AIR QUALITY CRITERIA AND THEIR IMPORTANCE FOR FORESTS

Wilhelm K n a b e

Landesanstalt für Immissions- und Bodennutzungsschutz des Landes Nordrhein-Westfalen, Essen, Germany

ABSTRACT

'Air quality criteria' are an expression of the relationship between air pollution and its adverse effects on man, animals, vegetation, and property. They indicate the nature and extent of the injury associated with certain levels of pollutants either single or in combination during various time periods.

In order to be precise, air quality criteria must be based on both criteria describing the effect and criteria describing the pollutant. They are needed as scientific base for 'air quality standards' which are set by governments or air quality control boards to limit the level of pollution for the protection of man and his environment. 'Air quality risks' and 'air quality goals' are regarded as necessary steps on that way.

In contrary to this concept forest field investigations of the past were mainly concerned with the detection of damage, proof of its origin and the assessment of the amount of damage or the area concerned. Only in recent years some field observations are vailable where the level of air pollution was determined at the same time. Results of fumigation studies can be used in addition even if it is obvious that conditions in green houses differ from those in a forest. Air quality criteria for some major pollutants are developed as far as forests are concerned. More investigations are needed to fill the open gaps. Ignoring this challenge forestry would willingly disclaim to influence proper air quality standards which would protect also the forests.

On the other hand it is unlikely that forestry can urge standards which will guarantee healthy growth of any sensitive tree species in industrial areas.

For this reason specific air quality criteria would considerably contribute to a realistic prognosis of the damage to be expected at levels below the air quality standards or what species should not be planted in a given area under expected levels of pollution.

INTRODUCTION

Forest scientists are facing a strange problem. They were way ahead of their colleagues of other desciplines in recognizing that the fumes of industrial works meant a thread to the surrounding environment one hundred years ago, and they made an awful lot of interesting studies since then, but now they look like strangers missing the plane at the airport because carrying inconvertible currency only. What is the matter?
The plane of environmental control has already taken off, pushed forward by increasing public interest and many progressive individuals. The goals of clean air were set, acts limiting the air pollution were passed, but we foresters had not yet prepared those data which fit into the system of environmental control by prescribing certain qualities of air as necessary for man's health and well-being.

This paper is concerned with the concept of air quality criteria and standards, what it means for forestry and what we may contribute to it with our present state of knowledge.

AIR QUALITY CRITERIA IN THE CONCEPT OF AIR MANAGEMENT

There are two main lines of approach to air pollution control. The "best practical means approach" stresses the principle that air pollution must be prevented as far as is practicable by reducing emissions at the source without reference to air quality guides or standards. The "air quality management approach", on the contrary, stresses, that air quality guides and standards are the basic elements in all control programs(PERSSON 197o). "Air quality criteria" are the base for the latter form of air resources management. They are, in essence, an expression of the relationship between air pollution and its adverse effects on man, animals, vegetation, and property (PRINDLE 1966). They indicate the nature and extent of the injury associated with certain levels of pollutants either single or in combination during various time periods and reflect the latest state of scientific knowledge in this respect (Air Quality Act 1967).

U.S. Air quality criteria end with conclusions which appear either as estimates of the risks connected with certain levels of pollutants (A.Q.C. Sulfur Oxides and A.Q.C. Particulate Matter) or as certain facts which have been observed (A.Q.C. Photochemical Oxidants and A.Q.C. Hydrocarbons). I should like to differentiate both interpretations and to accept the latter definition as correct. Then air quality criteria rather summarize our knowledge of the known facts than the expected risks. This would mean that we need a new term for the previous interpretation of those conclusions. 'Air quality risks' seem to be appropiate and suitable for that purpose.

THE ESTABLISHMENT OF AIR QUALITY CRITERIA

Sometimes it is overlooked what requirements must be fulfilled for the establishment of air quality criteria. It is not enough to say just "Norway spruce is injured at a concentration of 1 ug HF/m^3," we need at least to ask, "in what respect and to what degree were the trees injured, how many of them, and how long was the period of impact?"

In order to be precise, air quality criteria must be based on both criteria describing the effect and criteria describing the immission situation (PRINZ and STRATMANN 1969). The term immission is used in Germany for the amount of pollutant in ambient air as it relates to a receptor.

