400	---	---	0.4500	---	---
	GREEN	0.4300	---	---	0.6500	---	---
	HAMBLEN	0.1300	---	---	2.7400	---	---
	HENRY	0.0200	---	---	0.7100	---	---
	HUMPHREYS	0.0300	---	---	0.2100	---	---
	KNOX	0.3700	---	---	3.9000	---	---
	LINCOLN	0.2800	---	---	0.2800	---	---
	MCMINN	0.1800	---	---	0.1800	---	---
	MADISON	0.1300	---	---	2.3300	---	---
	MARION	0.1500	---	---	0.2200	---	---
	MAURY	0.4000	---	---	2.4700	---	---
	MONTGOMERY	0.2300	---	---	0.9200	---	---
	OBION	0.2400	---	---	0.5700	---	---
	POLK	0.3700	---	---	1.4200	---	---
	PUTNAM	0.1700	---	---	0.7800	---	---
	ROANE	0.3300	---	---	1.9000	---	---
	ROBERTSON	0.2300	---	---	0.4500	---	---
	RUTHERFORD	0.2400	---	---	0.8200	---	---
	SHELBY	0.2500	---	---	5.5700	---	---
	SULLIVAN	0.2300	---	---	2.2900	---	---
	SUMNER	0.2100	---	---	0.4900	---	---
	WARREN	0.2200	---	---	0.4200	---	---
	WASHINGTON	0.6300	---	---	0.6300	---	---
	WILLIAMSON	0.2700	---	---	0.2700	---	---

A INDICATES ONLY ONE STATION REPORTING

TABLE C-5. AIR QUALITY DATA FOR LEAD

STATE	COUNTY	MINIMUM (UG/M3) OBS	MINIMUM (UG/M3) ARITH MEAN	MINIMUM (UG/M3) GEO MEAN	MAXIMUM (UG/M3) OBS	MAXIMUM (UG/M3) ARITH MEAN	MAXIMUM (UG/M3) GEO MEAN
	WILSON	0.2500	---	---	0.2900	---	---
TX	BEE	0.0200	---	---	0.1300	---	---
	BEXAR	0.0200	0.4400A	0.2800A	4.3500	0.4400A	0.2800A
	BOWIE	0.0200	0.4200A	0.3300A	1.9500	0.4200A	0.3300A
	BRAZORIA	0.0200	0.1400	0.0900	0.7400	0.1900	0.1200
	BRAZOS	0.0200	0.3700A	0.3000A	0.8700	0.3700A	0.3000A
	BROWN	0.0200	---	---	1.8100	---	---
	CALHOUN	0.0200	---	---	0.1300	---	---
	CAMERON	0.0200	0.0500	0.0300	1.2300	0.1700	0.1000
	CHAMBERS	0.0200	---	---	0.2000	---	---
	DALLAS	0.0200	0.2300	0.1700	8.0200	2.9280	2.6310
	DENTON	0.0200	---	---	0.7200	---	---
	ECTOR	0.0200	0.4400A	0.3900A	1.0700	0.4400A	0.3900A
	ELLIS	0.0200	---	---	1.5000	---	---
	EL PASO	0.0200	0.0900	0.0500	4.0900	1.1100	1.0200
	GALVESTON	0.0200	0.4500A	0.3800A	1.2000	0.4500A	0.3800A
	GRAY	0.0200	---	---	0.1800	---	---
	GRAYSON	0.0800	---	---	1.9900	---	---
	HALE	0.0200	---	---	0.1300	---	---
	HARRIS	0.0010	0.1500	0.0900	3.9100	0.8500	0.6700
	HAYS	0.0200	---	---	1.2300	---	---
	HIDALGO	0.0200	0.0300	0.0300	1.2500	0.2800	0.2100
	HOWARD	0.0200	0.0700	0.0500	0.0200	0.0700	0.0500
	JEFF DAVIS	0.0200	---	---	0.0200	---	---
	JEFFERSON	0.0200	0.1300	0.0800	0.9600	0.5200	0.5000
	LUBBOCK	0.0200	---	---	1.9600	---	---
	MCLENNAN	0.0200	---	---	0.7900	---	---
	MCMULLEN	0.0200	---	---	0.3300	---	---
	MATAGORDA	0.0	---	---	0.2100	---	---
	MAVERICK	0.1000	0.4900A	0.3900A	1.9000	0.4900A	0.3900A
	MIDLAND	0.0200	0.1200A	0.0900A	0.6000	0.1200A	0.0900A
	MONTGOMERY	0.0200	---	---	0.7000	---	---
	MOORE	0.0200	---	---	0.1400	---	---
	NACOGDOCHES	0.0700	---	---	0.5500	---	---
	NUECES	0.0200	0.3600	0.2400	17.3000	0.6100	0.5300
	ORANGE	0.0200	0.1100A	0.0700A	0.7200	0.1100A	0.0700A
	POTTER	0.0200	---	---	1.4300	---	---
	SAN PATRICIO	0.0200	---	---	0.1100	---	---
	SCURRY	0.0200	---	---	0.2700	---	---
	SMITH	0.0600	0.5000A	0.3900A	1.4000	0.5000A	0.3900A
	TARRANT	0.0010	0.6910A	0.5340A	3.8000	0.8650A	0.8060A
	TAYLOR	0.0200	0.1700A	0.1300A	0.7400	0.1700A	0.1300A

