Working Paper

Emergency Air Protection: A Survey of Smog Alarm Systems

Meinhard Breiling
Joseph Alcamo

WP-92-52
August 1992

IIASA International Institute for Applied Systems Analysis □ A-2361 Laxenburg □ Austria
Telephone: +43 2236 715210 □ Telex: 079 137 iiasa a □ Telefax: +43 2236 71313

Emergency Air Protection: A Survey of Smog Alarm Systems

Meinhard Breiling
*Joseph Alcamo**

WP-92-52
August 1992

(*)Leader, Project on Toxic Pollution and the European Environment 1991.

IIASA International Institute for Applied Systems Analysis □ A-2361 Laxenburg □ Austria
Telephone: +43 2236 715210 □ Telex: 079 137 iiasa a □ Telefax: +43 2236 71313

Contents

Foreword

As Central and Eastern Europe looks to its future, it is faced with a legacy of environmental pollution from its recent past. Three main environmental tasks confront the region: to reduce the burden of pollutants, to revitalize the environment, and to prevent future pollution by implementing "clean technologies." Unfortunately, the funds are not available for taking on all of these huge tasks at once, at least not in an effective way. For this reason it is of utmost importance to set near-term priorities for environmental protection. Faced with a difficult decision, perhaps we must choose the protection of human health as a number one near-term priority. This paper describes one approach to protecting human health from pollutants which can also be accomplished in the coming years; the authors aim to provide an overview of smog alarm systems to experts and citizens in Central and Eastern European cities so that they can consider the option of building such systems in their own cities. To the authors' knowledge, this is the first review of its kind, and it is hoped that it will lead to a closer examination of this practical and effective control strategy.

Acknowledgments

This study was partly funded by Grant Number 158 from the Regional Environmental Center for Central and Eastern Europe.

Special thanks go to everyone who contributed to the study in the eight selected countries, in particular to: Dr. Danninger, Dr. Hojevsky, Dipl. Ing. Pankratz, Dr. Pillmann, Doz. Pleschberger, Mag. Scheicher, Dr. Semmelrock, Dr. Smekal, Dipl. Ing. Begert, Dr. Bruckmann, Dipl. Ing. Enge, Dr. Hammje, Dr. Hohmeyer, Dr.Knetsch, Dr. Kutzner, Dr. Lenschow, Dr. Pfeffer, Dipl. Ing. Römermann, Dr. Wyzif, Dr. Wunderlich, Dr. Zimmermann, Dr. Calori, Dr. Castrofino, Prof. Finzi, Dr. Gianelle, Dr. Inaba, Dr. Mizunu, Mr. Nishio, Dr. Nishioka, Mr. Nomoto, Mr. Ozaki, Mr. Shibaike, Ir. Buitekamp, Dr. Burn, Dr. Tveita, Dr. Eggli, Prof. Hanggartner, Dr. Sommer, Dr. Lockee, Mrs. Pearson, and Mrs. Shelton.

We also want to thank the Kawasaki Pollution Monitoring Center and the Kitakyushu Department for Environmental Conservation. The authors wish to thank B. Lübkert-Alcamo for reviewing the manuscript and H. Pankl for writing the tables.

Chapter 1

Introduction

Although the seriousness of environmental problems in Central and Eastern Europe is widely recognized, there are many factors that are likely to delay their solution for some decades. These include the high costs of pollution control, the competition between pollution control and economic development for available funds, and the inadequate "environmental infrastructure" in the region needed to deal with environmental problems (see, e.g., Alcamo, 1992).

At the same time, the threat to public health from severe air pollution (see, e.g., WHO, 1992[1]), demands that action be taken as soon as possible to reduce the exposure of the population to dangerous levels of pollutants. With this in mind, an appropriate near-term policy should be "emergency environmental protection," namely, the immediate protection of public health from the greatest and most obvious environmental hazards using readily available measures. Among these measures are smog alarm systems which alert the public to impending or occurring air pollution episodes and, in some cases, specify measures to counter the sources and impacts of these episodes. Although measures such as smog alarm systems only treat the symptoms rather than the cause of the region's environmental problems, they have the advantage of being quick to implement, inexpensive, and, most important of all, effective in protecting public health.

Smog alarm systems can be set up relatively quickly because they do not require very large institutions or investments. Their most expensive component is a necessary air quality monitoring network, but these networks are already being set up in many Eastern European cities for other reasons, for example, to determine the location of areas most severely affected by air pollution, or to validate models used for developing air quality management plans. Moreover, smog alarm systems have the potential to reduce the exposure of urban populations to high levels of pollutants because the most dangerous levels occur only for short periods of time during especially unfavorable meteorological conditions (about 30 to 35 days or less in a year). For example, data presented in UNEP(1980) indicate that WHO norms for sulfur dioxide are exceeded in Zagreb during 8% of the time in an average year. WHO norms for ambient smoke levels are exceeded in Wroclaw 8% of the time on average and in Warsaw 5% of the time. *Table 1.1* lists the WHO general air quality standards.

Alarm systems are targeted to both *winter* and *summer* smog. Winter smog usually has to do with high concentrations of sulfur dioxide, particulate matter, and other industrial pollutants which build-up in the lower layer of the atmosphere over cities and industrial areas when this layer is capped by a temperature inversion. Episodes of winter smog are often local in scale because pollutants emitted from furnaces, industrial processes, and other sources are trapped near their origin by the temperature inversion. Sometimes, however, a winter smog episode can

[1]WHO (1992). Acute effects on health of smog episodes. European Series No. 43. WHO Regional Office for Europe. Copenhagen.

Table 1.1. WHO general air quality standards in micrograms per cubic meter.

	SO_2	SPM	NO_2	CO	O_3
Annual mean	40–60	60–90			
98%ile	100–150	150–230			
24 hours			150		
8 hours				10,000	150–200
1 hour			400	30,000	120
30 min				60,000	
15 min				100,000	

be continental in scale, as in the case of the January 1985 episode in Europe when sulfur dioxide accumulated in the stagnant atmosphere over Eastern Europe and was then blown westward by moderate winds (Lübkert, 1989).

Summer smog, by comparison, is manifested by high photo-oxidant levels (including nitrogen oxides and ozone) in the lower atmosphere. This is brought on by the build-up of gases from traffic-related emissions in a stagnant atmosphere; these gases are then converted by intense solar radiation into secondary pollutants such as ozone. Summer smog episodes normally cover a wider area than winter smog episodes because (1) the gases from traffic emissions (nitrogen oxides, for example) travel some distance from their source before being converted to photo-oxidant pollutants and (2) traffic emissions — the main source of smog — are much more evenly distributed across the landscape than the industrial emissions that cause summer smog episodes. As far as Europe is concerned, summer smog is more an affliction of the West because of the greater number of vehicles in this region, and winter smog troubles the East more often because of the greater amount of uncontrolled emissions from energy conversion and industry and the lower number of vehicles in this region. Of course, if the number of vehicles without pollution control greatly increases in Central and Eastern Europe, then the frequency of summer smog episodes will also increase there. All in all, smog alarm systems can provide "emergency air protection" for European urban populations from winter and summer smog until the source of this smog is permanently curtailed.

The purpose of this paper is to survey selected smog alarm systems around the world and to provide background information to individuals and organizations in Central and Eastern Europe for setting up smog alarm systems in their own cities. Of course, not all Western experience is relevant to Central and Eastern Europe, but we believe much of it is.

The alert systems from 19 different smog areas in 8 different countries are reviewed and summarized in this paper. Information was provided by local experts through interviews (conducted by one of the authors, M.B.) or by answering a questionnaire prepared by the authors. Additional written information was made available by the experts. The authors are indebted to these experts (listed in the Acknowledgments) for their assistance.

In this paper we first describe some of the common elements of smog alarm systems, and then present specific information about these systems in different countries. We then compare the systems and draw some conclusions and recommendations that are particularly relevant to cities in Central and Eastern Europe.

Chapter 2

Elements of Smog Alarm Systems

The purpose of a smog alarm system is to alert the public and particular groups to dangerously high air pollution levels and, in some cases, to act to reduce the impact of these levels. A smog alarm is usually called by local government officials based on results of real-time monitoring of air quality, weather forecasts of episodic conditions, and the advice of experts. The smog alarm itself is typically divided into various stages — pre-alarm, level 1, level 2, etc., referring to the severity of the air pollution episode. These stages are based on various critieria, such as the concentration of a particular pollutant exceeding a prescribed threshold for a given amount of time. For each stage of alarm a variety of counter-measures are prescribed from very simple, such a health advisory, to rather stringent such as severe traffic restrictions. These counter-measures, together with a plan to implement them, are contained in an Emergency Action Plan which is implemented by local officials on the advice of experts. The authority for local officials to develop such a plan and carry it out is invested in a smog regulation which may stem from the municipal, provincial, or national government. The Plan is coordinated from an Emergency Action Center, physically based at an appropriate government bureau such as the offices of the weather service or environmental agency. These key elements of a smog alarm system are now described in more detail.

Monitoring of Air Quality

A necessary element of an episode warning system is a city-wide network of automatic monitors for measuring in real-time the levels of sulfur dioxide, particulate matter, carbon monoxide, photochemical smog, and other important pollutants. Since, as already noted, smog alarm systems aim to protect public health, the pollutants monitored are considered to have special public health impacts. The current minute-to-minute trend of these pollutants is used in combination with meteorological forecasts to predict the likelihood of an episode. Real-time air quality data are also used during an episode to select the appropriate level of alarm, as we will describe shortly. Based on our survey of smog alarm systems, about 0.5 to 2.0 monitoring stations are typically used per 100,000 inhabitants (see Chapter 11 of this report). The number of stations depends on many factors, such as the complexity of terrain and meteorological situations, the frequency and severity of air pollution episodes, as well as the simple availability of funds to finance the equipment. Indeed, these monitors are likely to be the single largest expense of a smog alarm system. Because of the high cost of these monitors and their importance in forecasting and assessing episodes, it is crucial to site them effectively. On the other hand, it is not quite correct to assign the full cost of this monitoring equipment to a smog alarm system because they are also used for many other purposes. Munn (1981) lists four functions in addition to episode warning systems: (1) to monitor air quality standards, (2) to track long-term trends in air quality, (3) to validate planning models, and (4) to investigate the relationship between air pollution and public health, materials damage, and other effects. These reasons alone provide sufficient justification for a montoring system, without taking into account their role in a smog alarm system.

Stages and Criteria for Calling Alarms

As noted above, the severity of an air pollution episode is indicated by the various stages of a smog alarm. A variety of criteria are employed for deciding which stage of an alarm should be announced including: (1) exceedance of an air concentration threshold, (2) number of hours a threshold is exceeded, (3) a forecast of persistence of unfavorable meteorological conditions, and (4) number of monitoring stations in which a threshold is exceeded. Sometimes a combination of these criteria is used.

The air concentration thresholds and other criteria vary substantially from country to country and city to city, as will be discussed in Chapter 11. There is an obvious need for harmonizing these thresholds.

Forecasting Episodes

The more advanced smog alarm systems not only announce alarms when episodic concentration occur, but try to anticipate their occurrence. This is done, as noted above, by combining the trend of real-time air quality data with weather forecasts of episodic conditions. These data are sometimes combined together in a computer model for improving the realibility of the forecasts.

Communication and Counter Measures

An essential part of a smog alarm system is the procedure to alert public officials, the public, and others when an episode occurs or is expected to occur.

In some, but not all, smog alarm systems various counter-measures are prescribed for the different stages of alarm. Usually only warnings are given in the pre-alarm stage along with recommended measures, whereas various actions are required in the higher stages of alarm. These can include, for example : (1) reduction or elimination of incineration processes, (2) restrictions on vehicle usage (3) required switching of fuels, and (4) reduction of room heating temperatures.

Organizational Aspects

The procedures to be taken in the event of an episode, as well as the criteria and other information needed for calling a smog alert as described above, are usually embodied in (1) a *smog ordinance* which is a binding governmental law, and (2) an *emergency action plan* which lays out the steps to be taken by local officials. In addition, most smog alarm systems also have a designated *emergency action center* where forecast information physically is brought together, and where experts and officials use this information to take decisions on a smog alarm. The center also serves as a communication center for informing the public and others about an episode. The emergency action center is commonly situated in the offices of the local environmental agency or weather service.

Chapter 3

Smog Alarm Systems of Austria

Austria's population density of 93 persons per km^2 is low according to European standards. This fact may explain why only three smog areas were regulated by the federal winter smog alarm law of 1991. In spring 1992 two winter smog areas were added to the region of Greater Vienna in Lower Austria, and Austria became the first European country to introduce a summer smog alarm law. The law divides the country into 12 districts covering all of Austria.

A smog alarm is called if the ambient concentration of SO_2, SPM, NO_2, CO, or O_3 exceeds specified thresholds (*Table 3.1*). The concentration must be exceeded at 33% of the available stations or, at least at two stations in the case of O_3. The smog alarm is declared over if no station exceeds the pre-alarm threshold for 12 hours. The announcement of a pre-alarm must specify the magnitude by which pollutants exceed the thresholds and the stations recording this value. At pre-alarms only health advisories are announced. In case of a level 1 alarm or level 2 alarm, the time when the measures are to be enforced must be announced.

Smog Alarm Communication

The smog alarm laws describe the communication procedure during the various stages of a smog alarm. Their detailed elaboration is left to the responsible authorities.

In all cases the Minister for Environment and the local mayor of the smog areas are informed. Also notified are local health-care officials, school administrators, local environmental protection authorities, trade and craft associations, district authorities, the police, the federal road division administration, the military, public transportation services, the post and telecommunication agency, and managers of the main industrial plants. On request citizen

Table 3.1. Threshold levels for smog alarms in Austria, in micrograms per cubic meter. All threshold values are three-hours mean values.

Constituent	Pre-alarm	Level 1 alarm	Level 2 alarm
SO_2	400	600	800
SO_2+SPM[a]	600	800	1,000
NO_2	350	600	800
CO	20,000	30,000	40,000
O_3	200	300	400

[a]SPM more than 200.