Criteria of Effect

'Criteria of effect' represent scales for assessing the effects of immission. They describe a certain part of the total effect only. They are quantitatively determined by 'indices of effect' (PRINZ and STRATMANN 1969). Various criteria of effect can be established for man, animals, vegetation, soil and materials. Some are listed in table 1. The colums refer to one group of subjects, criteria in the same line express a loose connection only. A special proposal for the assessment of the effects of air pollution on trees and forests is shown in table 2 and 3. I have followed the proposal of GUDERIAN et al. (196o) to divide the harmful effects up into 'injury' and 'damage', the first describing the response of the plant resulting from the action of air pollutants, the second determining the impairment in economic value. Criteria of effect must not express a general condition or quality in my opinion, but describe the change in condition or quality, e.g. the difference or relation to a normal situation. The risk caused by a yearly average of 1 ug HF/m^3 in ambient air to Norway spruce, e.g., cannot be expressed by the total yield per hectare, but by the difference to a healthy stand on a similar site or the relative reduction of yield to that control.

TABLE 1

SOME CRITERIA OF HARMFUL EFFECTS OF AIR POLLUTION ON VARIOUS SUBJECTS

Man	animals	plants	soil	materials
Accumulation of air pollutants	do.	do.	do.	do.
Reaction within individual cells	do.	do.	reaction of individual molecules	do.
histological changes	do.	do.	structural changes	do.
metabolic interference	do.	do.	changes in soil biology	-
functional disturbances (e.g. reproduction)	do.	do.	do. (e.g.water retention	do. (e.g. conductivity and insulation)
growth disturbances	do.	do.	-	-
impairment in performance	do.	decreased yield	decreased fertility	decreased stability
molestation (individual feeling)	do.	decreased aesthetic value	-	soiling
illness	do.	do. (in special cases)	degradation	staining corrosion
death	do.	withering	-	destruction

do. = same criteria as that to the left on same line

TABLE 2

SOME SUITABLE CRITERIA OF INJURY CAUSED BY AIR POLLUTION TO FOREST TREES AND FORESTS

Criteria of effect	subject of investigation				
	part of a plant	individual plant	number of individuals	population (stand)	ecosystem
changes in cell components	x	x	x	-	-
changes in metabolism	x	x	x	-	-
changes in cell structure	x	x	x	-	-
degree of chlorosis or necrosis	x	x	x	(x)	-
premature leaf abscission or needle cast	x	x	x	(x)	-
decreased growth	(x)	x	x	x	-
percentage of plants injured to a certain degree	-	-	x	x	(x)
percentage of dead plants	-	-	x	x	(x)
decreased production of organic matter or decreased increment per area	-	-	-	x	x
changes in number of species	-	-	-	(x)	x
changes in abundance	-	-	-	(x)	x
changes in coverage	-	-	-	(x)	x
changes in general health conditions	-	-	x	x	x

TABLE 3

SOME SUITABLE CRITERIA OF FUME DAMAGE TO FOREST TREES AND FORESTS
(cf. GUDERIAN et al. 1960)

Criteria of effect	Subject of investigation				
	part of a plant	individual plant	number of individuals	population (stand)	ecosystem
Impairment in economic value:					
by reduced yields	-	x	x	x	-
by reduced quality (constituent value, external appearance)	x	x	x	x	-
by impact on soil and surrounding	-	-	-	x	x
by decreased resistance to biotic and abiotic influences (e.g.bark beetles, frost)	-	x	x	x	x
by increase of forest pests		-	-	x	x
Impairment in welfare functions:					
by reduced recreational value	-	-	-	x	x
by alterations in forest influences (e.g.filter capacity)	-	-	x	x	x
Impairment in ideal value	-	x	x	x	x

Such a comparison between an exposed population and its control in clean air is based on counting individuals with certain qualitites or measuring certain qualitites of them, e.g. counting the number of trees having less than four needle sets only or measuring the width of the annual rings by means of increment cores. The collected data can be expressed by 'characteristics' like the percentage of trees having less than four needle setsor the arithmetic mean of the annual radial increment in breast height. Such characteristic expresses rather the influence of all genetic and environmental factors than the effect of air pollution alone.
We shall obtain an 'index of effect' of air pollution, however, if we compare those two values of one characteristic taking that of the control as 1oo.

Immission Criteria

Criteria of Air Pollution Related to a Receptor

"Immission criteria represent scales for evaluating a given immission situation". PRINZ and STRATMANN (1969) have already defined immission rate and immission supply. They can be expressed by immission characteristics as shown below. These characteristics, however, do not describe real qualities or properties but constitute the briefest possible formula for a conceptional classification of the phenomena, e.g. the fluctuation of concentration and wind speed during a given period and in all three dimensions of the atmosphere.
Reviewing the literature on fume damage to forests, it must be admitted that even those papers which use precise criteria of effect do not describe the level of air pollution with the same accuracy. Hence I think it is helpful to list at least a few immission characteristics which are used in the literature on air quality criteria (STRATMANN and BUCK 1966, STRATMANN et al. 1968).