A INDICATES ONLY ONE STATION REPORTING

TABLE C-5. AIR QUALITY DATA FOR LEAD

STATE	COUNTY	MINIMUM (UG/M3) OBS	MINIMUM (UG/M3) ARITH MEAN	MINIMUM (UG/M3) GEO MEAN	MAXIMUM (UG/M3) OBS	MAXIMUM (UG/M3) ARITH MEAN	MAXIMUM (UG/M3) GEO MEAN
	TITUS	0.0200	0.1100A	0.0700A	0.5800	0.1100A	0.0700A
	TOM GREEN	0.0200	0.1000A	0.0700A	0.6500	0.1000A	0.0700A
	TRAVIS	0.0200	0.0400	0.0300	2.6000	0.7300	0.6400
	VAL VERDE	0.0200	---	---	0.6000	---	---
	VICTORIA	0.0200	---	---	0.8300	---	---
	WALKER	0.0200	---	---	0.3300	---	---
	WEBB	0.0200	---	---	0.7100	---	---
	WICHITA	0.0200	0.4600A	0.4000A	1.2100	0.4600A	0.4000A
	WISE	0.0200	---	---	0.6500	---	---
UT	EMERY	0.0010	---	---	0.1600	---	---
	GARFIELD	0.0010	0.0150	0.0070	0.1700	0.0170	0.0080
	KANE	0.0010	0.0170A	0.0080A	0.0900	0.0170A	0.0080A
	SALT LAKE	0.3500	---	---	4.9100	---	---
	SAN JUAN	0.0010	0.0110	0.0050	0.1400	0.0200	0.0080
	WASHINGTON	0.0010	0.0190	0.0070	0.2400	0.0300	0.0160
	WEBER	0.2300	---	---	3.5500	---	---
VT	CHITTENDEN	0.0020	0.6860	0.4710	1.2600	0.7900	0.7600
	ORANGE	0.0500	---	---	1.1800	---	---
VA	0000	0.1300	0.5200	0.4400	3.7500	0.9700	0.8600
	FAIRFAX	0.2100	---	---	2.1400	---	---
	PAGE	0.0300	0.2400A	0.1900A	0.8100	0.2400A	0.1900A
	PITTSYLVANIA	0.1800	0.5700A	0.4800A	1.9300	0.5700A	0.4800A
	WYTHE	0.0200	0.0900	0.0800	0.1900	0.0900	0.0800
WA	KING	0.0700	1.4600A	1.3100A	4.4800	1.4600A	1.3100A
	PIERCE	0.1600	0.9500A	0.8200A	2.1900	0.9500A	0.8200A
	SPOKANE	0.1800	---	---	1.2900	---	---
WV	CABELL	0.2200	---	---	2.2900	---	---
	KANAWHA	0.1200	0.5200	0.4400	2.6900	0.6240	0.7200
WI	DANE	0.1400	0.6000A	0.5200A	1.3000	0.6000A	0.5200A
	DOOR	0.0	---	---	0.5500	---	---
	DOUGLAS	0.0300	0.2300A	0.1900A	1.0700	0.2300A	0.1900A
	EAU CLAIRE	0.1500	---	---	0.9800	---	---
	KENOSHA	0.0800	---	---	1.0300	---	---
	MILWAUKEE	0.3200	---	---	1.6100	---	---
	RACINE	0.1300	0.4200A	0.3500A	1.4700	0.4200A	0.3500A
WY	LARAMIE	0.1100	---	---	0.6600	---	---

A INDICATES ONLY ONE STATION REPORTING

TABLE C-5. AIR QUALITY DATA FOR LEAD

STATE	COUNTY	MINIMUM (UG/M3) OBS	MINIMUM (UG/M3) ARITH MEAN	MINIMUM (UG/M3) GEO MEAN	MAXIMUM (UG/M3) OBS	MAXIMUM (UG/M3) ARITH MEAN	MAXIMUM (UG/M3) GEO MEAN
	NATRONA	0.0800	---	---	0.4400	---	---
	PARK	0.0	---	---	0.0300	---	---