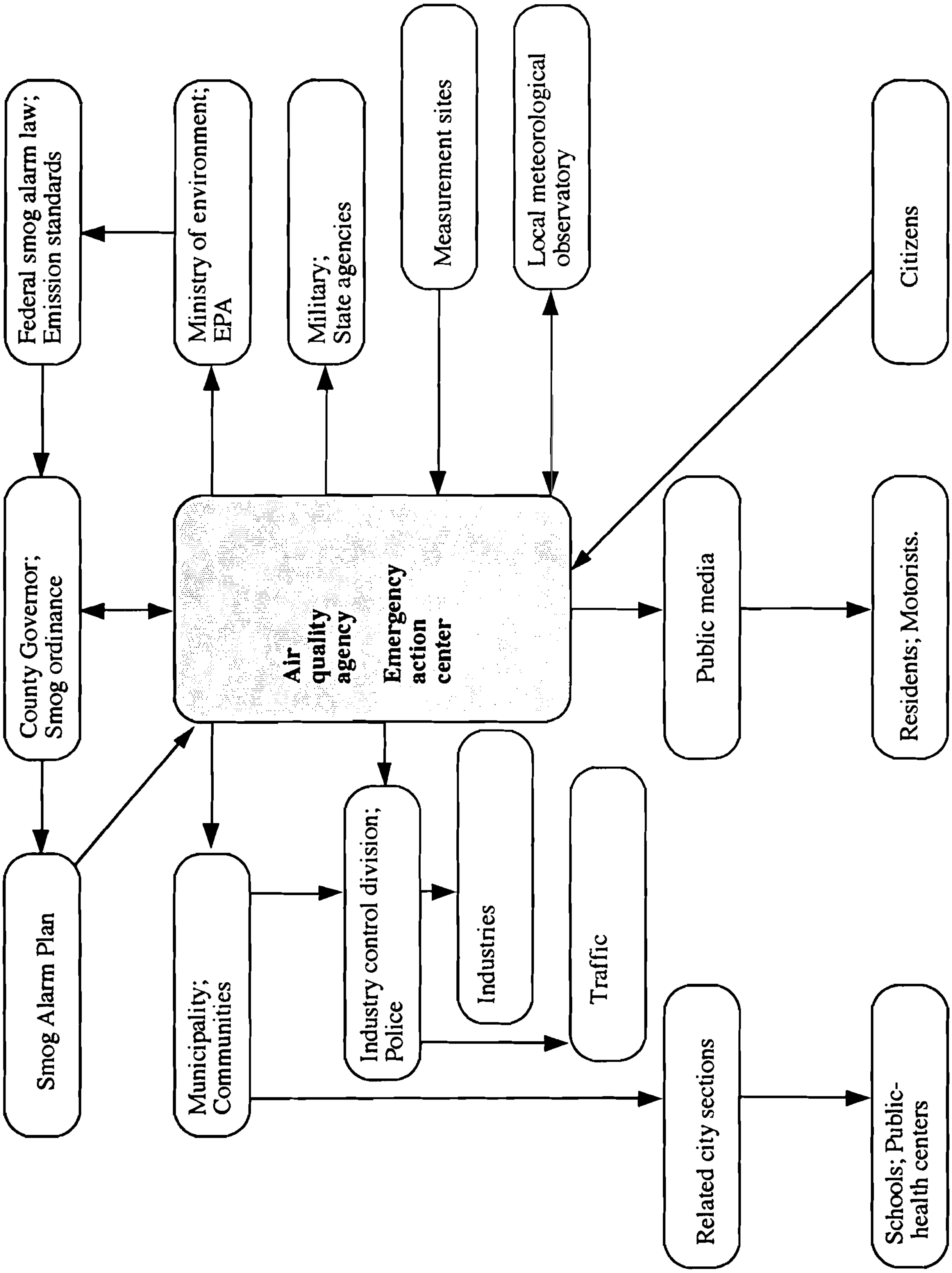

Figure 3.1. Smog alarm communication in Austria.

Table 3.2. Austrian winter smog alarm measures.

	Pre-alarm	Level 1 alarm	Level 2 alarm	Exemptions
Industry	Voluntary measures to reduce emissions such as the use of low-sulfur fuels.	Implementing plans for main polluters; Banning of high-sulfur fuels.	Level 1 measures plus possible closing of industry.	Possible according to approved plans.
Traffic	Avoiding use of private cars; Encouraging use of public transportation.	Instituting traffic regulations for private cars such as restricted zones.	Level 1 measures plus prohibiting major public gatherings.	Cars with catalytic converter mounted after January 1987; Public transport; Ambulances; Doctors; Veterinarians; Fire brigades; Military vehicles; Emergency vehicles.
Heating	Lowering room thermostats.	Further lowering of room thermostats; Introducing upper limits of room temperature.	Level 1 measures plus lowering upper limit of room temperature.	Schools; Hospitals

groups and newspapers can be included in the information system. The various steps of the smog alarm have to be announced to the public through the media together with a general health advice. Recently, teletext information was introduced. (See also *Figure 3.1.*)

Measures

A series of measures are prescribed in the federal law (*Table 3.2*). Pre-alarms are meant to stimulate voluntary measures, and to give health advice to risk groups, while level 1 and level 2 measures place restrictions on industry, traffic, and domestic heating.

Until now little experience has been gained in implementing countermeasures because no alarms have occurred in Austria since the federal guidelines were adopted in 1991. However it is anticipated that it will be easier to counter industrial emissions than to counter traffic and other emissions because the main industries producing emissions are relatively few in number and are being checked by pollution-control authorities. Traffic emissions and domestic heating are not comprehensively controlled.

The new summer smog alarm law of April 1992 regulates ozone and recommends measures to reduce the precursor substances of ozone during smog periods. It is expected that by 1994 plans will be under way to achieve this. The summer smog law covers large, separately defined smog alarm regions in Austria. These regions are larger than the winter smog areas.

Graz

Graz is the second largest city in Austria and capital of the province of Styria, with a population of 249,000 on 127 km^2. The smog area includes parts of the neighboring communities of Feldkirchen and Seiersberg. The emergency action center is within the air-quality department of the federal province of Styria in Graz. The winter smog alarm area is situated in a canyon which makes it particularly vulnerable to temperature inversions and consequently to air-pollution episodes.

There are six multicomponent measurement sites, with six measuring NO_2, four measuring SO_2 and SPM, and two measuring CO and O_3. Until now only NO_2 emissions have exceeded the pre-alarm level. At least two stations have to exceed threshold levels and the continuation of the inversion has to be expected to last longer than 12 hours for a pre-alarm to be announced.

The cost of establishing the entire measurement network for Styria (44 stations, thereof 42 measuring SO_2, 28 measuring SPM, 37 measuring NO_x, 4 CO and 17 O_3) was about US$ 5 million. In addition there are annual costs of US$ 0.5 million to maintain the network. Every five years the measurement network is replaced to provide exact measurements.

Major sources of pollution are automobile traffic (which was responsible for exceeding the NO_2 pre-alarm threshold on the shopping Saturdays before Christmas in 1988 and 1989), local industries, and domestic heating. No summer smog alarm has been registered.

Smog Alarm Communication

In addition to institutions mentioned above at level 1, the Austrian railways are informed. Direct information can be obtained by telephone.

Measures at Different Alarm Steps

All measures in *Table 3.2* are enforced. Additional level 1 alarm measures include:

- From 5 a.m. to 9 p.m. cars with certain number plates may not be used if the alarm was announced before 8 p.m. the previous day.
- Industrial plants without flue-gas cleaners are forbidden to heat with fuels over 1% S content or 0.4 g S content for each megajoule heating unit.
- The room temperature has to be lower than 18°C. Kindergartens, retirement homes, and convalescent homes are exempted from this restriction. Gas heating with emissions lower than 100 mg $NO_x/N\ m^{-3}$ are also excluded from this regulation.
- Industries have to save at least 25% of the final energy that is used on average.
- Each measure of industrial unit over 100 kW incineration power has to be documented for eventual checks by the control authority.

Additional level 2 alarm measures are:

- Two hours after the announcement all traffic not exempted is prohibited.
- Room temperatures have to be further reduced to 17°C.
- Industries have to save at least 50% of the final energy that is used on average.

Linz

Linz is the third largest city in Austria with a size of 98 km^2 and 203,000 inhabitants. The actual smog area of Linz is about 150 km^2 and is split into three zones: zone one comprises the town of Linz and neighboring Steyregg; zone two is made up of the communities Asten, St. Florian, Enns, and Luftenberg; and zone three comprises Leonding, Pasching, Traun, and Ansfelden. The emergency action center is situated within the air-quality department of the federal province of Upper Austria in Linz. There are 10 measurement sites in the smog area, and 7 are in Linz. The winter smog area is surrounded by mountains which trap polluted air in the west, north, and east. For a smog alarm at least three stations have to exceed threshold levels, and the inversion has to be expected to last longer than 12 hours.

The cost to establish the measurement network for Linz and Upper Austria (20 stations), which was established in 1977, was about US$ 7 million; the annual cost to maintain the network is US$ 0.5 million. Ten people are employed by the network. Every five years the measuring equipment is replaced.

The main polluting sources of Linz are local industries, traffic, and domestic heating. Long-range transport has had only a small impact on local smog episodes.

Since 1977 the winter smog alarm regulation has been changed three times: 1980, 1985, and 1989. (The last change in 1989 was in accordance with the national smog alarm law of 1991.) A level 1 alarm has never been achieved even though single stations have exceeded the threshold of SO_2 (Steyregg in 1985). Nine smog pre-alarms have been registered since 1980. All of them were caused by the combination of SO_2 and SPM. In addition one station has exceeded the level 1 threshold for NO_2 (Steyregg in 1985).

Smog Alarm Communication

The necessary steps of the smog alarm are broadcast on the radio and repeated every hour. In addition there is a telephone service to provide information to the public. Newspapers can directly contact the center, and interested institutions can have direct access to data.

Citizen groups in Linz and Steyregg have had an influence on the design of the smog alarm ordinance, but they are not involved in its implementation.

Measures at Different Alarm Steps

The measures are the same as described in *Table 3.2*.

Vienna

Vienna is part of the largest winter smog alarm district of Austria; this district includes three smog alarm areas. Since April 1992 Greater Vienna in Lower Austria has had a winter smog alarm regulation too. Some 1,590,000 people live in Vienna on 415 km^2. Smog episodes have not affected Vienna severely, because winds generally prevent the buildup of air pollutants.

Regulations do not exist for summer smog yet, but are expected to be developed by November 1992. With regard to winter smog a pre-alarm or a level 1 alarm is automatically proclaimed in Vienna if a level 1 or 2 alarm is proclaimed in neighboring Lower Austria. There are two emergency action centers situated in the center of Vienna. One is for the city of Vienna and another one for the federal province of Lower Austria.

The city of Vienna has 14 multicomponent stations which measure smog-relevant data of SO_2, SPM, and NO_2; six of them measure CO and four measure O_3. At least 33% of the stations have to exceed threshold values to proclaim a smog alarm (i.e., five stations for SO_2, SPM, and NO_2; two stations for CO and O_3). In addition, the smog situation should be forecasted to continue for more than 12 hours.

The main polluting sources are traffic, domestic heating, and industry. Long-range transport is not very important. Until now no pre-alarm has been registered. A pre-alarm would have been given for ozone in 1990 if the 1992 summer smog alarm law had been enforced.

Smog Alarm Communication

In addition to following the federal communication standards, Vienna has air-quality displays mounted on the sides of two buildings in the center of the city. Before proclaiming a pre-alarm the governor of Lower Austria must be informed.

Smog Alarm Measures

The smog alarm measures are indicated in *Table 3.2*. It has not yet been necessary to enforce any of these measures in Vienna.

Chapter 4

Smog Alarm Systems of Germany

There are 93 smog areas in Germany. Fifty-three are situated in the former German Democratic Republic and have recently been established according to the standards of the Federal Republic of Germany. Each German state (Länder) determines which of the most polluted areas are to be declared smog alarm areas. Only these areas are regulated by the winter smog ordinance. No summer smog ordinance exists in Germany.

In 1987 a federal smog ordinance *(Mustersmogverordnung)* was established by a group of experts; it provides guidelines for all smog areas. *Table 4.1* lists the guidelines. Unless otherwise indicated, all threshold values in the table are three-hour mean concentrations that have to be exceeded for another three hours. Only the SO_2/SPM index is a 24-hour average. If the pre-alarm concentration continues for 72 hours, a level 1 alarm is proclaimed. If a level 1 concentration continues for 72 hours, a level 2 alarm is proclaimed. The smog alarm terminates when values for SO_2 are under 400 $\mu g\ m^{-3}$, values for SPM are under 300 $\mu g\ m^{-3}$, values for NO_2 are under 200 $\mu g\ m^{-3}$, and values for CO are under 30,000 $\mu g\ m^{-3}$.

Measurement sites should not be more than 10 km from each other; however, as smog alarm areas have been very diverse in size and topography, no recommendations on the number of measurement sites have been made.

Smog-relevant concentrations are collected every three hours. According to the guidelines, a winter smog alarm must be announced under the following conditions: an inversion under 700 meters; a minimum wind speed during the last 12 hours of 1.5 to 4 meters per second; a forecasted continuation of the inversion for the next 24 hours; at least one-third of the stations exceed threshold levels or the mean of one constituent of all stations relevant to the smog alarm exceeds the threshold or a concentration of a constituent is exceeded in at least two neighboring measurement sites.

Although the states must follow the guidelines, they can decide independently which areas are to be regulated by the smog ordinance.

Table 4.1. Threshold values in the German federal smog ordinance, in micrograms per cubic meter.

Constituent	Pre-alarm	Level 1 alarm	Level 2 alarm
SO_2	600	1,200	1,800
SO_2 + 2 x SPM (24-hour)	1,100	1,400	1,700
NO_2	600	1,000	1,400
CO	30,000	45,000	60,000

Ozone is not currently regulated in the German smog ordinance. However an advisory value of 180 $\mu g\ m^{-3}$ (30-minute average) and a pre-alarm value of 240 $\mu g\ m^{-3}$ (30-minute average) are under discussion.

Smog Alarm Communication

The emergency action center collects the data and advises the Minister of Environment on the smog situation. Smog measures are valid one hour after the first announcement. The warning has to be repeated several times on radio and television. In addition key institutions that are directly involved in implementing the smog measures (e.g., the police or local control authorities) are informed by fax or telephone. Teletext information on summer smog and winter smog is also available.

In this chapter four different smog areas in Germany are described: Berlin (which was isolated for many years as a western enclave in eastern territory), Hof (which is in the smog area of Nordostoberfranken; almost all pollution is imported), the Rhine Ruhr area (which is the most densely populated area in western Germany), and the new smog areas of Sachsen and Sachsen-Anhalt (which includes Dresden, Halle, and Leipzig).

Recommended Measures

The smog alarm measures in the German federal ordinance are listed in *Table 4.2*. Exemptions from smog alarm measures are granted by the smog alarm commission, based in the Ministry of Environment in each state.

Table 4.2. Recommended smog measures.

	Pre-alarm	Level 1 alarm	Level 2 alarm	Exemptions
Industry	Voluntary measures to reduce emissions such as the use of low-sulfur fuels.	Implementing approved plans for main polluters; 40% emission reduction required; Banning of high-sulfur fuels for less polluting plants.	Closing of main polluting industry.	Possible according to approved plans (such as furnaces for public buildings, store houses, warm water facilities).
Traffic	Avoiding use of private cars; Encouraging use of public transportation; Free public transport in some cities.	Instituting traffic regulations for private cars such as restricted zones during 6 a.m. to 10 a.m. and 3 p.m. to 8 p.m.	Restricted zones all day plus prohibiting major public gatherings.	Autobahn travel; Electric cars; Cars with catalytic converter; Public transport and services; Cabs; Cars for the handicapped; Ambulances; Doctors; Veterinarians; Fire brigades; Military vehicles; Emergency vehicles; Election day.
Heating	Lowering room thermostats	Further lowering of room thermostats; Introducing upper limits of room temperature (e.g., 18°C in Berlin).	Level 1 measures plus lowering upper limit of room temperature (e.g., 15°C in Berlin).	Schools; Hospitals.