Immission Supply

Immission Supply is a scale for the quantitative description of immission. It is approximately expressed by the concentration of a pollutant in the air close to the place of effect.

1. Characteristics of immission supply

1.1 Concentration (mg m^{-3})

Short term measuring intervals are necessary for the assessment of acute injury. Intervals of 1/2 hour, 1 hour or 4 to 8 hours are in use. The shorter the measuring interval or the smaller the sample the higher peaks will be revealed in ambient air. Larger samples and longer intervals level those peaks to a certain degree.

The concentration over longer periods is usually given as the arithmetic mean ($\bar{x}$) of continuous monitoring or distinct samples.
Additional information on the frequency distribution is contained in characteristics like the standard error or the standard deviation. German workers refer to characteristics which include both the arithmetic mean and its standard error or deviation (STRATMANN and BUCK 1966).
Hence we can list the following immission characteristics:

$\bar{x}_{year}$ = arithmetic mean of all measurements in a year

$\bar{x}_{summer}$ = from April 1 to Sept.3o

$\bar{x}_{winter}$ = from Oct. 1 to March 31

$\bar{x}_{veg}$ = from April 1 to Oct. 31 at the Biersdorf field experiment (GUDERIAN and STRATMANN 1968)

$I_1 = \bar{x}_{year} + \Delta\bar{x}$ = upper limit of the 97.5 % confidence range for the arithmetic mean

$I_2 = \bar{x}_{year} + \Delta x$ = upper limit of the 97.5 confidence range for the individual values. The immission characteristic I_2 approx. corresponds to the 97.5 % value of the cumulative frequency distribution.

The arithmetic means are the same for a longer period independently of the measuring intervals. I_1 and even more I_2 positively react to shorter intervals.

1.2 Mean supply value (cf. STRATMANN et al.1968)

Mean supply value = $(\sum_{1-n} c_i \quad v_i) : n$ = the sum of all products of concentration in ambient air (c) times wind speed (v) divided by the number of measurements

$(mg \quad m^{-3} \quad m \quad sec^{-1} = mg \cdot m^{-2} . sec^{-1})$

The mean supply value might be of especial value when dealing with fluoride immissions because of the higher uptake at higher wind speed (KNABE 1968 and 197o).

Immission Rate

Immission rate is the quantity of air pollutants converted during the immission process per unit time referred to a specific acceptor or receptor, a certain number of such acceptors or a geographical area (PRINZ and STRATMANN 1969).

2.1 Immission rate per surface, e.g. the daily precipitation of dust per square meter ($mg \cdot d^{-1} \cdot m^{-2}$)

2.2 Immission rate per dry matter, e.g. in biological indicators exposed for a fortnight ($mg \cdot d^{-1} \cdot 100\ g^{-1}$ dry matter)

The immission rate cannot be determined without knowing the time of exposure. The accumulation of SO_2 in lead candles, filter paper or clothes impregnated with $Ba(OH)_2$ and glycerin is also a determination of the immission rate, if the time of exposure is known.

Approaches to Air Quality Criteria

Knowing both the appropriate criteria of effect and the right immission criteria we should be able to establish precise air quality criteria, unless, and this happens often enough, the experimental data do not fit into our system. Hence we should at least try to start new experiments under this considerations. We already know very much about the response of plants in fumigation chambers, they have helped us to learn something about the mechanism of effect and the relative susceptibility of various species. We could also prove doses with acute or synergistic effects by these fumigation experiments. We are, however, still missing sufficient data on dosage-response relations from field observations. Just these observation will help us to find realistic air quality criteria and air quality risks.
I should like to recommend the following approaches to meet this challenge:

1) Biological observations near those stations where continuous measurements are carried out for regional air pollution control programs.
2) Additional measurement of immission with generally accepted methods at those sites where intensive biological research is carried out.
3) Additional measurement of immission with simple field methods at sites where biological investigations of medium level are carried out. Biological indicators can be helpful here, too (HECK 1966, SCHÖNBECK et al. 197o)

All three approaches will help to collect those data we are still missing, and make our experiments and observations much more effective because we can compare them with the work of other groups at different sites. We should at no times forget that air quality criteria are established for the sake of man. So we should prepare our data in a manner as it is used for air pollution control programs.