TABLE C-6. AIR QUALITY DATA FOR MANGANESE

STATE	COUNTY	MINIMUM (UG/M3) OBS	MINIMUM (UG/M3) ARITH MEAN	MINIMUM (UG/M3) GEO MEAN	MAXIMUM (UG/M3) OBS	MAXIMUM (UG/M3) ARITH MEAN	MAXIMUM (UG/M3) GEO MEAN
AZ	APACHE	0.0	0.0060	0.0020	0.1200	0.0130	0.0040
	COCONINO	0.0	0.0040	0.0010	0.1300	0.0160	0.0080
	MARICOPA	0.0	0.0310	0.0200	3.0840	0.1430	2.7652
	MOHAVE	0.0	0.0050	0.0010	0.1500	0.0090	0.0030
	NAVAJO	0.0	0.0080A	0.0020A	0.1900	0.0080A	0.0020A
CO	LA PLATA	0.0	0.0060A	0.0020A	0.0700	0.0210A	0.0100A
	MONTEZUMA	0.0	0.0070A	0.0020A	0.0400	0.0070A	0.0020A
IN	ALLEN	0.0170	---	---	0.0440	---	---
	BARTHOLOMEW	0.0060	---	---	0.0530	---	---
	CLARK	0.0230	---	---	0.1860	---	---
	DUBOIS	0.0130	---	---	0.0570	---	---
	ELKHART	0.0120	---	---	0.0530	---	---
	GRANT	0.0150	---	---	0.0400	---	---
	HOWARD	0.0250	---	---	0.2500	---	---
	JASPER	0.0060	---	---	0.0170	---	---
	JEFFERSON	0.0070	---	---	0.0230	---	---
	KNOX	0.0080	---	---	0.0400	---	---
	LAKE	0.0050	---	---	0.1010	---	---
	LA PORTE	0.0180	---	---	0.0770	---	---
	MARION	0.0040	---	---	0.0510	---	---
	MONROE	0.0090	---	---	0.0410	---	---
	ST. JOSEPH	0.0150	---	---	0.0490	---	---
	STEUBEN	0.0080	---	---	0.0450	---	---
	TIPPECANOE	0.0130	---	---	0.0490	---	---
	VANDERBURGH	0.0110	---	---	0.0330	---	---
	VIGO	0.0160	---	---	0.1150	---	---
	WAYNE	0.0190	---	---	1.1320	---	---
MO	ADAIR	0.0260	---	---	0.1020	---	---
	AUDRAIN	0.0290	---	---	0.0800	---	---
	BOONE	0.0210	---	---	0.1120	---	---
	BUCHANAN	0.0040	---	---	0.1220	---	---
	BUTLER	0.0190	---	---	0.1150	---	---
	CALLAWAY	0.0190	---	---	0.0700	---	---
	CAMDEN	0.0130	---	---	0.0520	---	---
	CAPE GIRARDEAU	0.0160	---	---	0.0540	---	---
	CLAY	0.0300	---	---	0.1250	---	---
	COLE	0.0210	---	---	0.0510	---	---
	JASPER	0.0330	---	---	0.1410	---	---
	JEFFERSON	0.0140	---	---	0.9730	---	---

A INDICATES ONLY ONE STATION REPORTING

TABLE C-6. AIR QUALITY DATA FOR MANGANESE

STATE	COUNTY	MINIMUM (UG/M3) OBS	MINIMUM (UG/M3) ARITH MEAN	MINIMUM (UG/M3) GEO MEAN	MAXIMUM (UG/M3) OBS	MAXIMUM (UG/M3) ARITH MEAN	MAXIMUM (UG/M3) GEO MEAN
	LIVINGSTON	0.0310	---	---	0.8280	---	---
	MARION	0.0190	---	---	0.0690	---	---
	NEW MADRID	0.0190	---	---	0.2720	---	---
	NODAWAY	0.0200	---	---	0.0710	---	---
	PETTIS	0.0310	---	---	0.0610	---	---
	PHELPS	0.0110	---	---	0.0730	---	---
	PLATTE	0.0230	---	---	0.0960	---	---
	ST. CHARLES	0.0230	---	---	0.1120	---	---
	STE. GENEVIEVE	0.0610	---	---	0.0610	---	---
	SCOTT	0.0020	---	---	0.3640	---	---
	VERNON	0.0340	---	---	0.0320	---	---
NM	RIO ARRIBA	0.0	0.0040A	0.0010A	0.0400	0.0040A	0.0010A
SC	CHARLESTON	0.0170	---	---	0.0170	---	---
TN	ANDERSON	0.0320	---	---	0.0420	---	---
	BEDFORD	0.0160	---	---	0.0240	---	---
	BLOUNT	0.0310	---	---	0.0450	---	---
	BRADLEY	0.0100	---	---	0.1290	---	---
	CAMPBELL	0.0200	---	---	0.0340	---	---
	CARTER	0.0200	---	---	0.0200	---	---
	COFFEE	0.0030	---	---	0.0330	---	---
	CUMBERLAND	0.0040	---	---	0.0250	---	---
	DYER	0.0060	---	---	0.1260	---	---
	GIBSON	0.0050	---	---	0.0300	---	---
	GREENE	0.0280	---	---	0.0340	---	---
	HAMBLEN	0.0160	---	---	0.0700	---	---
	HENRY	0.0060	---	---	0.0260	---	---
	HUMPREYS	0.0120	---	---	0.6960	---	---
	LINCOLN	0.0360	---	---	0.0360	---	---
	MCMINN	0.0190	---	---	0.0190	---	---
	MADISON	0.0160	---	---	0.0350	---	---
	MARION	0.0270	---	---	0.0290	---	---
	MAURY	0.0310	---	---	0.0810	---	---
	MONTGOMERY	0.0080	---	---	0.0410	---	---
	OBION	0.0160	---	---	0.1030	---	---
	POLK	0.0370	---	---	0.0440	---	---
	PUTNAM	0.0060	---	---	0.0180	---	---
	ROANE	0.0610	---	---	0.9720	---	---
	ROBERTSON	0.2500	---	---	0.0270	---	---
	RUTHERFORD	0.0100	---	---	0.0240	---	---
	SULLIVAN	0.0060	---	---	0.1670	---	---