Berlin

Berlin's population is 3,350,000 on an area of 883 km^2. Before unification the two million people of West Berlin were living in a western enclave of 480 km^2 amidst the Eastern European environment. The import of pollutants was West Berlin's largest source of air pollution and the cause of smog alarms. Between 1969 and 1989 the annual average SO_2 concentration was reduced by 60% to 80 μg m^{-3}. This is much higher than the annual average in other western German cities, but lower than the values in Halle, Leipzig, and Dresden. West Berlin was equipped with 38 multicomponent measurement sites. Before unification there were only six stations in East Berlin. Since then some stations in the western part of the city have been transferred to the eastern part. Thirty-six stations are smog relevant: 33 stations measure SO_2 and SPM; 21 measure NO_2; 19 measure CO; and 9 measure O_3.

Between 1980 and 1991 17 smog alarms were announced in West Berlin (since 1990 entire Berlin). Smog pre-alarms were announced 11 times; level 1 alarms were announced 4 times; and level 2 alarms given twice. The most severe episodes were mainly caused by emissions from domestic heating in the early 1980s. In the late 1980s pollution import from the neighboring areas was most important. The more stringent requirements of the new smog ordinance, adopted in 1990, would have increased the number of smog alarms in the 1980s by 20%.

Smog Alarm Communication

If all conditions are met, a smog alarm is announced on the radio and TV. All institutions directly involved in the winter smog alarm plan are informed. Summer smog information is available to risk groups, schools, and health-care services if three of the nine measurement sites exceed a 30-minute mean of 180 μg m^{-3}.

Smog Alarm Measures

Three hours after a smog alarm announcement the traffic restrictions listed in *Table 4.2.* take effect. Public transportation and industries have to execute emergency plans.

Some experts claim executing only local measures is inefficient, because these measures cannot reduce total pollution concentration by more than 10%. Local measures obviously cannot control pollutants from outside the city.

Hof

Hof is in the smog district Nordostoberfranken I in Bavaria. Some 120,000 inhabitants live on an area of 903 km^2. The area is not densely populated. Hof receives air pollution from neighboring areas, mainly from eastern Germany and the CSFR.

Two component measurement sites measure all smog-relevant components. The environment agency of Bavaria in Munich is responsible for the maintenance of the measurement network. Between 1985 and 1990 SO_2 pre-alarms were announced six times.

Smog Communication and Measures

In the case of a smog alarm the general communication standard applies to Hof. Only industries have to execute smog alarm plans. There are no restricted zones for private traffic, and no plans exist to reduce local heating.

Rhine Ruhr Area

The Rhine Ruhr area (*Ruhrgebiet*) in the German state of Nordrhein-Westfahlen has long been a smog area. The 7 million people living on its 3,700 km^2 were exposed to several smog periods during the 1960s and 1970s when sulfur dioxide concentrations reached 2,000 to 3,000 $\mu g\ m^{-3}$. The annual average was over 200 μg in 1964, which corresponds to today's values for polluted industrial zones in Eastern Europe. Today the Rhine Ruhr area has about 30 $\mu g\ m^{-3}$, the best annual mean SO_2 value of all areas described in this chapter. Winter smog is no longer a problem.

There are 66 multicomponent measurement sites in the area, but only 54 are relevent for smog episodes. All sites measure SO_2, SPM, NO_2, and CO, and 33 sites measure O_3. The emergency action center is situated in Essen at the Landesanstalt für Immissionsschutz (LIS). All stations are directly connected to the center (there is no preprocessing of the data at the stations), and every minute a value is transferred to the central computer at LIS. The current 30-minute value for all stations is depicted on a screen. Comparisons between single stations and early interpretations of smog episodes are then carried out.

The cost for one multicomponent station is some US$ 300,000. All together the measurement network costs US$ 20 million. The network is also used for other air-quality purposes. The annual cost to maintain the measurement network is about US$ 1.6 million. Before 1986 the Rhine Ruhr area was divided into two smog areas; today it is divided into five areas.

The threshold levels for SO_2 and SPM have changed drastically. Legislation concerning episodes did not exist before 1974, when the worst episodes had already occurred. However, guidelines regulating SO_2 have existed since 1963. *Table 4.3* lists the guidelines established in 1963, 1972, 1973, 1974, and 1985.

For a short period the index was calculated over 24 hours. In the last 30 years smog alarm plans have developed from simple guidelines into rather complicated ordinances. There is no longer an acute danger from regulated constituents like SO_2. Nevertheless, health risks are assumed to be higher due to the still unregulated ozone.

In the 1960s local industrial activities and domestic heating with sulfur-rich coal were by far the most important source of air pollution. However in recent years the situation has changed. Today automobile traffic and long-range transport from Eastern Europe is considered to be more important.

Smog Communication

When a smog episode has been forecast, an advisory board is called in by the Ministry of Environment in Düsseldorf. The board stays in direct contact with the data processing center at the LIS in Essen. Every 30 minutes the Minister of Environment is informed about the situation; the Minister determines whether to announce an alarm. Some 60 faxes are sent out to key institutions such as the Ministry of Internal Affairs and the Ministry of Economy, all subordinate administrators who execute the regulations, and the media. A smog alarm is announced to the public on the radio and TV.

The police and various industrial inspectors carry out the smog alarm plan. Although emergency action plans were initiated by politicians, and not by citizen groups, the role of citizen groups is very important because they put pressure on decision makers to take action.

Smog Alarm Measures

All measures described in *Table 4.2* are valid. In addition pre-alarm measures like closing smokestacks and not heating swimming pools are advised. The experience of the Rhine Ruhr

Table 4.3. Threshold values in the Rhine Ruhr area, in micrograms per cubic meter.

Constituent	Pre-alarm	Level 1 alarm	Level 2 alarm
1963			
SO_2		2,500	5,000
1972			
SO_2		2,000	5,000
1973			
SO_2		1,000	2,000
1974			
SO_2	800	1,600	2,400
NO_2	600	1,200	1,800
CO	30,000	60,000	90,000
Index[a]	4	8	12
1985			
SO_2	600	1,200	1,800
NO_2	600	1,000	1,400
CO	30,000	45,000	60,000
Index[b]	1.1	1.4	1.7

[a] $SO_2/0.4 + NO_2/0.3 + CO/15 +$ total $C/2.5$.
[b] $SO_2 + 2 \times SPM$.

area demonstrates that the winter smog alarm problem can be solved efficiently. Even though long-term measures are mainly responsible for the improved air quality, short-term smog alarm measures have given economic incentives to industries to improve their facilities.

Sachsen and Sachsen-Anhalt

The new state of Sachsen-Anhalt is situated on 20,292 km^2 and has a population of 3.1 million. Sachsen is smaller (17,713 km^2) but has a larger population (5.1 million). The inhabitants of these two new states of Germany were exposed to extremely high pollution loads when the region was still part of the German Democratic Republic. The area had the highest per caput SO_2 emissions of Europe. The old districts of Dresden, Halle, Leipzig, and Karl-Marx Stadt (Chemnitz) had an annual average SO_2 concentration ranging between 50 $\mu g\ m^{-3}$ and 530 $\mu g\ m^{-3}$. The urban areas had an annual average concentration of 200 $\mu g\ m^{-3}$. Even though emissions were drastically reduced by the closing of some of the main polluting industries (experts estimate a 30% emission reduction), health risks due to winter smog are still very high.

The first winter smog ordinance for the GDR was introduced in 1987, and regulated only SO_2. It was revised in 1989 and valid until new smog ordinances were set up according to the 1991 federal guideline. Each state has 10 smog areas. The measurement network in these areas is still under development. The old GDR measurement network concentrated only on problem areas where population densities were high.

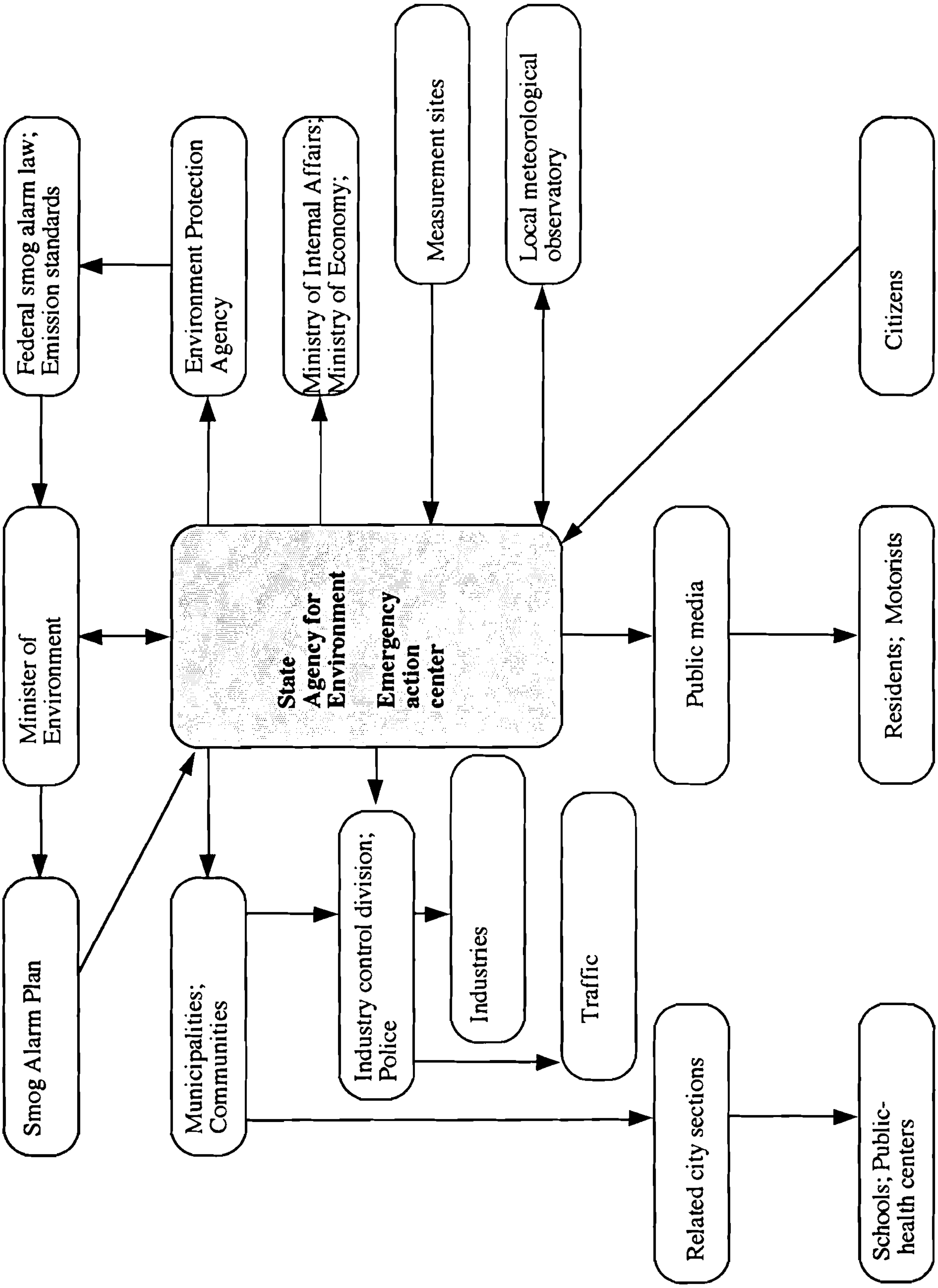

Figure 4.1. Smog alarm communication in Germany.

There are 33 multicomponent measurement sites in Sachsen. The constituents measured at each station are not indicated. In Sachsen-Anhalt there are 26 multicomponent measurement sites: 20 measure SO_2 and SPM; 8 measure NO_x, CO, and O_3.

In both states, industries, electric power generation, and domestic heating have been responsible for smog episodes. Outdated heating plants without filters had an efficiency rate that was under 30%. High-sulfur coal with up to 9% sulfur content was used; its share increased in the 1980s because this coal originated from local sources. Plants were often used over their capacity, and the incineration processes were not properly performed.

After the unification several of the main polluting plants were closed, thus reducing industrial emissions. However, automobile traffic, which was not a problem before, has grown rapidly. In addition to the local air pollution, long-range transports from neighboring CSFR and Poland have become a problem.

Smog Alarm Communication

The Ministry of Environment of Sachsen-Anhalt in Magdeburg and Sachsen in Dresden announce the various steps of a smog alarm. A smog alarm is announced on the radio and TV and becomes valid for citizens and the control authorities after its proclamation.

Smog Alarm Measures

Measures are the same as those listed in *Table 4.2.* Until this year exemptions were frequently granted to give citizens and industries the chance to adapt to the new situation. In addition the winters have been mild, and very critical situations like the ones in the mid-1980s have not re-occurred. (See also *Figure 4.1.*)

Chapter 5

Smog Alarm Systems of Italy

Italy has no federal smog alarm regulation. General air quality standards are defined by a national law of 1983.

Milan

Milan, the commercial center of northern Italy with 1,561,000 inhabitants on 182 km^2, has unfavorable climatic conditions with wind speeds less than two meters per second and during the winter a temperature inversion at a height of 300 to 400 meters. This is the main reason for frequent smog alarm episodes, which occur about three times a year and last seven to ten days. Similar to Eastern European countries, the mean annual concentration of SO_2 is exceeded by as much as three times the recommended WHO guidelines (40 to 60 µg m^{-3}). In the 1970s and 1980s, SO_2 values of up to 2,700 µg m^{-3} were registered during the winter. Milan is the only locale that has developed a smog alarm system for winter smog. As a first step in regulating summer smog an ozone measurement network will be installed by 1995 to measure photo-oxidants. Only two levels of alarm have been established, pre-alarm and alarm. Milan's smog ordinance is based on the 1983 national law of air quality (*Table 5.1*).

The main source of local SO_2 concentrations is home heating; industrial smokestacks contribute more to long-range export than to local episodes. Although high levels of SO_2 occasionally occur, a greater air pollution problem are photo-oxidant pollutants. The main precursors are NO_x and hydrocarbon gases, mainly originating from the 700,000 to 900,000 vehicles entering Milan every day. In 1973 Milan started measuring SO_2 concentrations; in 1986 it began measuring NO_x; and measurements of CO were initiated in 1989. Milan has 10 multicomponent measurement sites, regularly measuring SO_2 (six), SPM (four), NO_x (five), CO (eight), and O_3 (two). There are 60 measurement sites in the whole province of Milan. The public health office of Milan province, where

Table 5.1. Air-quality standards in Italy, in microgram per cubic meter.

Constituent	Max. 24-hour mean	Max. 1-hour mean
SO_2	80	250 (98 percentile)
SPM	150	300 (95 percentile)
NO_2		200
CO	10,000 [a]	40,000
O_3		200

[a]Eight-hour mean.