SOME FOREST CONTRIBUTIONS TO AIR QUALITY CRITERIA

Sulfur dioxide seems to be a good example to show the possible contributions of forest science to the establishment of air quality criteria.

Sulfur Dioxide

The U.S. air quality criteria for sulfur oxides summarize the known relations between concentrations of SO_2 in ambient air and injury to forests in the U.S.A. and Canada. I want to accomplish these data with some from Central Europe

Injury to Norway Spruce in the Erzgebirge Mountains

The findings of Czech and German scientists in the Erzgebirge mountains are most interesting. There are large lignite burning power plants in the North Bohemian valley with a daily emissions of 2.000 tons of SO_2 which is estimated to be increased to 3.500 tons by 1975. The fumes of these plants have caused injury to spruce forests on the mountains even in a distance of 25 to 30 km north of the sources. About 46.600 hectares are more or less injured in the northern German part alone (STEIN and DÄSSLER 1968). The affected area in Czechoslovakia is much larger. Measurements in both countries allow a comparison between the level of SO_2 immission and fume damage on the Erzgebirge mountains (Table 4).

The data of the original papers cited in table 4 were re-calculated and condensed so that they could be compared. DÄSSLER (1970) stresses, that his values which are marked with G, are results of first years measurements in the DDR and should be replaced by results of longer periods. At the present time, however, we must be glad to use them as first estimate of the immission load. MATERNA and his co-workers report on the same period of measurement but on different sites in Czechoslovakia. His data are marked with C. He used a continuous monitoring device, evaluated, however, measurement intervals of 3o minutes. The figures relate to the following stations:

severe injury: G: Deutscheinsiedel, C: Behánky
medium " : G: station 3, 4, 6, 1o, 11, 12
C: Celná, Vykmanov
slight G: station 1, 7, 8

Values of 24 hours measurements in table 4 are generally higher than those of short measurement intervals. DÄSSLER and STEIN (1968) explain the difference by the suggestion that peaks preferably occur in the late morning and afternoon, whereas their measurement times were fixed at 6.oo, 12.oo and 18.oo. Randomized measuring hours seem to be a must for precise investigations. The difference is especially high at Deutscheinsiedel which is situated at the crest of the mountains. MATERNA found that the relatively low concentrations need about three years to show significant effects. Hence Vykmanov was grouped to medium injury inspite of the fact that injury was just showing up in 1967, the year of measuring. In 1969 the spruce stands were severely affected. Excessive concentration of fluorine were neither found in the needles nor in snow samples. Hence immissions of fluorine are not regarded as possible cause for the damage. It might be noticed that SO_2-immission listed in table 4 are higher in winter than in summer, an observation which can be confirmed by measurements in the Ruhr area.

Norway spruce (Picea abies Karst) has proved very susceptible to SO_2-immissions on the Erzgebirge mountains. It is suggested that the hard climate of the elevations above 7oo m considerably contribute to the extent of injury. Those parts of the mountains, however, are just natural spruce forests where broadleaved trees do not appear as promising alternative, except of the mountain ash (Sorbus aucuparia L.) which is of no commercial value.

TABLE 4

CONTRIBUTIONS TO AIR QUALITY CRITERIA FOR SULFUR DIOXIDE

A) Response of Stands of Norway Spruce on the Erzgebirge mountains (G = German data acc. to DÄSSLER and STEIN 1968 and STEIN and DÄSSLER 1968, C = Czech data acc. to MATERNA 1966, 1969 and MATERNA et al. 1969)

source of data	immission characteristic	measurement interval	criteria of effect (zone of damage)		
			severe injury	medium injury	slight injury
			immission criteria concentration (mg $SO_2 \cdot m^{-3}$)		
G	$\bar{x}_{year}$	20 minutes (3 samples/day)	0.16	0.06-0.13	0.07-0.09
C		30 minutes (cont.monit)	0.12	0.06-0.09	-
G		24 hours	0.53	0.07-0.24	0.09-0.10
G	$\bar{x}_{summer}$	20 minutes	0.12	0.05-0.09	0.05-0.09
C		30 minutes	0.12	0.04-0.08	-
G		24 hours	0.43	0.05-0.13	0.05-0.09
G	$\bar{x}_{winter}$	20 minutes	0.20	0.07-0.22	0.10
C		30 minutes	0.12	0.07-0.10	-
G		24 hours	0.63	0.09-0.33	0.12-0.14
C	I_1	30 minutes	0.15	0.12	-
C	I_2	30 minutes	0.37	0.32	-
G	% days $> 0.15 mg SO_2 \cdot m^{-3}$	24 hours	56 %	35-40 %	?
C		30 minutes	?	27 %	?
C	% half hours $> 0.5 mg\ SO_2 \cdot m^{-3}$	30 minutes	?	3.2 %	?