A INDICATES ONLY ONE STATION REPORTING

TABLE C-6. AIR QUALITY DATA FOR MANGANESE

STATE	COUNTY	MINIMUM (UG/M3) OBS	MINIMUM (UG/M3) ARITH MEAN	MINIMUM (UG/M3) GEO MEAN	MAXIMUM (UG/M3) OBS	MAXIMUM (UG/M3) ARITH MEAN	MAXIMUM (UG/M3) GEO MEAN
	SUMNER	0.0180	---	---	0.0250	---	---
	WARREN	0.0070	---	---	0.0250	---	---
	WASHINGTON	0.0350	---	---	0.0350	---	---
	WILLIAMSON	0.0370	---	---	0.0370	---	---
	WILSON	0.0100	---	---	0.0230	---	---
TX	BEE	0.0200	---	---	0.0900	---	---
	BEXAR	0.0200	---	---	0.1400	---	---
	BOWIE	0.0200	---	---	0.1000	---	---
	BRAZORIA	0.0200	---	---	0.1600	---	---
	BRAZOS	0.0200	---	---	0.0900	---	---
	BROWN	0.0200	---	---	0.0700	---	---
	CALHOUN	0.0200	---	---	0.0900	---	---
	CAMERON	0.0200	---	---	0.3100	---	---
	CHAMBERS	0.0200	---	---	0.1000	---	---
	DALLAS	0.0200	---	---	0.1900	---	---
	DENTON	0.0200	---	---	0.0700	---	---
	ECTOR	0.0200	---	---	0.3100	---	---
	ELLIS	0.0200	---	---	0.0500	---	---
	EL PASO	0.0200	---	---	0.2000	---	---
	GALVESTON	0.0200	---	---	0.1300	---	---
	GRAY	0.0200	---	---	0.1500	---	---
	GRAYSON	0.0200	---	---	0.0700	---	---
	HALE	0.0200	---	---	0.0800	---	---
	HALE	0.0	---	---	1.1500	---	---
	HAYS	0.0200	---	---	0.1400	---	---
	HIDALGO	0.0200	---	---	0.1500	---	---
	HOWARD	0.0200	---	---	0.0900	---	---
	JEFF DAVIS	0.0200	---	---	0.1400	---	---
	JEFFESON	0.0200	---	---	0.1400	---	---
	LUBBOCK	0.0200	---	---	0.1000	---	---
	MCLENNAN	0.0200	---	---	0.0500	---	---
	MCMULLEN	0.0200	---	---	0.0300	---	---
	MATAGORDA	0.0200	---	---	0.0200	---	---
	MAVERICK	0.0200	---	---	0.0700	---	---
	MIDLAND	0.0200	---	---	0.3700	---	---
	MONTGOMERY	0.0200	---	---	0.1000	---	---
	MOORE	0.0200	---	---	0.1600	---	---
	NACOGDOCHES	0.0200	---	---	0.0200	---	---
	NUECES	0.0200	---	---	2.6600	---	---
	ORANGE	0.0200	---	---	0.2200	---	---
	POTTER	0.0200	---	---	0.1600	---	---
	SAN PATRICIO	0.0200	---	---	0.0200	---	---

A INDICATES ONLY ONE STATION REPORTING

TABLE C-6. AIR QUALITY DATA FOR MANGANESE

STATE	COUNTY	MINIMUM (UG/M3) OBS	MINIMUM (UG/M3) ARITH MEAN	MINIMUM (UG/M3) GEO MEAN	MAXIMUM (UG/M3) OBS	MAXIMUM (UG/M3) ARITH MEAN	MAXIMUM (UG/M3) GEO MEAN
	SCURRY	0.0200	---	---	0.0600	---	---
	SMITH	0.0200	---	---	0.0900	---	---
	TARRANT	0.0200	---	---	0.1000	---	---
	TAYLOR	0.0200	---	---	0.0600	---	---
	TITUS	0.0200	---	---	0.0700	---	---
	TOM GREEN	0.0200	---	---	0.1700	---	---
	TRAVIS	0.0200	---	---	0.1000	---	---
	VAL VERDE	0.0200	---	---	0.0200	---	---
	VICTORIA	0.0200	---	---	0.0700	---	---
	WALKER	0.0200	---	---	0.0600	---	---
	WEBB	0.0200	---	---	0.0600	---	---
	WICHITA	0.0200	---	---	0.0300	---	---
	WISE	0.0200	---	---	0.0600	---	---
UT	EMERY	0.0	---	---	0.0400	---	---
	GARFIELD	0.0	0.0070	0.0020	0.0500	0.0140	0.0070
	KANE	0.0	0.0050A	0.0010A	0.0400	0.0050A	0.0010A
	SAN JUAN	0.0	0.0040	0.0010	0.0300	0.0100	0.0030
	WASHINGTON	0.0	0.0070	0.0030	0.0800	0.0070	0.0030