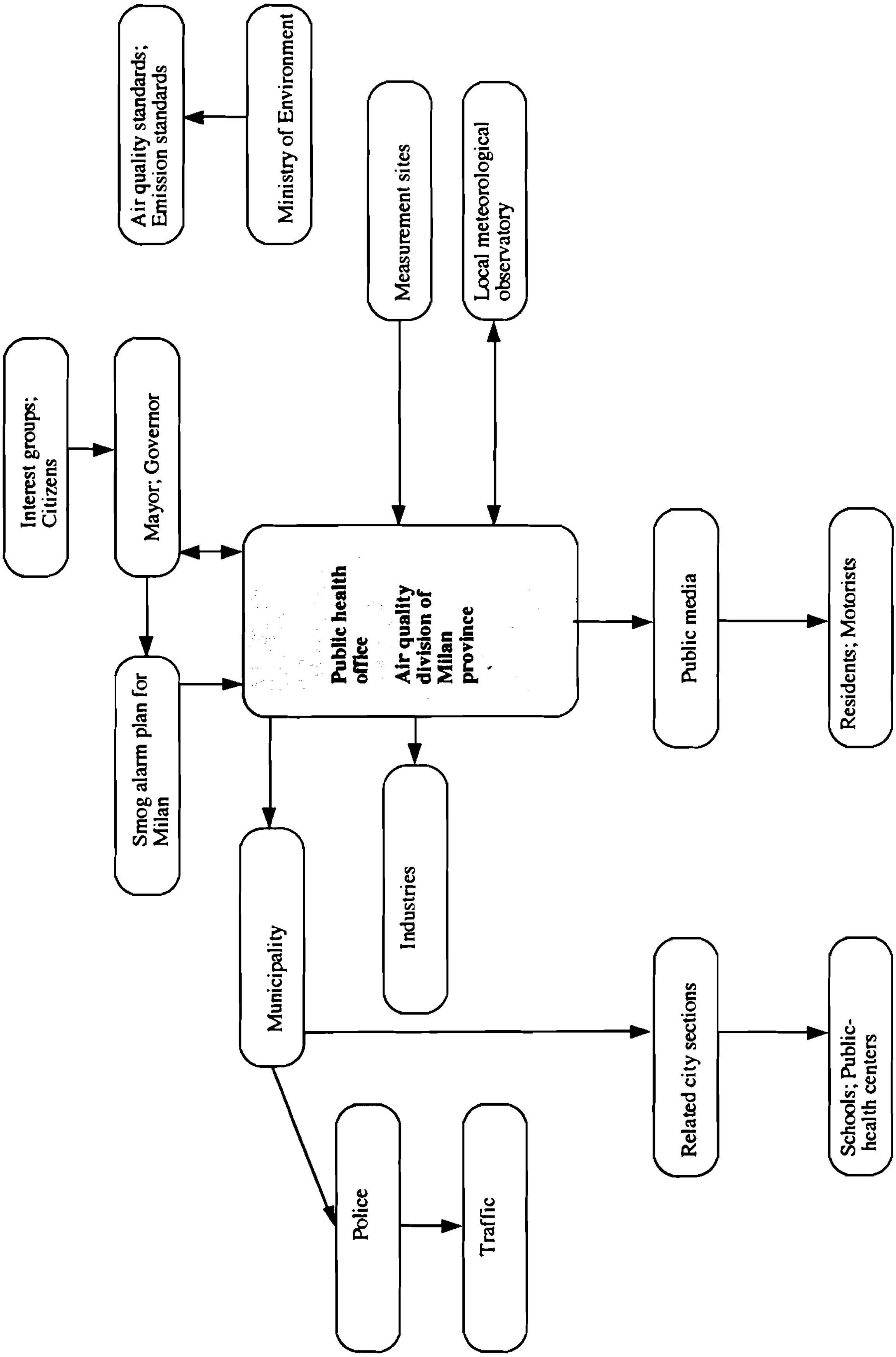

Figure 5.1. Smog alarm communication in Italy (Milan).

Table 5.2. Threshold levels for smog alarms in Milan, in micrograms per cubic meter. All threshold values are one-hour mean values.

Constituent	Pre-alarm[b]	Alarm
SO_2	250	500
SPM[a]	150	300
NO_2	200	400
CO	10,000	30,000

[a]Not indicated as smog alarm constituent.
[b]After 120 hours prealarm the alarm level is announced

the emergency action center is located, is responsible for maintaining this network and for organizing the emergency action center. Data are collected and processed at 20 to 30 seconds intervals. Every half hour these data are sent to a central computer. In addition, the meteorological service supplies the emergency action center with current weather conditions and forecasts of general atmospheric circulations that effect the area (see also *Figure 5.1*).

Pre-alarms and alarms for winter smog are announced when 50% of all stations exceed the threshold levels listed in *Table 5.2.* But the fact that some stations operate less than 50% of the time, due to technical breakdowns, reduces the likelihood that a smog alarm will be announced. Nevertheless, pre-alarms are frequently called.

Air pollution concentrations are greater on weekdays than on Saturdays and Sundays. Therefore many pre-alarm situations are concluded by the weekend. If the pre-alarm lasts from Monday to Friday a smog alarm is announced on Saturday and countermeasures must be taken on Sunday. After a Sunday with a smog alarm, instead of counting the previous days with smog pre-alarm, the counting for new smog situations begins on Monday.

In the late 1970s G. Finzi *et al.* from the Polytechnico in Milan developed a model to predict SO_2 episodes, 24 hours in advance. This model had a reliability of 80%, but is not used to predict episodes.

Smog Alarm Communication

The emergency center, situated at the public health office, informs when threshold levels are exceeded. Faxes are sent to the institutions involved in the smog alarm plan. The alarm is broadcasted in the radio (see *Figure 5.1*).

Smog Alarm Measures

No specified measures have to be taken to reduce SO_2 emissions during an alarm. Measures are required to reduce NO_x and hydrocarbon emissions during smog alarms. During episodes motorists are prohibited from the city center. In addition, on specific days only vehicles with certain number plates are allowed to drive in Milan. This reduces the traffic not by 50% but only by some 15%. Individuals often do not want to use public transport, which is regarded as unreliable. Bus drivers claim that it is not possible to be reliable because private cars block the streets. Italy has not yet introduced legislation requiring the use of catalytic converters.
During episodes people suffering from health problems are advised to stay indoors.

Chapter 6

Smog Alarm Systems of Japan

Japan has winter and summer smog alarm ordinances in 47 smog areas, which are determined according to the borders of provinces (prefectures). While the problem of winter smog is considered to be solved, summer smog continues to cause smog alarm episodes. In 1988 a pre-alarm (240 $\mu g\ m^{-3}$, one-hour mean value) was announced in 16 prefectures on 86 days, about half as many days as in 1987.

Smog alarm regulations were developed in the 1970s as a result of public pressure. The 47 prefectures designed guidelines for the cities according to the 1977 national air-pollution control law. This law defines general air-quality standards (*Table 6.1*). Municipalities have designed their smog alarm ordinances according to these guidelines.

Because of permanent pollution controls, the reduction of SO_2 concentration was dramatic. The average SO_2 station measured 150 $\mu g\ m^{-3}$ in 1967 and 26 $\mu g\ m^{-3}$ in 1986. Today only 1.2% of all values are over the recommended guidelines. SPM fell from 59 $\mu g\ m^{-3}$ in 1974 to 41 $\mu g\ m^{-3}$ in 1987.

NO_x levels, however, have increased. In 1970 the average measurement of NO_2 was 44 $\mu g\ m^{-3}$; today it is 56 $\mu g\ m^{-3}$. Some 37% of all values exceed the 98 percentile.

Four alarm steps have been established for O_3, including a smog information step. In Japan the recommended hourly O_3 values for smog pre-alarm (240 $\mu g\ m^{-3}$) are exceeded 5.2 days on average during the year. However, pre-alarms are less frequent in the Tokyo and Osaka bay areas (2.6 and 2.1 days on average in 1987).

Smog Alarm Communication

Smog alarm communication is similar in all prefectures. Each city in a prefecture has its own emergency action center. The prefecture coordinates these emergency action centers and

Table 6.1. Air-quality standards in Japan, in micrograms per cubic meter (original values for SO_2, NO_2, CO, and O_3 in ppb).

Constituent	Max. 1-hour mean	Max. daily mean	98 percentile[a]
SO_2	267	107	107
SPM	200	100	
NO_2		80–120	120
CO	12,500	25,000	
O_3	120		

[a]98% of all daily mean values.

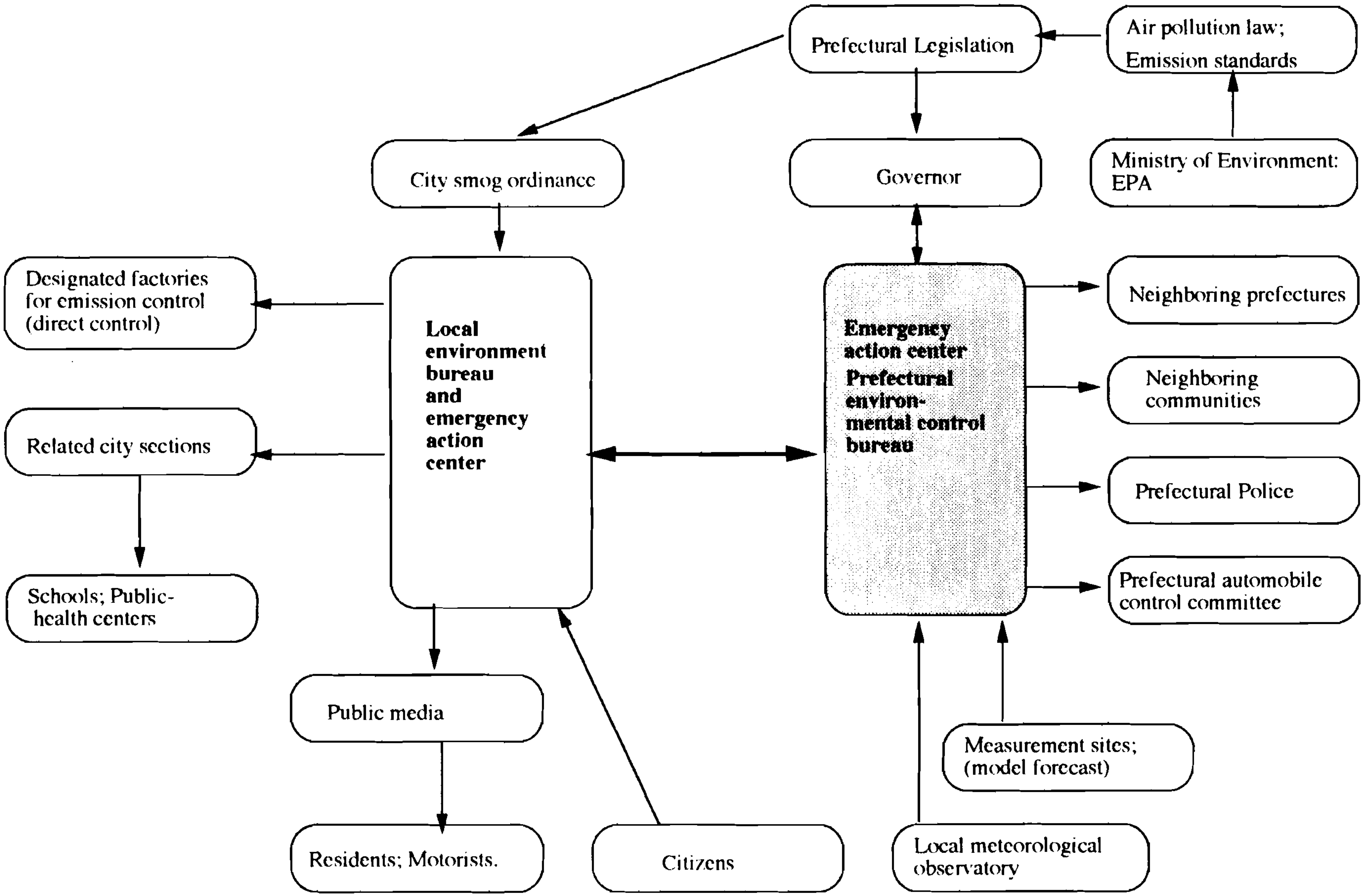

Figure 6.1. Smog alarm communication in Japan.

measures to reduce the regional emissions within the prefecture; it also stays in contact with neighboring prefectures. The communication at the city level is presented in *Figure 6.1*.

Smog Alarm Measures

Several cities in a prefecture belong to the same smog area. Therefore, if threshold values are exceeded in one city, measures may also be required in neighboring cities in the same prefecture. The alarm levels between smog areas can differ significantly.

In general measures are stricter for industries than for automobile users and domestic heating. This is because auto emissions are considered to have a relatively small impact on air quality and domestic heating emits low levels of emissions because it is generated by low-sulfur fuels, gas, or electricity (mainly originating from nuclear energy). In addition, large industries are easier to control than other sources.

Kawasaki

Kawasaki is situated between the Tokyo and Yokohama harbor. Some 1,188,000 people live on 144 km^2. It is supposed to be one of most air polluted areas in Japan.

The first measurements of pollutants (SO_2) were taken in 1957. In 1964 the first automatic station was established. The first centralized air-monitoring system was introduced in 1968, and in 1972 the air-monitoring agency was established. Since then nine multicomponent measurement stations have been installed. All of them measure SO_2, NO_2, and O_3; three also measure CO. In addition there are nine stations not used in the smog alarm system; all are situated near highways to measure auto emissions. The smog regulations are listed in *Table 6.2*.

A winter smog has not occurred in the last 20 years. Domestic heating is not a main polluter because sulfur is removed from heating oil at the refinery. In addition, natural gas and nuclear power are used for heating. Summer smog alarms occurred 30 times in the period from 1981 to 1990. Twenty-four factories are responsible for 90% of NO_x and SO_2 gases from stationary sources.

Table 6.2. Smog regulations for Kawasaki, in micrograms per cubic meter (original values in ppb).

	3-hour mean	2-hour mean	1-hour mean
	(2 stations)	(2 stations)	(1 station)
Winter smog (SO_2)			
Pre-alarm	534	801	1,335[a]
Level 1 alarm	–	–	1,335
Level 2 alarm	–	–	1,870
Summer smog (O_3)			
Information	–	–	160
Pre-alarm	–	–	240
Level 1 alarm	–	–	400
Level 2 alarm	–	–	800

[a]One measurement value

Smog Alarm Communication

The emergency action centers send out faxes to related city agencies. They inform some 700 organizations such as hospitals, schools, and the police about the alarm. All relevant agencies of Kanagawa prefecture are notified. Neighboring cities are also informed about the smog alarm in Kawasaki; these cities then notify their local factories. The 31 main polluting factories of Kawasaki are informed directly by the emergency action center. Pollution reduction measures are controlled directly by the center, which has on-line access to the data of the emission exhaust measurement sites of these factories. The alarm is announced on the radio and by loudspeakers (see also *Figure 6.1*).

Smog Alarm Measures

Pre-alarm measures. Total fuel consumption must be reduced by 30% at industrial sites such as refineries and incinerators.

Flue gases are measured and the measurements are sent to Kawasaki Pollution Control Center. There they are compared with predetermined values in the case of a smog alarm. No traffic measures are undertaken at the pre-alarm level.

Level 1 and level 2 alarm measures. Measures are specific for each industry. The governor of the prefecture may impose traffic restrictions.

Kitakyushu

Kitakyushu is the industrial center of the island, covering an area of 466 km^2 with a population of 1,065,000 million. There are 64 industries in the area, including Nippon Steel and Sumitomo Metal Co. Industries, electric power plants, and automobiles are the main polluters.

The air-pollution monitoring center was established in 1970. Today there are 14 smog-relevant multicomponent measurement sites in Kitakyushu. In addition there are five automobile-exhaust inspection stations and two air-pollution measurement sites.

The last winter smog alert was announced in 1974. A summer smog has not been announced in the last 15 years. In addition to threshold values, the meteorological forecast is relevant in determining an alarm.