Distribution of Scots Pine in the Ruhr

A network of sample points for distinct air measurements is laid over the industrial regions of North Rhine Westphalia, especially the Ruhr district (STRATMANN and BUCK 1966). After three years the relations between the distribution of pine stands (Pinus sylvestris L.) and SO_2-immissions were investigated (KNABE 1970a). They are listed in table 5. SO_2 acts there both as toxicant and as indicator for the general degree of air pollution. It cannot be said that SO_2 has killed the pines, but we have not found andy old stand of Scots pine which has tolerated a higher concentration than mentioned in table 5. Individual trees of higher resistance single or in mixed forests were neglected. Norway spruce was affected even more. There was no living stand of that species within the given margin.

TABLE 5

CONTRIBUTIONS TO AIR QUALITY CRITERIA FOR SULFUR DIOXIDE

B) Relations between SO_2-immissions and the distribution of Scots pine in the Ruhr area

	criteria of effect		
Immission characteristic	pine stands slightly injured	pine stands severely injured, but still present	pine stands no longer found
	immission criteria concentration (mg SO_2 m^{-3}) (highest values of immission characteristics within 3 years)		
$\bar{x}_{veg.}$ (1.4.-31.1o.)	o.08	o.18	≥ o.19
$\bar{x}_{year}$		o.2o	≥ o.21
I_1		o.24	≥ o.25
I_2		o.75	≥ o.76

Measurement intervals: 1o minutes

Results of the Biersdorf Field Experiment

The results of the famous Biersdorf field experiment near an iron ore smelter in West Germany (GUDERIAN and STRATMANN 1969) were not considered in the U.S. Criteria for sulfur oxides. It is, so far I know, the first experiment where immission criteria and criteria of effect have been consequently applied. GUDERIAN and van HAUT (197o) summarize some of the results. BUCK (197o) has calculated the values of additional immission characteristics. Table 6 contains only some data relevant to forests. Concentrations were converted from ppm to mg $SO_2 \cdot m^{-3}$ by multiplication with the factor 2.5.

TABLE 6

CONTRIBUTIONS TO AIR QUALITY CRITERIA FOR SULFUR DIOXIDE

C) Immission Load at which the growth of trees was reduced at the Biersdorf field experiment in 1959 and 196o

Immission characteristic	criteria of effect: significant growth reduction of Quercus robur L., Fagus sylvatica L., Picea abies Karst, Pinus sylvestris L., Larix decidua Mill.	criteria of effect: no significant growth reduction
	immission criteria concentration (mg SO_2 m^{-3})	
$\bar{x}_{veg}$ Biersdorf $= \bar{c}_m$ (GUD.a.STR.)	o.o38-o.o6o	o.o22-o.o25
I_1-veg (BUCK 197o)	o.o8	o.o7
I_2-veg (BUCK 197o)	o.98	o.59

It has to be added that the arithmetic mean of the growing season (April 1 to October 31) was determined under omission of all measurement values below o.o25 mg $SO_2 \cdot m^{-3}$ at Biersdorf which were set equal to zero at that time. Adding those values to the total sum which is divided by the number of all measurements, $\bar{x}_{veg}$ might be increased by about 25 percent. The immission pattern of Biersdorf is that of a single source type, that means low mean and relatively high peaks. Hence the ratio $I_2:I_1$ amounts to about 1o : 1 at Biersdorf compared to a ration of 3-5:1 in urban areas in North-Rhine Westphalia (BUCK 197o).