TABLE C-7. AIR QUALITY DATA FOR SELENIUM

STATE	COUNTY	MINIMUM (UG/M3) OBS	MINIMUM (UG/M3) ARITH MEAN	MINIMUM (UG/M3) GEO MEAN	MAXIMUM (UG/M3) OBS	MAXIMUM (UG/M3) ARITH MEAN	MAXIMUM (UG/M3) GEO MEAN
TX	BEE	0.0100	---	---	0.0100	---	---
	BEXAR	0.0100	0.0100A	0.0200A	0.0400	0.0100A	0.0200A
	BOWIE	0.1000	0.0100A	0.0200A	0.0300	0.0100A	0.0200A
	BRAZORIA	0.0100	0.0100	0.0200	0.0100	0.0100	0.0200
	BRAZOS	0.0100	0.0100A	0.0200A	0.0100	0.0100A	0.0200A
	BROWN	0.0100	---	---	0.0300	---	---
	CALHOUN	0.0100	---	---	0.0100	---	---
	CAMERON	0.0100	0.0100	0.0200	0.0100	0.0100	0.0200
	CHAMBERS	0.0100	---	---	0.0300	---	---
	DALLAS	0.0100	0.0100	0.0200	0.0100	0.0100	0.0200
	DENTON	0.0100	---	---	0.0600	---	---
	ECTOR	0.0100	0.0100A	0.0200A	0.0100	0.0100A	0.0200A
	ELLIS	0.0100	---	---	0.0400	---	---
	EL PASO	0.0100	0.0100	0.0200	0.0100	99.0000	99.0000
	GALVESTON	0.0100	---	---	0.1300	---	---
	GRAY	0.0100	---	---	0.0100	---	---
	GRAYSON	0.0100	---	---	0.0300	---	---
	HALE	0.0100	---	---	0.0100	---	---
	HARRIS	0.0100	0.0100	0.0200	0.0800	0.0100	0.0200
	HAYS	0.0100	---	---	0.0300	---	---
	HIDALGO	0.0100	0.0100	0.0200	0.0100	0.0100	0.0200
	HOWARD	0.0100	0.0100A	0.0200A	0.0100	0.0100A	0.0200A
	JEFF DAVIS	0.0100	---	---	0.0100	---	---
	JEFFERSON	0.0100	0.0100A	0.0200A	0.0100	0.0100A	0.0200A
	LUBBOCK	0.0100	---	---	0.0100	---	---
	MCLENNAN	0.0100	---	---	0.0400	---	---
	MCMULLEN	0.0100	---	---	0.0100	---	---
	MATAGORDA	0.0100	---	---	0.0100	---	---
	MAVERICK	0.0100	0.0100A	0.0200A	0.0100	0.0100A	0.0200A
	MIDLAND	0.0100	0.0100A	0.0200A	0.0100	0.0100A	0.0200A
	MONTGOMERY	0.0100	---	---	0.0100	---	---
	MOORE	0.0100	---	---	0.0100	---	---
	NACOGDOCHES	0.0100	---	---	0.0100	---	---
	NUECES	0.0100	0.0100	0.0200	0.0300	0.0100	0.0200
	ORANGE	0.0100	0.0100A	0.0200A	0.0100	0.0100A	0.0200A
	POTTER	0.0100	---	---	0.0100	---	---
	SAN PATRICIO	0.0100	---	---	0.0100	---	---
	SCURRY	0.0100	---	---	0.0100	---	---
	SMITH	0.0100	0.0100A	0.0200A	0.0300	0.0100A	0.0200A
	TARRANT	0.0100	9.0000	99.0000	0.0300	99.0000	99.0000
	TAYLOR	0.0100	0.0100A	0.2000A	0.0100	0.0100A	0.2000A
	TITUS	0.0100	0.0100A	0.0200A	0.0100	0.0100A	0.0200A

A INDICATES ONLY ONE STATION REPORTING

TABLE C-7. AIR QUALITY DATA FOR SELENIUM

STATE	COUNTY	MINIMUM (UG/M3)			MAXIMUM (UG/M3)		
		OBS	ARITH MEAN	GEO MEAN	OBS	ARITH MEAN	GEO MEAN
	TOM GREEN	0.0100	---	---	0.0100	---	---
	TRAVIS	0.0100	0.0100	0.0200	0.0500	0.0200	0.0200
	VAL VERDE	0.0100	---	---	0.0100	---	---
	VICTORIA	0.0100	---	---	0.0400	---	---
	WALKER	0.0100	---	---	0.0100	---	---
	WEBB	0.0100	---	---	0.0100	---	---
	WICHITA	0.0100	---	---	0.0300	---	---
	WISE	0.0100	---	---	0.0100	---	---