The air-pollution monitoring center of Kitakyushu is cooperating with the Japan International Cooperation Agency (JICA) in offering a course on techniques and management of pollution control in Third World countries. This course, which lasts from one to three months, might be useful for people in Eastern Europe.

Smog Communication

A flowchart of the communication process in Kitakyushu is provided in *Figure 6.1*. The emergency action center is the focal point in a smog alarm. The data from the measurement sites are studied by experts at the meteorological observatory. The city mayor is responsible for announcing the alarm. The prefectural agencies coordinate smog measures on a regional scale and control the execution of measures. The emergency action center is in direct contact with the main industrial polluters, and in indirect contact with schools and health services through city agencies as well as with the public through the media.

Smog Measures

If concentrations exceed the alarm levels companies have to reduce emissions to the levels defined in the smog alarm plan, which is revised every five years. A pre-alarm demands an emission reduction of 20%. More rigid measures may be undertaken at level 1 and level 2 alarms.

Kobe

Kobe has an area of 542 km^2 and a population of 1,777,000. The environmental-pollution monitoring center runs an environmental-monitoring telemeter system (emission stations) and a source-monitoring telemeter system (automobile-exhaust stations and industrial-emission stations). Both are connected to the data processing system (central monitoring station) that combines the subsystems during a smog alarm.

There are 13 emission stations for SO_2 and SPM, 12 for NO_x and photochemical oxidants (indirect O_3), and 1 for direct O_3 measurements. Each hour the emission and pollution-source monitoring stations, which are equipped with a telementer, transfer the data to the central monitoring station. These data are use to forecast the air-pollution level in Kobe. The smog regulations for Kobe are listed *Table 6.3.*

The latest announcement of a winter smog pre-alarm was in 1973; the latest level 1 alarm was in 1971. The summer smog pre-alarm level (240 $\mu g\ m^{-3}$) was reached four times in 1990. Level 1 (400 $\mu g\ m^{-3}$) and level 2 (800 $\mu g\ m^{-3}$) summer smog alarms have never been announced.

Smog Alarm Communication

Every morning the forecast of photochemical oxidents for the day is given to all interested institutions or citizens. In the case of a pre-alarm the scheme in *Figure 6.1* is executed.

Nagoya

Nagoya is an industrial center of Japan. Some 2,080,000 people live on 326 km^2. Two smaller cities belong to the smog alarm area of Nagoya. There are 34 multicomponent measurement

Table 6.3. Smog regulations for Kobe, in micrograms per cubic meter (original values in ppb).

	3-hour mean	2-hour mean	1-hour mean
Winter smog (SO_2)			
Pre-alarm	267	–	–
Smog alarm	534	801	–
Summer smog (O_3)			
Information	–	–	160
Pre-alarm	–	–	240
Level 1 alarm	–	–	400
Level 2 alarm	–	–	800

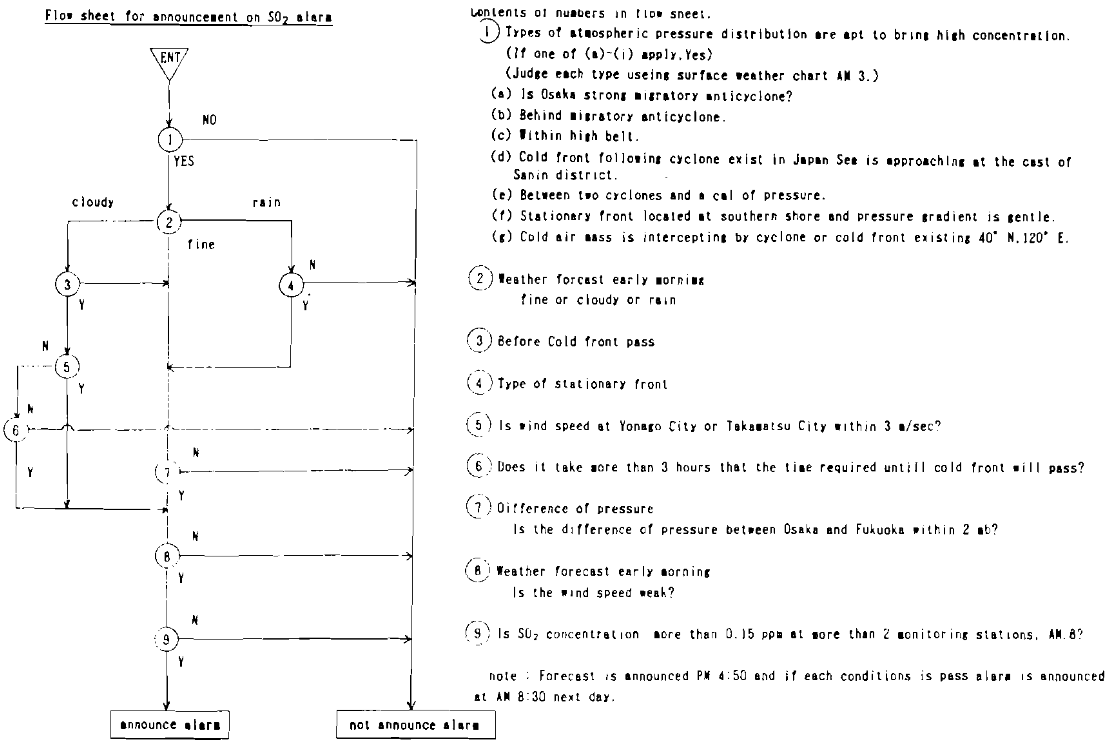

Figure 6.2. Flowchart for announcing a winter smog alarm (SO_2 alarm) in Osaka. Source: Provided to IIASA by Hideuki Nomoto and Masako Sibaike of Osaka Air Pollution Control District.

Table 6.4. Theshold values for Osaka, in micrograms per cubic meter.

Constituent	Pre-alarm	Level 1 alarm	Level 2 alarm
SO_2	534 (2 hours)	1,335[a]	1,335 (3 hours)
			1,869 (2 hours)
SPM	2,000 (2 hours)	–	3,000 (3 hours)
NO_2	960 (1 hour)	–	1,920 (1 hour)
O_3[b] 160 (information)	240 (1 hour)	00400 (1 hour)	800 (1 hour)

[a]Only one value.
[b]O_3 has four alarm steps including the a smog information step.

sites: 20 measure photochemical oxidants in Nagoya city but only 9 stations within Aichi prefecture are able to measure summer smog pollutants. In addition there are 28 emission stations installed at the largest factories.

Only summer smog is important in Aichi prefecture. The threshold values are the same as those for Kobe (*Table 6.3*). Meteorological conditions are also important. There is no model in use to forecast episodes. However, the city of Nagoya collaborates closely with the prefecture of Aichi on the sources of summer smog and the efficiency of measures. The main reason for episodes is assumed to be traffic.

Smog Alarm Communication

The smog alarm communication process for the city of Nagoya is illustrated in *Figure 6.1*.

Smog Alarm Measures

Factories have to reduce their emissions by 10% at each alarm step, including the advisory level. Therefore, if a level 2 alarm is announced, industries must reduce their emissions by 40%.

In certain situations the governor of Aichi, who is responsible for the proclamation of episodes, can order traffic restrictions.

Osaka

Osaka is a metropolitan area with 7,750,000 million people living on 1863 km^2. The area is divided into seven summer smog alarm areas and three winter smog alarm areas. The main polluting sources are factories (power stations, incinerators, petrochemical complexes, food industry) and automobiles. There are 121 multicomponent measurement sites. In addition there are 124 exhaust-monitoring sites at the main polluting factories and 1 mobile station.

In addition to SO_2 and O_3, SPM and NO_2 are regulated by the smog ordinance of Osaka. Winter smog is no longer a problem. *Figure 6.2* illustrates the process for declaring a smog alarm in Osaka. The pre-alarm for summer smog was reached 27 times in 1990, in at least 1 of the 7 summer smog alarm districts. *Table 6.4* lists the threshold concentration values necessary to announce an alarm in Osaka.

Smog Alarm Communication

The alarm is broadcasted by radio to the public. The communication between institutions is similar to the information transfer of the other Japanese cities (see *Figure 6.1*).

Smog Alarm Measures

Reduction plans for the different pollutants are made according to the actual pollution level and the standards required for the main pollutants.

Chapter 7

Smog Alarm Systems of the Netherlands

The Netherlands is the most densely populated European country, with a population of 14.4 million on 40,844 km^2. The design of its smog alarm systems is the same in each of 12 provinces. Each province is also a smog alarm district, because when a smog alarm is announced it takes effect in the whole province — not just one location. Summer smog is considered more important than winter smog.

The Rhine Basin has the highest intensity of industries and traffic. Automobile traffic is a major problem. Currently there are 6 million cars in the country, and it is estimated that 9.6 million will be registered in the year 2000. Industrial standards have constantly been improving. Energy generation and domestic heating are mainly from natural gas.

The measurement network and its maintenance, is a national responsibility. The National Institute of Public Health and Environmental Protection (RIVM) in Bilthoven is responsible for this task. The emergency action center for all 12 provinces is situated there.

There are 85 SO_2 measurement sites situated at approximately 40-km distances from each other. In the Rhine region the distance between sites is reduced to 4 km. Most of the sites measure other pollutants as well. There are 23 sites measuring SPM, 45 measuring NO_2, 26 measuring CO, and 38 measuring O_3. Every station processes its data and stores the last 120-minute values and mean hour concentration values. Only if values exceed normal concentrations are they directly transferred to the emergency action center at RIVM. The RIVM provides the provinces with information about smog severity.

Winter smog is mainly caused by long-range transport, while summer smog is to a large extent locally produced. The new smog values enforced as of January 1992 are listed in *Table 7.1.* (The summer smog values are one-hour mean values.) There are only two alarm steps.

During May and June 1989 some major summer smog episodes occurred. Almost all provinces recorded hourly mean values between 240 and 360 $\mu g\ m^{-3}$.

Table 7.1. Enforced smog values in the Netherlands as of January 1992, in micrograms per cubic meter. The threshold values for winter smog (O_3) are 24-hour mean values.

Constituent	Pre-alarm	Smog alarm
SO_2	150	350
SO_2 + SPM[a]	450	700
O_3[b]	240	360

[a]Index = SO_2 + SPM - 10.
[b]Five information steps according to the new law: 120 μg (no smog); 180 μg (moderate); 240 μg (severe); 300 μg (very severe); 360 μg (smog alarm).

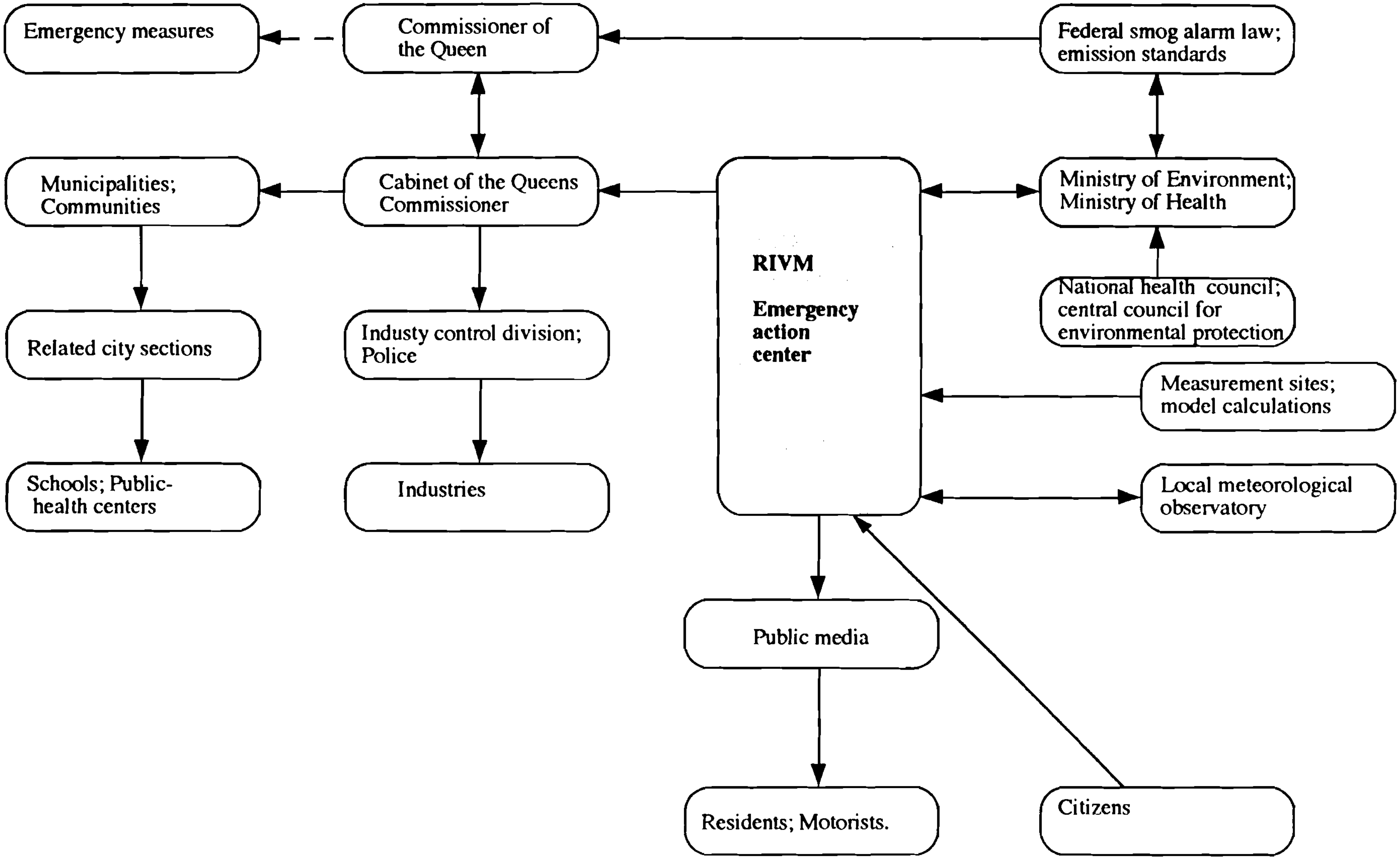

Figure 7.1. Smog alarm communication in The Netherlands.

The likelihood of an episode occurring was also calculated by several models by the RIVM.

- Winter Smog Model (RIVM): On average a pre-alarm occurs once every three years for several days on a regional scale, once a year in large cities, and once or twice a year on busy streets. According to the existing reduction plans in the Netherlands, and elsewhere, the average would be once every five years on regional scale, once every three years in large cities, and once every two years on busy streets. On average a smog alarm happens every 15 years on a regional scale, every five years in cities, and every two years on busy streets. It is predicted that in the year 2000 smog alarms will happen every 50 years on a regional scale, every 30 years in large cities, and every 10 years on busy streets. This model calculation demonstrates that winter smog alarm periods are a minor problem.
- Industrial Emission Model (Nieustadt *et al.*, Royal Netherlands Metereological Institute, 1977): This model calculates the potential emissions of industries under the worst conditions during winter smog. This model determines each industry's ranking in the Elevated Air Pollution Company List (see Smog Alarm Measures).
- Summer Smog Model (RIVM): The number of episodes is expected to remain the same until the year 2000. There are reduction plans for the main ozone precursors, NO_x and VOC. Emissions of these elements are expected to fall by about 20% between 1985 and 2000. At the same time the baseline of the less reactive components, CO and CH_4, is expected to rise by about 1% a year.
- Ozone Concentration Models (de Leeuw *et al.*, 1991): The models calculate the influence of local measures in the Netherlands and the European measures to counter summer smog in the the Netherlands.