Other Toxicants

General considerations to air quality criteria for other toxicants cannot be discussed at that time. I want to mention at least the following literature:
U.S. Air Quality Criteria for Carbon Monoxide 197o, for Hydrocarbons 197o, for Particulate Matter 1969 and for Photochemical Oxidants 197o, also GUDERIAN and STRATMANN (1969), BRANDT (197o) and McCUNE (197o) for fluorides and HEGGESTAD (1969) for ozone. This list is a very incomplete one, and has to be completed It must be taken inot account that any of these toxicants may act in a different way what might require different immission characteristics

THE USE OF AIR QUALITY CRITERIA

Establishment of Air Quality Risks

After having collected abundant data for air quality criteria the next step must be to estimate the risks of certain levels of pollution. In the case of SO_2 we may say that a mean concentration during the growing season of o.o8 mg $SO_2 \cdot m^{-3}$ will probably cause slight injury to Scots pine and Norway Spruce in the lowlands of Germany, but will severely affect Norway spruce in elevations above 7oo m.
It is obvious that the data which are available at the present time do not allow a description of all the risks for forests. We especially need a critical evaluation which immission characteristic correlates with relevant effects. In the case of SO_2 e.g., we should know to what extent the average and the peaks of immission supply contribute to the total effect. In the case of fluorine we also need the information whether we have to introduce wind speed into the equation. It can be suggested that the immission rate will give better correlations to effects than the immission supply, especially for fluorine.

The Use of Air Quality Risks

Air Quality risks may serve several purposes after having been established. First they are a basic information for legislation and administration to pass acts and decrees. The politician who cannot study all the scientific background of air pollution control will get an extract of all data which he can try to understand. This extract might be misleading in some cases, but it is a better base for an act than emotions or the influence of industrial lobby.
Public opinion may react in a similar way. Information on the possible risks of present or future levels of air pollution will force the responsible people to action. Then the estabishment of air quality goals would be the next step.

Air quality goals may be set in such a way that the risks for man and his environment are limited without regard of economic and technological considerations. These air quality goals will create a constant pressure in urban areas to improve the situation.
The "best practical means approach" will also contribute to this change to the better, but it will fail there if used alone. Reducing the lead content of gasoline to 50 percent of the present level, e.g., would appear as great victory of environmental control, but be meaningless for the reduction of hazards to public health in a city if the number of cars and the fuel consumption have doubled in the same period.

On the contrary, a comparison of established air quality goals with the present level of pollution would show, that stricter measures are necessary to avoid untolerable risks. Therefore air quality standards must be set as limit values, prescribing the level which must not be exceeded. They might be based on the concentration of lead in the atmosphere or in plants, animals and men. Then air quality control can show whether these standards are exceeded. In that case a further reduction of lead in gasoline, a limitation of the density of population or man's freedom to buy or use cars would be required. Economically feasible and personally acceptable alternatives to fuel burning cars for transportation will hardly be developed without this pressure. We can summarize that air quality risks will first serve as base for the establishment of air quality standards.

Land zoning, industrial planning and land management are regarded as second useful application of air quality risks, which describe the relations between present and expected level of air pollution and its effect on the surrounding, also below the air quality standards which are in forde.
Present German air quality standards for SO_2, e.g., limit both the mean and the peaks of concentrations by prescribing limit values of $I_1 = 0.4o$ and $I_2 = 0.75$ mg $SO_2 . m^{-3}$ (TAL). These standards guarantee a certain degree of general protection but do not include sensitive plants. Therefore two new fuel burning power stations in the mountains, designed to remain just below the tolerated level of emissions, would mean a real danger to spruce forests in the surrounding. Land planning has to consider that before building the plant.

On the contrary, Norway spruce and Scots pine will not get old in an industrial region with SO_2- imissions just below the values mentioned above. No returns can be expected from planting these species. Here forestry has to consider the prospects and make another choice for reforestation.

CONCLUSIONS

Forest science has to see the present competition between the "best practical means approach" and the "air management approach" in air pollution control. The first can help forestry in undeveloped and underdeveloped areas that no easily avoidable emissions will take place. The latter is based on the carefully investigated relations between the degree of air pollution and its effects on man, animals, vegetation and property. Hence this approach offers the best possibilties to influence air pollution control by forestry, not by lamenting damage caused by unknown scurces, but by contributing scientific data which fit into the great concept.

The more data we offer the better forests will be protected by general prescriptions which are justified by the increasing public interst in forest recreation and other welfare functions, also by the fact that coniferous forest as a whole act as sensitive indicator for decreasing air quality. They will give a warning signal to the public and their officials that measures of air pollution control cannot be postponed anymore.
Ignoring this challenge forest science willingly disclaim to influence proper air quality management as part of general environmental control which has become inevitable for the survival of mankind.

Zeitschrift/Journal: Mitteilungen der forstlichen Bundes-Versuchsanstalt Wien

Jahr/Year: 1971

Band/Volume: 92_1971

Autor(en)/Author(s): Knabe Wilhelm

Artikel/Article: Air Quality criteria and their importance for forests 129-145