TABLE C-8. AIR QUALITY DATA FOR VANADIUM

STATE	COUNTY	MINIMUM (UG/M3) OBS	MINIMUM (UG/M3) ARITH MEAN	MINIMUM (UG/M3) GEO MEAN	MAXIMUM (UG/M3) OBS	MAXIMUM (UG/M3) ARITH MEAN	MAXIMUM (UG/M3) GEO MEAN
TN	ANDERSON	0.0200	---	---	0.0200	---	---
	BEDFORD	0.0200	---	---	0.0200	---	---
	BLOUNT	0.0200	---	---	0.0200	---	---
	BRADLEY	0.0200	---	---	0.0200	---	---
	CAMPBELL	0.0200	---	---	0.0200	---	---
	CARTER	0.0200	---	---	0.0200	---	---
	COFFEE	0.0200	---	---	0.0200	---	---
	CUMBERLAND	0.0200	---	---	0.0200	---	---
	DYER	0.0200	---	---	0.0200	---	---
	GIBSON	0.0200	---	---	0.0200	---	---
	GREENE	0.0200	---	---	0.0200	---	---
	HAMBLEN	0.0200	---	---	0.0200	---	---
	HENRY	0.0200	---	---	0.0200	---	---
	HUMPREYS	0.0200	---	---	0.0200	---	---
	LINCOLN	0.0200	---	---	0.0200	---	---
	MCMINN	0.0200	---	---	0.0200	---	---
	MADISON	0.0200	---	---	0.0200	---	---
	MARION	0.0200	---	---	0.0200	---	---
	MAURY	0.0200	---	---	0.0200	---	---
	MONTGOMERY	0.0200	---	---	0.0200	---	---
	OBION	0.0200	---	---	0.0200	---	---
	POLK	0.0200	---	---	0.0200	---	---
	PUTNAM	0.0200	---	---	0.0200	---	---
	ROANE	0.0200	---	---	0.0200	---	---
	ROBERTSON	0.0200	---	---	0.0200	---	---
	RUTHERFORD	0.0200	---	---	0.0200	---	---
	SULLIVAN	0.0200	---	---	0.0200	---	---
	SUMNER	0.0200	---	---	0.0200	---	---
	WARREN	0.0200	---	---	0.0200	---	---
	WASHINGTON	0.0200	---	---	0.0200	---	---
	WILLIAMSON	0.0200	---	---	0.0200	---	---
	WILSON	0.0200	---	---	0.0200	---	---
TX	BEE	0.0010	---	---	0.0020	---	---
	BEXAR	0.0010	---	---	0.0010	---	---
	BOWIE	0.0010	---	---	0.0010	---	---
	BRAZORIA	0.0010	---	---	0.0020	---	---
	BRAZOS	0.0010	---	---	0.0030	---	---
	BROWN	0.0010	---	---	0.0040	---	---
	CALHOUN	0.0010	---	---	0.0010	---	---
	CAMERON	0.0010	---	---	0.0020	---	---
	CHAMBERS	0.0010	---	---	0.0010	---	---

A INDICATES ONLY ONE STATION REPORTING

TABLE C-8. AIR QUALITY DATA FOR VANADIUM

STATE	COUNTY	MINIMUM (UG/M3) OBS	MINIMUM (UG/M3) ARITH MEAN	MINIMUM (UG/M3) GEO MEAN	MAXIMUM (UG/M3) OBS	MAXIMUM (UG/M3) ARITH MEAN	MAXIMUM (UG/M3) GEO MEAN
	DALLAS	0.0010	---	---	0.0020	---	---
	DENTON	0.0010	---	---	0.0010	---	---
	ECTOR	0.0010	---	---	0.0010	---	---
	ELLIS	0.0010	---	---	0.0010	---	---
	EL PASO	0.0010	---	---	0.0020	---	---
	GALVESTON	0.0010	---	---	0.0070	---	---
	GRAY	0.0010	---	---	0.0010	---	---
	GRAYSON	0.0010	---	---	0.0020	---	---
	HALE	0.0010	---	---	0.0010	---	---
	HARRIS	0.0010	---	---	0.0030	---	---
	HAYS	0.0010	---	---	0.0010	---	---
	HIDALGO	0.0010	---	---	0.0010	---	---
	HOWARD	0.0010	---	---	0.0020	---	---
	JEFF DAVIS	0.0010	---	---	0.0010	---	---
	JEFFERSON	0.0010	---	---	0.0230	---	---
	LUBBOCK	0.0010	---	---	0.0020	---	---
	MCLENNAN	0.0010	---	---	0.0020	---	---
	MCMULLEN	0.0010	---	---	0.0010	---	---
	MATAGORDA	0.0010	---	---	0.0010	---	---
	MAVERICK	0.0010	---	---	0.0010	---	---
	MIDLAND	0.0010	---	---	0.0010	---	---
	MONTGOMERY	0.0010	---	---	0.0010	---	---
	MOORE	0.0010	---	---	0.0010	---	---
	NACOGDOCHES	0.0010	---	---	0.0010	---	---
	NUECES	0.0010	---	---	0.0010	---	---
	ORANGE	0.0010	---	---	0.0020	---	---
	POTTER	0.0010	---	---	0.0010	---	---
	SAN PATRICIO	0.0010	---	---	0.0010	---	---
	SCURRY	0.0010	---	---	0.0010	---	---
	SMITH	0.0010	---	---	0.0030	---	---
	TARRANT	0.0010	---	---	0.0100	---	---
	TAYLOR	0.0010	---	---	0.0010	---	---
	TITUS	0.0010	---	---	0.0010	---	---
	TOM GREENE	0.0010	---	---	0.0010	---	---
	TRAVIS	0.0010	---	---	0.0030	---	---
	VAL VERDE	0.0010	---	---	0.0010	---	---
	VICTORIA	0.0010	---	---	0.0010	---	---
	WALKER	0.0010	---	---	0.0010	---	---
	WEBB	0.0010	---	---	0.0010	---	---
	WICHITA	0.0010	---	---	0.0010	---	---
	WISE	0.0010	---	---	0.0020	---	---