Institutional Set Up and Smog Communication

The following institutions are involved in the smog alarm systems in the Netherlands:

- The Ministry of Housing, Physical Planning, and Environment (VROM) is responsible for smog policy.
- The Ministry of Welfare, Health, and Culture (WVC) provides information about health effects to risk groups.
- The National Institute of Public Health and Environmental Protection (RIVM) provides the daily smog expertise (winter SO_2 values, summer O_3 values), the measurement network, and scientific support through smog models.
- The Health Council evaluates new smog ordinances according to their effectiveness in protecting public health.
- The Central Council for Environmental Protection evaluates the new smog ordinances according their effectiveness in protecting the environment.
- Provincial institutions are responsible for executing smog regulations, informing the public, and enforcing the measures. The provincial institutions are the Regional Environmental Inspectorate (RIMH), the Cabinet of the Queen's Commissioner, and the Public Relations Department of the province.

Also included are:

- Groups exposed to higher risks, e.g., sport associations and schools.
- The mass media.
- Citizen groups who play a very active role in the information process. They have complained that measures against summer smog are inadequate.

Smog Alarm Measures

Temporary measures are executed in a restrictive way; they are carried out only during winter smog episodes and apply only to industries. They are listed in an emissions inventory (Elevated Air Pollution Company List). This list ranks potential emissions under the worst conditions.

During summer smog episodes health advice is given only to risk groups. It is argued that there is not enough scientific evidence to recommend short-term measures. The Dutch summer smog model predicts only 4% ozone reduction if local short-term measures were performed, but if regional measures were introduced ozone concentrations would be reduced by 28%.

In principle, smog alarm measures could be performed if the Queen's Commissioner proclaimed a level 2 alarm. So far this has never occurred.

Chapter 8

Smog Alarm Systems of Norway

In comparison with other parts of Europe, Scandinavia has a low population density, which makes a smog alarm situation more unlikely. Nevertheless, some particular regions or urban areas might be confronted with heavy pollution loads.

There is no legally defined smog area in Norway. However, one of the most industrialized regions of Norway, Grenland has established a permanent measurement network which is planned to be need for smog alarm systems. A smog alarm law has not yet been enacted, but general guidelines exist (*Table 8.1*).

The Grenland area covers the southern Telemark province which includes the cities of Porsgrunn, Skien, Brevik, Herre, Heistad, and Langesund. Some main industrial facilities of Norway such as Hydro Porsgrunn and Statoil are situated there. In addition, traffic contributes to air pollution in this region. The main source of heating is electricity provided by hydropower, so domestic heating does not generate air pollution. Nine measurement stations measure the smog-relevant constituents SO_2, SPM, NO_2, and O_3. These stations are located in high risk areas.

The annual budget of the local pollution control division is about US$ 1 million, not including the costs to maintain the measurement network. Industries are the main polluters and are taxed to cover the costs of the local control division (Statens Forurensningstilsyn Nedre Telemark). The air- and water-pollution division employs 13 people.

The annual concentration of SO_2 has never been higher than 40 $\mu g\ m^{-3}$ even during the cold winters in 1985, 1986, and 1987; the annual NO_2 concentration is under 10 $\mu g\ m^{-3}$. However, other industrial contaminants might be of significance to winter smog. The situation is different with summer smog. Regularly one hour concentration values exceed 100 $\mu g\ m^{-3}$ during May and July.

Since 1991 Grenland has an air-pollution forecasting model developed by INDIC, a Swedish consulting group. This tool can predict smog episodes 24 hours in advance.The daily values are sent out to newspapers (see also *Figure 8.1*)

Table 8.1. Maximum allowable concentrations of pollutants in Norway, in micrograms per cubic meter.

Constituent	1-hour value	24-hour value	6-month value
SO_2		100–150	40–60
SPM		100–150	40–60
NO_2	200–350	100–150	75
O_3	100–200		

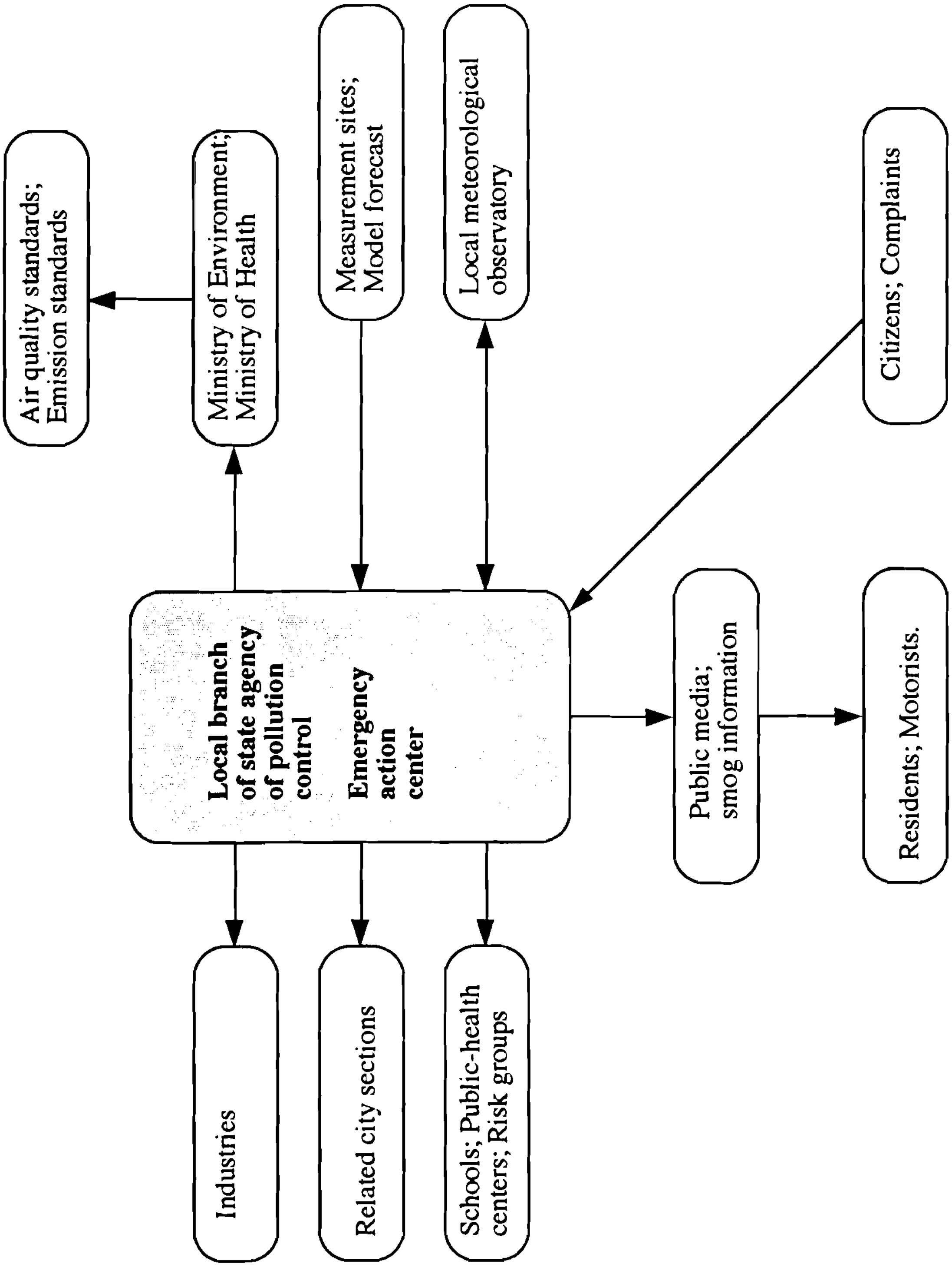

Figure 8.1. Smog alarm communication in Norway.

Chapter 9

Smog Alarm Systems of Switzerland

Switzerland has 25 cantons, which are responsible for developing their own smog alarm ordinances. The general emission standards for industrial plants and automobiles are stricter in Switzerland than in most other European countries. Therefore the development of smog alarm plans did not seem necessary to most of the cantons with the exception of Tessin. Winter smog alarms are unlikely, because the annual mean concentration of SO_2, the leading pollutant, is less than 30 $\mu g\ m^{-3}$ in Switzerland. Summer smog is more important; the national recommended value of O_3 is often exceeded. Long-term strategies to reduce future emissions are more important than smog alarm issues. Nevertheless, guidelines on concentration values for winter and summer smog, derived from the national air-quality ordinance, were established in 1987 (*Table 9.1*). In the case of winter smog, short-term measures are advised if concentrations are higher than the smog alarm level. No measures or warnings have been recommended in the case of summer smog.

SO_2, the leading substance of winter smog, is no longer exceeded and temporary measures are not necessary. NO_2 is the more relevant problem, but many cantons have not introduced guidelines on it in their winter smog ordinance because of insufficient evidence. Summer smog (photooxidants such as O_3) is not regulated yet, but is assumed to be an important problem. For example O_3 exceeds the recommended health standard (*Table 9.1*) by an alarmingly high amount in many areas of Switzerland.

In the 1986 Federal Suisse Air Quality Ordinance two guiding principles on protecting human health and environment were defined:

1. Preventive emission reductions using state-of-the-art technology.
2. Restrictive measures in areas with an overload of emissions.

Industrial plants are inspected every three years by the cantonale air-quality inspectorate. Incineration plants are checked every two years by the municipality. Automobiles are inspected every year.

Table 9.1. National recommended air pollutant thresholds in Switzerland, in micrograms per cubic meter.

Constituent	Health standard	Pre-alarm[a]	Smog alarm[a]
SO_2 (24 hour-mean)	100	200	350
NO_2 (24 hour-mean)	80	160	280
O_3 (1 hour-mean)	120	240	420

[a]Recommendations are not binding to cantonal legislation.

Zürich

The most densely populated canton in Switzerland is Zürich with 1.11 million inhabitants on 1,729 km^2. Zürich canton includes the city of Zürich and the surrounding communities. The canton's 12 multicomponent measurement sites measure SO_2, SPM, NO_x, CO, and O_3. Five sites are situated in the city of Zürich at places with the highest population exposure to smog pollutants. The costs for the measurement network and its maintenance are relatively low. For background measurements inexpensive but labor-intensive passive samples are used.

Zürich is almost completely responsible for its pollution. The major problem is automobile traffic. Each day 250,000 cars travel to the city of Zürich; despite heavy investments in public transportion, the traffic situation has not improved.

A general cost-benefit analysis has been made for air-quality standards in Zürich. Measures that reduce the amount of emissions until the year 2000 may cost only 0.2% of the regional GNP, despite their high initial costs.

The winter smog recommendations in the 1987 national air-quality standards are generally met. In 1985 measurements of SO_2 over 200 $\mu g\ m^{-3}$ were recorded on only 12 days; in 1986, only three days. Since then no value over 200 $\mu g\ m^{-3}$ has been registered.

The situation for summer smog episodes is quite different. No ozone value should exceed 120 $\mu g\ m^{-3}$ for more than one hour a year. But unlike the SO_2 values, no station could comply with the recommended value during the summer in 1990. In the city of Zürich the value was exceeded for between 14 hours (Bahnhof Wiedikon) and 88 hours (Zürich-Schwamendingen); in the cantonal station of Wallisellen the value was exceeded for 472 hours; and the station in Bachtel (with the highest summer smog levels) recorded values above the limit for 1,339 hours. The highest one-hour mean concentration was 250 $\mu g\ m^{-3}$. A planned summer smog regulation was developed and accepted by the city council of Zürich, but was rejected by the canton in 1991.

Smog Communication

The public administration aims at providing active environmental protection instead of waiting for complaints from citizens. Because of this strategy the number of complaints was reduced by 75% in recent years.

A private meteorological service provides the city with a summer smog prognosis, which is sent to over 40 organizations, mainly newspapers and interest groups. In addition teletext information is available on the three Suisse TV channels.

The Role of Citizen Groups in Air-Pollution Strategies

A telephone hotline gives pertinent information to citizens and interested institutions. Citizens have pressured politicians into supporting bicycles as the desired means of transportation in the city. The police department is currently testing the use of bicycles on busy streets. Several citizens groups support long- and short-term measures to protect against ozone. But there are also other citizen groups like the Autopartei that oppose measures to reduce automobile traffic.

Smog Measures

Advice is provided during winter episodes. People are asked not to use their cars or are encouraged to form carpools. No car should be used for distances under three kilometers. Shopping and leisure rides should be avoided. Room thermostats should be lowered to 18°C, and no solid-fuel-fired stoves should be used. It is advised to stay indoors.

During hot summer days, when the likelihood of an episode is very high, the following advice is given: car rides less than three kilometers should be avoided; cars should be parked in the shade; work with gasoline-driven machines and with solvents should be postponed.

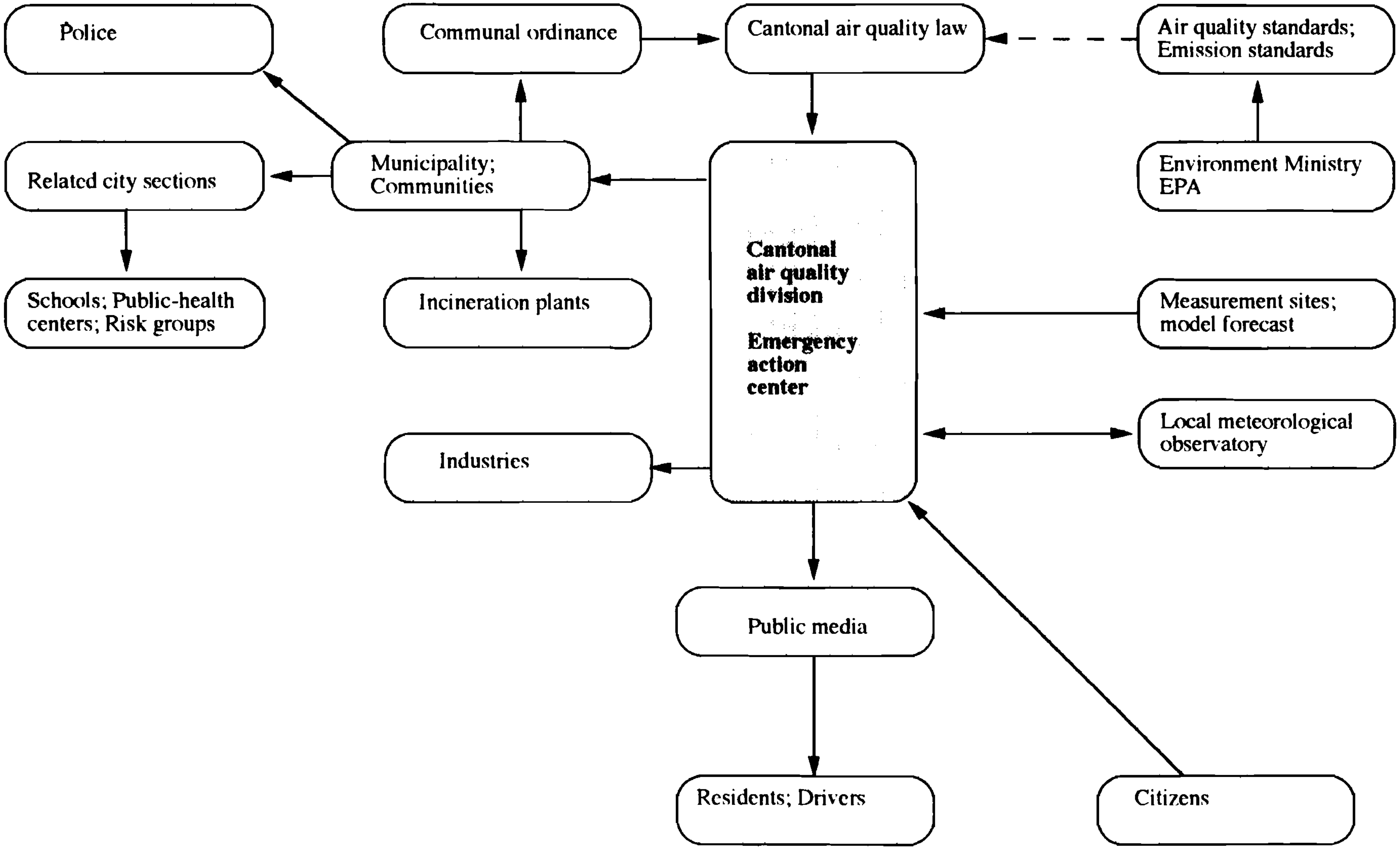

Figure 9.1. Smog alarm communication in Switzerland.

Proposed temporary measures to reduce the precursor substances of ozone, NO_x and VOC, were rejected in 1991. Included in these measures were a temporary traffic ban on cars without catalytic converters during July and August; banning specific cars on specific days; a reduced speed limit of 30 km per hour (reducing speed from 120 to 80 km per hour halves the amount of pollutants); and banning automobile traffic in the city center.

Chapter 10

Smog Alarm Systems of the United States

Regulations on monitoring air contaminants and establishing a smog alarm system are included in Title 40 of the Code of Federal Regulations. *Table 10.1* lists ambient air-quality standards established by the EPA.

In addition to EPA standards there is the 1986 law entitled Prevention of Air Pollution Emergency Episodes. This law defines extreme areas (priority I), serious areas (priority IA), and moderate areas (priority II) that are in violation of air pollution thresholds (*Table 10.2*).

There are some 100 smog areas in the US. Only the Los Angeles area, which is described in detail in this chapter, is considered a priority I area because of O_3, CO, and NO_x concentrations.

Table 10.3 lists the significant harm levels in the US; these values must not be sustained. In practice it is highly unlikely that these values will be obtained.

Every priority I or priority II smog area has to have an emergency action plan, which must be revised regularly on the basis of recent data (*Table 10.4*). If one smog area has few measurement sites adequate models must be used to calculate the pollution concentrations.

Each state uses national guidelines to determine its own standards. The state standards must not go above the federal standards, but they can be stricter.

In general a smog pre-alarm is announced when values for the constituents are 200% of the standard. A level 1 alarm is announced when the value is more than 275% of the standard, and a level 2 alarm is announced if the value is more than 400% of the standard.

Table 10.1. Ambient air-quality standards, in micrograms per cubic meter (original values in ppb).

Constituent	Concentration
SO_2	78 (annual mean)
	360 (24-hour mean)
SPM	50 (annual mean)
	150 (24-hour mean)
NO_2	100 (annual mean)
	475 (1-hour mean)
CO	10,000 (8-hour mean)
	40,000 (1-hour mean)
O_3	240 (1-hour mean)

Table 10.2. Classification of regions for smog alarm plans (§51.150).

Constituent	Concentration (μg m^{-3})
*Priority I smog areas (more than one constituent); Priority IA (one constituent)**	
SO_2	> 100 (annual arithmetic mean)
	> 455 (max. annual 24-hour mean)
SPM	> 95 (annual geometric mean)
	> 325 (max. annual 24-hour mean)
NO_2	> 100 (annual arithmetic mean)
CO	> 55,000 (max. annual 1-hour mean)
	> 14,000 (max. annual 8-hour mean)
O_3	> 195 (1-hour mean)
*Priority II smog areas**	
SO_2	60–100 (annual arithmetic mean)
	260–455 (max. annual 24-hour mean)
	1,300 (any value above)
SPM	60–95 (annual geometric mean)
	160–325 (max. annual 24-hour mean)

*An area is designated as Priority I when two or more of the constituents below exceed the given threshold. For Priority IA, more than one constituent must exceed the threshold. For Priority II, one constituent below must exceed the threshold.

Table 10.3. Significant harm levels, in micrograms per cubic meter.

Constituent	Level
SO_2	2,620 (24-hour mean)
SPM	600 (24-hour mean)
NO_2	3,750 (1-hour mean)
CO	57,500 (8-hour mean)
	86,300 (4-hour mean)
	144,000 (1-hour mean)
O_3	1,200 (2-hour mean)

Each state can have one or more smog alarm areas, so-called "multi-county districts." These districts can, in turn, be subdivided into smog sub-districts. The county administration is responsible for the measurement net and for the organization of smog countermeasures, while the executive officer proclaims the alarms. Measures are taken at the area level.

The EPA has a direct influence on the smog situation by designing guidelines for maximum emission exhaust of various facilities and automobiles. In the following section the South Coast Air Quality Management District, the area around Los Angeles, is described.

Table 10.4. Federal guidelines for smog alarm thresholds, in micrograms per cubic meter.

Constituent	Pre-alarm	Level 1 alarm	Level 2 alarm
SO_2	800 (24h)	1,600 (24h)	2,100 (24h)
SPM	350 (24h)	420 (24h)	500 (24h)
NO_2	1,130 (1h)	1,325 (1h)	3,000 (1h)
	282 (24h)	565 (24h)	750 (24h)
CO	17,000 (8h)	34,000 (8h)	46,000 (8h)
O_3	400 (1h)	800 (1h)	1,000 (1h)

Los Angeles

The South Coast Air Quality Management District (SCAQMD) covers some 30,000 km^2. The district includes the Los Angeles, Orange, Riverside, and San Bernadino counties. These counties have over 100 metropolitan areas with a population of 13 million people. It is the worst summer smog area in the US. Established in 1946, it is also the oldest air-pollution control district in the US. In the mid-1950s a control agency for motor vehicle emissions was established. Since the 1970s smog episodes and other tasks related to air-pollution control have been regulated by the EPA, influenced in part by the previous work of the South Coast Air Quality Management District (SCAQMD), which was reorganized in 1976. SCAQMD contains 34 county air-pollution control districts, 7 multicounty districts, and is one of the largest air quality management regions in the US.

There are 11 sites measuring SO_2, 7 measuring SPM, 23 measuring NO_x, 21 measuring CO, and 33 measuring O_3. A few districts do not perform any measurements, but use the measurements from the nearest measuring smog alarm district.

The cost for one monitoring station is US$ 100,000. Another $100,000 is needed to maintain a station for one year. The equipment requires 20 m^2 if only gaseous substances are measured. Another 20 m^2 are needed if nongaseous substances are also monitored.

Federal standards are used for SO_2, SPM, NO_2, and CO. For ozone health guidelines, the California state standards are used. The equipment at all measurement stations are serviced at the same time. The organization of smog alarm systems are adjusted to the local situation. The air pollution control districts are organized according to air basins and not on political borders.

The criteria for proclaiming an alarm are the thresholds of ambient air-quality standards listed in *Table 10.1*. In addition some California air quality standards are lower than the federal standards.

Figure 10.1 illustrates the percent of days exceeding federal or state standards for seveal constituents between 1975 and 1989. SO_2 has not been a problem, but all other constituents have registered measurements above the standard. On average there were more than 180 days with O_3 concentrations over 240 $\mu g\ m^{-3}$. The SPM standard was exceeded on 62 days; the CO standard was exceeded on 58 days; and the NO_x standard was exceeded on 10 days.

The smog alarm plan is based on federal standards (*Table 10.5*). A pre-alarm is called if the constituents are more than 200% of the standards. A level 1 alarm is announced if they are more than 275% of the standards, and a level 2 alarm is given if they are more than 400% of the standards. In addition to these alarm levels, an ozone advisory is announced if the ozone level is more than 138% of federal standards.

During the summer (May until October) a very persistent marine, thermal inversion traps pollutants in the area. High temperatures accelerate the creation of ozone, the most important smog pollutant. Smog episodes are frequent. Nevertheless, no level 2 alarm has ever been

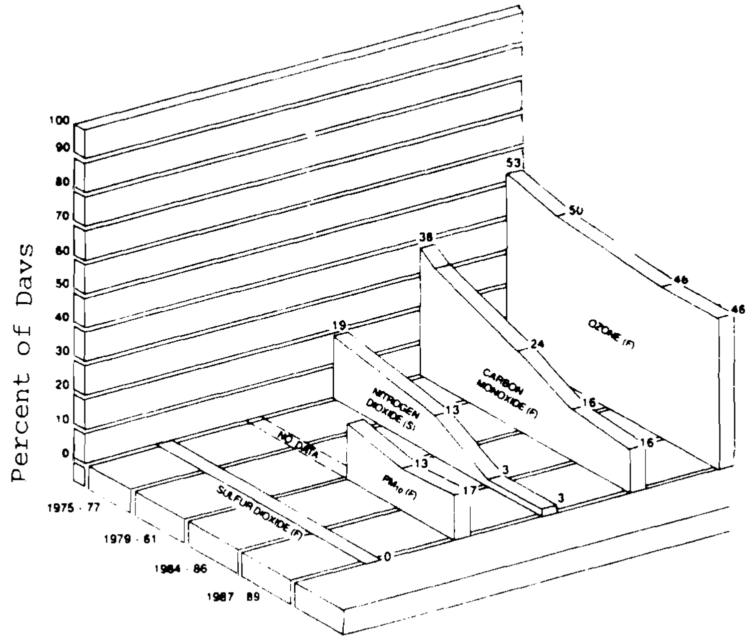

Figure 10.1. Percent of days that various air pollutants exceed federal (f) or state (s) standard (1975–1989). Note: An applicable federal standard does not exist for NO_2. Source: Air quality managment plan (Los Angeles), 1990.

Table 10.5. Thresholds for smog alarms in the Los Angeles area, in micrograms per cubic meter.

Constituent[a]	Pre-alarm	Level 1 alarm	Level 2 alarm
SO_2	720 (24h)	990 (24h)	1,440 (24h)
SPM	300 (24h)	413 (24h)	600 (24h)
NO_2[b]	960 (1h)	1,320 (1h)	1,920 (1h)
CO	20,000 (8h)	27,500 (8h)	40,000 (8h)
	80,000 (1h)	110,000 (1h)	160,000 (1h)
O_3 330 (1h, advisory)	480 (1h)	660 (1h)	960 (1h)

[a]In addition there are some combined threshold values for particular areas within the South Coast Air Quality Management District (see Ref. Reg. VII).
[b]State standard.

announced. Between 1980 and 1990 advice or alarms were given on the following constituents: for O_3 health advice was given 1,493 times, pre-alarms were given 844 times, and level 1 alarms were announced 34 times; 82 CO pre-alarms were announced; 56 NO_2 pre-alarms were announced. During an average year O_3 advice is given on 136 days; O_3 pre-alarms are given on 77 days; O_3 level 1 alarms are given on 3 days. CO pre-alarms are announced on 7 days and NO_2 alarms on 5 days during an average year.

Extensive research on the sources of the pollutants has been undertaken. *Table 10.6* lists the main contributors to pollution.

Table 10.6. Origin of pollutants according their sources, in percent.

Constituent	Industry	Residential	Traffic
SO_2	35	11	54 (25)[a]
SPM	84	10	6 (–)
NO_2	14	14	72 (13)[a]
CO	2	2	96 (9)[a]
O_3	25	23	52 (6)[a]

[a]Values in parentheses indicate non-road traffic.

Smog Alarm Communication

The local area officer informs the executive officer at the SCAQMD about the episode. The executive officer can announce a smog episode up to level 1 alarm; only the governor can proclaim a level 2 alarm, which would indicate an acute emergency. The alarm has to be announced before 2:30 p.m. on the day when the prediction is made to ensure the execution of measures by midnight. In case of a smog alarm or forecast the district personnel notify officials in the local government, industry, health services, and school districts. These officials then begin to implement the emergency action plans. (See *Figure 10.2.*)

The institutions that must be informed are the South Coast Air Quality Management District, the California Air Resources Board, local and state law enforcement agencies, public safety agencies, establishments described in Regulation VII, traffic organizations, specific factories, the media, local public health offices and hospitals, schools offices, elected officials, and officials from neighboring air basins in which the state emergency plan is applicable. The alarm is also announced on the radio. Private citizens can call toll-free numbers and obtain current air-quality information and episode forecast information. Information on the alarm level and predicted duration, the affected source and receptor areas, and the contaminants for which the episode is declared is given to callers. The smog alarm is terminated by the executive officer when the episode criteria are no longer reached and the available data do not indicate an immediate increase.

Measures During Smog Alarms

According to Regulation VII of the South Coast Air Quality Management District, temporary measures must be taken not only if a pre-alarm or health advisory is given, but also if a smog alarm is forecasted for the next day. This is to control the duration of the episode.

Rule 708.1 specifies the kind of plants which have to establish emergency action plans. Rule 708.2 defines exact procedures to carry out these measures. All medium-sized or large plants

Table 10.7. The most important measures during a smog alarm.

	Pre-alarm	Level 1 alarm	Level 2 alarm
Industry	Smog alarm coordinators have to reduce emissions by 10%.	Approved plans for main polluters; 40% emission reduction required.	Closing of industry; Holiday scheme.
Traffic	Smog alarm coordinators have to execute traffic reduction plans with 10% savings in mileage by car pooling.	Further savings in mileage; use of mass transportation.	Only emergency vehicles are allowed.