TABLE C-9. AIR QUALITY DATA FOR ZINC

STATE	COUNTY	MINIMUM (UG/M3) OBS	MINIMUM (UG/M3) ARITH MEAN	MINIMUM (UG/M3) GEO MEAN	MAXIMUM (UG/M3) OBS	MAXIMUM (UG/M3) ARITH MEAN	MAXIMUM (UG/M3) GEO MEAN
AZ	APACHE	0.0100	---	---	0.2800	---	---
	COCONINO	0.0200	---	---	0.1500	---	---
	GILA	0.0100	---	---	0.1900	---	---
	GRAHAM	0.0200	---	---	0.0900	---	---
	GREENLEE	0.0300	---	---	0.2300	---	---
	MARICOPA	0.0001	---	---	0.8410	---	---
	MOHAVE	0.0001	---	---	0.1700	---	---
	NAVAJO	0.0100	---	---	0.1400	---	---
	PIMA	0.0001	---	---	0.3000	---	---
	PINAL	0.0300	---	---	0.2200	---	---
	SANTA CRUZ	0.1100	---	---	0.1100	---	---
	YAVAPAI	0.0100	---	---	0.1800	---	---
	YUMA	0.0200	---	---	0.1000	---	---
ID	SHOSHONE	0.0100	---	---	8.9000	---	---
IN	ALLEN	0.0550	---	---	0.1590	---	---
	BARTHOLOMEW	0.0480	---	---	0.1140	---	---
	CLARK	0.0924	---	---	0.6551	---	---
	DUBOIS	0.0478	---	---	0.2774	---	---
	ELKHART	0.0590	---	---	0.0780	---	---
	GRANT	0.0772	---	---	0.2285	---	---
	HOWARD	0.2010	---	---	1.4440	---	---
	JASPER	0.0543	---	---	0.1368	---	---
	JEFFERSON	0.0215	---	---	0.0976	---	---
	KNOX	0.0410	---	---	0.0851	---	---
	LAKE	0.0410	---	---	0.3990	---	---
	LA PORTE	0.0634	---	---	0.1971	---	---
	MARION	0.1000	---	---	0.4960	---	---
	MONROE	0.0430	---	---	0.0960	---	---
	ST. JOSEPH	0.0645	---	---	0.4068	---	---
	STEUBEN	0.0602	---	---	0.2873	---	---
	TIPPECANOE	0.0687	---	---	0.0995	---	---
	VANDERBURGH	0.0520	---	---	0.1720	---	---
	VIGO	0.1391	---	---	0.4640	---	---
	WAYNE	0.0736	---	---	0.3921	---	---
SC	CHARLESTON	0.3500	---	---	0.3500	---	---
TX	BEE	0.0	---	---	0.0300	---	---
	BEXAR	0.0	0.0200A	0.0100A	0.2100	0.0200A	0.0100A
	BOWIE	0.0	0.0500A	0.0300A	0.7400	0.0500A	0.0300A

A INDICATES ONLY ONE STATION REPORTING

TABLE C-9. AIR QUALITY DATA FOR ZINC

STATE	COUNTY	MINIMUM (UG/M3) ODS	MINIMUM (UG/M3) ARITH MEAN	MINIMUM (UG/M3) GEO MEAN	MAXIMUM (UG/M3) ODS	MAXIMUM (UG/M3) ARITH MEAN	MAXIMUM (UG/M3) GEO MEAN
	BRAZORIA	0.0	0.0300	0.0200	0.5300	0.0400	0.0300
	BRAZOS	0.0	0.0400A	0.0300A	0.0900	0.0400A	0.0300A
	BROWN	0.0	---	---	0.4500	---	---
	CALHOUN	0.0	---	---	0.0600	---	---
	CAMERON	0.0	0.0100	0.0100	0.4200	0.0400	0.0200
	CHAMBERS	0.0	---	---	0.7400	---	---
	DALLAS	0.0	0.0200	0.0100	0.2400	0.0200	0.0200
	DENTON	0.0	---	---	0.1000	---	---
	ECTOR	0.0	0.0600A	0.0400A	0.1600	0.0600A	0.0400A
	ELLIS	0.0	---	---	0.1400	---	---
	EL PASO	0.0	0.0500	0.0200	2.3400	0.1500	0.0700
	GALVESTON	0.0	0.0800A	0.0700A	6.7000	0.0800A	0.0700A
	GRAY	0.0100	---	---	0.0500	---	---
	GRAYSON	0.0	---	---	0.1600	---	---
	HALE	0.0100	---	---	0.0300	---	---
	HARRIS	0.0	0.0400	0.0200	2.0600	0.1300	0.0800
	HAYS	0.0	---	---	0.1000	---	---
	HIDALGO	0.0	0.0100	0.0100	0.2200	0.0200	0.0100
	HOWARD	0.0	0.0200A	0.0100A	0.1700	0.0200A	0.0100A
	JEFF DAVIS	0.0	---	---	0.1000	---	---
	JEFFERSON	0.0	0.0400A	0.0200A	0.4800	0.0400A	0.0200A
	LUBBOCK	0.0	---	---	0.3100	---	---
	MCLENNAN	0.0	---	---	0.1200	---	---
	MCMULLEN	0.0	---	---	0.1800	---	---
	MATAGORDA	0.0	---	---	0.0600	---	---
	MAVERICK	0.0	0.0500A	0.0300A	0.3600	0.0500A	0.0300A
	MIDLAND	0.0	0.0400A	0.0200A	0.1300	0.0400A	0.0200A
	MONTGOMERY	0.0200	---	---	0.1000	---	---
	MOORE	0.0	---	---	0.0900	---	---
	NACOGDOCHES	0.0300	---	---	0.1000	---	---
	NUECES	0.0	0.0300	0.0200	23.6100	2.5200	1.1500
	ORANGE	0.0	0.0400A	0.0300A	0.4700	0.0400A	0.0300A
	POTTER	0.0	---	---	0.1800	---	---
	SAN PATRICIO	0.0	---	---	0.0400	---	---
	SCURRY	0.0	---	---	0.1200	---	---
	SMITH	0.0	0.0400A	0.0300A	0.1700	0.0400A	0.0300A
	TARRANT	0.0	---	---	1.5000	---	---
	TAYLOR	0.0	0.0300	0.0200	0.1600	0.0300	0.0200
	TITUS	0.0	0.0400A	0.0200A	0.3600	0.0400A	0.0200A
	TOM GREEN	0.0	---	---	1.1400	---	---
	TRAVIS	0.0	0.0100	0.0100	1.8300	0.0500	0.0400
	VAL VERDE	0.0	---	---	0.0900	---	---
	VICTORIA	0.0	---	---	0.0700	---	---

A INDICATES ONLY ONE STATION REPORTING

APPENDIX D

Effects of Deposited Particulate Matter

APPENDIX D

EFFECTS OF DEPOSITED PARTICULATE MATTER

Most evidence for particulate toxicity is derived from studies of domestic animals. It is often not clear if the symptoms of toxicity are the result of ingestion, inhalation, or both. Only those studies which clearly indicated ingestion of dust-covered vegetation are summarized here. There appears to be a definite relationship between deposition of fine particles of arsenic, fluoride, lead, and copper on vegetation; their ingestion by animals; and chronic or acute injury to animals.[59,60] Other metals which may also be implicated are zinc and cadmium. The surfaces of vegetation, especially those covered with fine hairs (stems, leaf petioles, and blades), provide a major filtration and reaction surface for metal-laden particles of 1-5 μm and less.[61]

Fluorides are reported to cause more damage to domestic animals than any other air pollutant.[62] Dietary fluoride is generally accepted as the major source of fluorosis in animals.[9] Fluorosis has been noted in most domestic livestock, presumably resulting from particulate fluoride deposited on vegetation and ingested by animals.[63,64] For cattle, the most susceptible domestic animal,[26,65,66] diets containing concentrations exceeding 40 ppmw fluoride may have severe toxic effects.[67] The safe range for soluble and insoluble fluorides has been specified at 30-50 ppmw and 60-100 ppmw, respectively, for cattle.[68] Sheep and swine (70-100 ppmw), chickens (150-300 ppmw), and turkeys (300-400 ppmw) are less sensitive to dietary fluoride levels.[68]

Arsenic deposited on vegetation from smelting operations has been known to kill livestock if enough was ingested.[62,69-72] Ingestion of arsenic-contaminated dust/soil on forage presents the greatest dangers to grazing animals.[73] However, a wide range of toxicity for arsenic compounds exists and is correlated to animal excretion rates.[9] The reported biological half-life of arsenic compounds ranges from 30-60 hours.[74,75] Those compounds excreted most rapidly tend to be least toxic.

Lead poisoning of cattle, horses, and other grazing animals as a result of ingestion of contaminated forage has been reported often.[76-80] Fodder contaminated by lead and zinc by atmospheric deposition from a foundry was responsible for the death and slaughter of 140 cows.[81] Ingestion of surface deposits of airborne lead on forage, especially adjacent to heavily traveled highways,[82] and inhalation of lead can be significant additions to the total body burden of animals.[83,84] Zoo animals (cats, primates, and snakes) are susceptible to lead aerosol poisoning.[85]

Several other elements have been implicated in the illness or death of grazing animals when deposited on forage. For example, soot containing vanadium at a concentration of 1 μg/g was dumped near a pasture and subsequently spread by wind. The pasture grass was covered with a film of soot and, when ingested by cattle, caused sickness and death.[86,87] Iron particles from a magnesium plant in Austria adversely affected the digestive tracts of grazing cattle.[88] Domestic animals grazing near specialized steel and alloy plants have been poisoned by ingesting dust containing molybdenum with vegetation.[62]

No specific studies are known which address the intake of trace elements by wildlife through ingestion of dust-coated vegetation.[9] Fluorosis has been identified in wild animals, especially deer and elk.[89] Honey bees, red deer, and wild hares are known to be especially sensitive to arsenic poisoning.[62] Newman[90] presents a state-of-knowledge review of the effects of industrial air pollution on wildlife. However, specific information dealing with surface-contaminated forage could not be identified. Ingestion of plant material which has concentrated heavy metals through uptake and inhalation of airborne particulates represents the majority of case histories.

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16. ABSTRACT

Section 165 of the Clean Air Act requires preconstruction review of major emitting facilities to provide for the prevention of significant deterioration (PSD) and charges Federal Land Managers (FLMs) with an affirmative responsibility to protect the air quality-related values of Class I areas. Regulations implementing these provisions require an analysis of the impairment to visibility, soils, and vegetation (52.21(o)).

The information and screening procedure presented here provide interim guidance: (1) to aid in determining whether emissions are significant or whether there are significant air quality impacts under Section 52.21(o), and (2) to aid in flagging sources which should be brought to the attention of an FLM under Section 52.21(p).

Impacts on vegetation and soils are the principal areas addressed by the procedure which thus takes a limited view of the possibly broad scope of air quality-related values. A selected review of impacts on fauna has also been included and the odor potential of regulated pollutants is addressed. This procedure is intended for use by air quality engineers and is not a manual for the assessment of impacts on plants, soils, and other air quality-related values such as would be suitable for an ecologist.

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