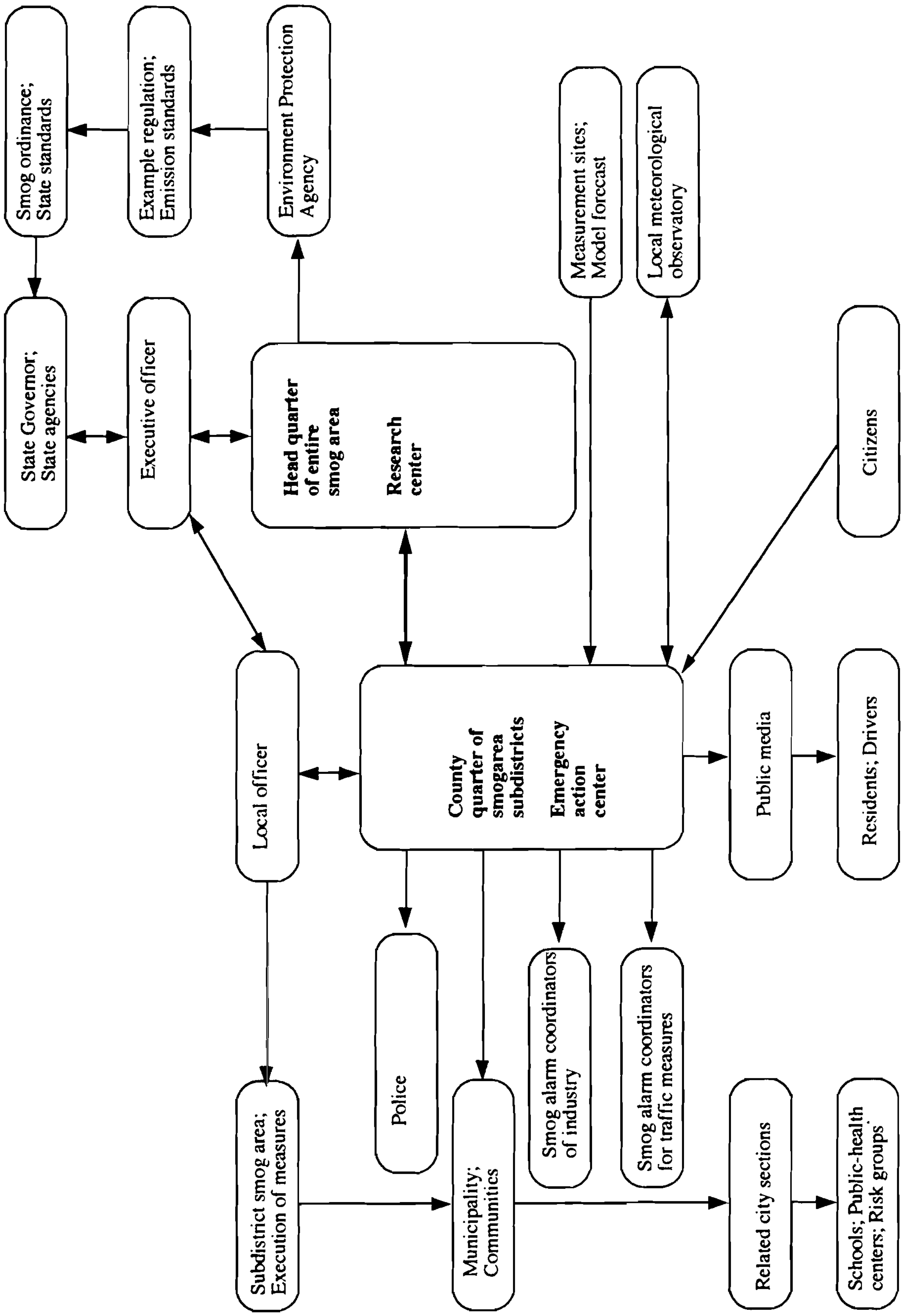

Figure 10.2. Smog alarm communication in the US.

have their own measures for the different alarm levels, which are approved by the South Coast Air Quality Management District. Rule 708.2 requires that each plant have a smog alarm coordinator, who will be informed by the South Coast Air Quality Management District about necessary measures that the plant must take.

Rule 708.3 defines transportation management plans for private companies and public services with more than 100 employees or over 50 cars. Officials have to design emission-reduction plans and provide proof of mileage savings.

A pre-alarm requires that people form car pools. Energy consumption and the mileage have to be reduced by 10%. A level 1 alarm imposes stricter measures than a pre-alarm, e.g., a reduction in energy and mileage by 20%. A level 2 alarm is equivalent to a disaster declaration; total mileage has to be reduced by from 65% to 75%; only use of emergency vehicles is allowed; and energy use should be reduced by 40%.

Chapter 11

Findings and Recommendations

In this paper we have surveyed existing smog alarm systems with the aim to provide background information to Eastern European cities interested in setting up similar systems. As noted at the beginning of this paper, these systems can offer near-term "emergency air protection" while long-term permanent pollution control measures are planned and undertaken. Although not all information presented in this paper is entirely applicable to Eastern European cities, in this chapter we try to summarize the most relevant information.

Size of Smog Areas

The smog areas surveyed in this report vary in size by two orders of magnitude (*Table 11.1*). However, the larger smog areas such as Los Angeles have been sub-divided into smaller smog districts, which means that the effective size of smog areas varies only one order of magnitude, between about 100 and 1000 km^2. This is the typical spatial coverage of a smog alarm system.

Monitoring Network

One of the key elements of a smog alarm system is the air quality monitoring network which detects the trend and occurrence of episodic pollutant levels. The networks in the cities reviewed in this paper measure the following pollutants: SO_2, SPM, NO_x, CO, and O_3 (*Table 11.1*).

Not only is a monitoring network critical to the design of a smog alarm system, but it is also likely to be the largest capital cost of the system.
Based on data presented herein and from elsewhere[1], the costs of stations range from about US$ 100,000 to US$ 350,000 (depending on the number of constituents measured, the sophistication of the equipment, and other variables). The annual maintenance costs per station varies very widely between US$ 10,000 and US$ 100,000, depending on how the maintenance is carried out — whether it is by staff of a local government agency, a private firm, or other.

Because of the high costs involved, it is particularly important for cities designing new smog alarm systems to select the most cost-effective number of stations necessary. The number of stations in the cities surveyed varies greatly as noted in *Table 11.1*; the number of stations in each smog area measuring at least one pollutant ranges between 4 and 121. To compare these data between smog areas we express them as the number of stations per unit population and per unit area (*Figures 11.1* through *11.5*). Note that the number of stations per unit population is

---

[1]An example not presented in the previous text is a World Bank consultant's estimate (in 1991) of $US 260,000 for each station in a new monitoring network for Cracow, Poland.

fairly consistent between cities, but the number of stations per unit area varies tremendously. This large variation is explained in *Figure 11.6*, which shows that the density of stations gradually increases along with population density. This confirms that although different cities have drastically different numbers of stations, they have roughly the same coverage per unit population. Indeed, *Figure 11.7* shows that 8 out of 15 smog areas have 1 or fewer stations per 100,000 inhabitants, and 13 of 15 have 2 stations or less. On average, there are 0.8 stations per 100,000 inhabitants. (We should note that there are two exceptions to this trend — Linz, Austria, and Grenland, Norway have four and five stations per 100,000 inhabitants, respectively, indicating a much denser coverage of stations.)

The preceding figures refer to the number of SO_2 stations. For other pollutants, the number of measurement sites is somewhat different (*Figures 11.2* to *11.5*) For ozone there is even greater consistency between areas; 12 of 15 areas have one site or less per 100,000 inhabitants, and nearly all cities have two or fewer sites per 100,000 inhabitants (*Figure 11.8*).

While there seems to be a *de facto* agreement between smog areas that the number of stations per unit population should be constant, the federal smog ordinance of Germany recommends a different criterion — that measurement sites be no greater than 10 km from each other. Nevertheless, German cities in the end have roughly the same coverage of stations as cities in other countries (*Figures 11.1* to *11.5*).

Criteria for Calling Alarms

The cities surveyed use different criteria and in different combinations to decide whether or not to call an alarm. These criteria include:

- Exceedance of a threshold value of a particular pollutant;
- Number of hours a threshold is exceeded;
- Forecast of persistence of unfavorable meteorlogical conditions;
- Number of stations in which a threshold must be exceeded.

Threshold Values. The values used by different cities vary by about a factor of two (*Table 11.2*). In a few cases, the thresholds for a level 1 alarm in a particular city are lower than the thresholds for a pre-alarm in other cities. For example, the SO_2 threshold for a level 1 alarm in Kobe (534 $\mu g\ m^{-2}$) is lower than the pre-alarm threshold for Berlin and other German cities (600 $\mu g\ m^{-2}$). These differences are partly justified by the differences in air quality between cities. For instance, if air quality is poor and the threshold is low, then alarms will be announced often, which can lead to an attitude that air pollution episodes are routine. This, in turn, can lead to a lack of enthusiasm for countermeasures, as occurred in Milan, where the 100 alarm days called over five years led to a general indifference to these warnings (see previous text). Although there is justification for thresholds being different in different cities, they should at least be related to public health guidelines for air pollutants since smog alarm systems are designed to help protect public health after all. However, these threshold values are all far from WHO guidelines as can be seen in *Table 1.1.* Some international harmonization of these thresholds is obviously needed.

Number of Hours a Threshold Exceeded. In addition to specifying a threshold value, most cities also specify a period of time for which the pollutant must exceed its threshold (*Table 11.3*). This varies from 1 to 24 hours, based on the type of pollutant and the particular city or smog area. This period of time corresponds in many cases to the typical or required collection time of pollutants. For example, suspended particulate matter (SPM) is often measured over a 24 hour sampling time, and hence the period of time for which SPM must exceed its threshold is frequently specified as 24 hours (*Table 11.3*).

Forecast of Meteorological Conditions. An additional critierion that some cities use for calling or continuing a smog alarm is to require that unfavorable meteorological conditions be forecast to continue. The period of this forecast is specified as either 12 or 24 hours (*Table 11.4*). Some of the cities which do not require this specific forecast.

Number of Stations Exceeded. It is not unusual for air pollution concentrations to vary somewhat from station to station within the same smog area because of the proximity of pollution sources or local variations in air ventilation. Consequently, smog ordinances often require that a specified minimum number of monitoring stations should measure concentrations exceeding a threshold before a smog alarm is called or continued (*Table 11.4*). On the average, one in three stations, or one in two stations must record high pollutant levels (*Table 11.4*).

Sources of Episodes and Smog Alarms. The expected sources of local air pollution levels are listed in *Table 11.5*. Only Austria and the US regulate all five smog constituents. The number of recent smog alarms is listed in *Table 11.6*.

Types of Countermeasures

There is some similarity among cities in the countermeasures they employ during the various stages of smog alarm. These measures can be grouped into four categories: (1) health advisories, (2) reductions of industrial emissions, (3) reduction of emissions from heating, and (4) reductions in emissions from traffic (*Table 11.7*).

During a pre-alarm, measures are usually recommended. However, all smog areas specify a health advisory during this stage, and some require emission reductions at industrial sites (*Table 11.7*). Also, Los Angeles requires measures to reduce traffic during the pre-alam stage. In many smog areas measures are *recommended* for reducing emissions from industry, heating, and traffic.

The most common measures are summarized in *Table 11.8*. In the level 1 alarm, most areas require specific measures at industrial sites. These include banning of sulfur-rich fuels, postponing production activities that produce additional emissions, and reduction of energy consumption. Also included are actions to control heating emissions by requiring a reduction in room temperatures in public buildings, and recommending the lowering of room thermostats in private homes. During this alarm stage it is also typical to restrict traffic somewhat by, for example, limiting areas in which private vehicles may be used or restricting usage of vehicles with odd or even license plate numbers.

When a level 2 alarm occurs, the measures prescribed are similar to level 1 but fewer exemptions allowed. In some cases industries are closed, and large public gatherings are prohibited (in order to avoid transporation-related emissions and to reduce population exposure to high pollutant levels). Despite the high level of alarm, exemptions are usually given for the use of furnaces in schools, hospitals, retirement homes, and other such buildings, as well as vehicles with catalytic converters and public transport vehicles. However, if the episode occurs on a weekday, the public transport system of the city may be put on a weekend schedule to discourage activity in the city.

Effectiveness of Countermeasures

Relatively little attention has been given to evaluating the effectiveness of episode countermeasures, and much work is needed in this area.

Some measures may seem ineffectual, but have less obvious aims. As an example, certain cities call for reduction in traffic when high levels of SO_2 occur, although traffic emissions can lead to high levels of photo-oxidants but never to SO_2. Nevertheless, air pollution authorities in Germany believe that traffic restrictions in this case are worthwhile because they build public awareness of high levels of air pollution.

A more serious concern about countermeasures has to do with the origin of summer smog in Western Europe. As noted in the Introduction, winter and especially summer smog episodes can extend over large parts of Europe and originate from the long-range transport of pollutants. Hence, measures to reduce the local sources of smog may be fruitless in reducing the severity of episodes if they are caused by long-range transport.

As another example, enforcement problems and personal freedom issues always arise when smog laws require reduction of room termperature in private homes.

Despite these problems countermeasures should, in principle, be able to reduce the severity of winter smog episodes, or at least the exposure of populations during these episodes. The most effective countermeasures can be identified with the help of computer models which establish the cause-effect relationship between sources, both local and distant, and occurrence of episodic air pollutant levels. A computer model was used in the Netherlands (see previous text) to identify the percentage reductions of different pollutants needed to reduce the severity of episodic pollutant levels.

Legal Provisions and Emergency Action Plan

The responsibility for announcing smog alarms normally lies with provincial or county government officials. Legal authority is usually derived from a national smog alarm law (Austria, Germany, Japan, the Netherlands, the USA) or provincial legislation (Italy, Switzerland). With this authority, a local government usually adopts a smog ordinance which specifies an *Emergency Action Plan*. Contained in the ordinance or plan are the criteria and procedure for calling an alarm, a specification of the lines of communication in the event of an episode, and the countermeasures that must be taken in its event (see *Figure 11.9*).

Smog Alarm Communication

During an episode, the Emergency Action Plan is coordinated from the *Emergency Action Center.* This is usually located in a main data processing center of a county or province, but can also be located at a national scientific institute (RIVM in the Netherlands) or within a municipality (as in several Japanese cities). Typically the center is located in the offices of the weather service or environmental protection agency. In the case of Los Angeles, there are several emergency action centers located in the offices of county districts.

As noted above, the local smog ordinance or Emergency Action Plan specifies the lines of communication during an episode. The Emergency Action Center contacts all main institutions involved in countermeasures via telephone or telefax. These institutions in turn pass the alarm on to institutions within their jurisdiction. For example, the local department of education will contact schools, and the health department will notify hospitals, etc. In Los Angeles, large workplaces are required to have smog alarm coordinators for coordinating episode countermeasures.

The Emergency Action Center also notifies the mass media which, in turn, informs the public. Some cities notify the public in other ways, for example by a loudspeakers (Kawasaki) or electronic board displaying ambient air quality values (Vienna). Other cities provide a telephone hot line for answering public inquiries about the smog situation (see *Figure 11.9*).

Timeliness of Organizing Smog Alarm Systems

One troubling observation from studying the smog areas in this paper is that many smog ordinances have come into effect long after air pollution episodes stopped being a local problem. This was the case in Japan, where winter smog alarm laws were not passed until 1978, four years after the last serious winter smog episode occurred. The same can be said of many Western European cities with smog alarm systems, because they usually only regulate winter smog which is not much of a problem as compared to summer smog in these cities. Only Austria has a summer smog law. This is not to say that winter smog regulations should be eliminated (since an episode may still occasionally occur), but that effective winter smog regulations should be implemented in a more timely way.

Other Problems in Implementing Smog Alarm Systems

An additional problem is the public or business opposition to the measures proposed to lessen the effect of an episode, such as traffic restrictions or reducing room temperatures. Occasionally opposition to measures originates at a different level of government, as in the case of Zurich when measures adopted by the city to reduce summer smog episodes were vetoed by the canton (provincial) government. Experience in other cities has shown that if organizers of the smog alarm system consult with these groups much of their opposition can be eliminated.

Another type of problem occurred in Milan where the breakdown of its monitoring stations led to difficulty in complying with its smog ordinance. In order to call an alarm, a threshold must be exceeded at several stations; however, because measurement devices at these stations failed to operate correctly, this requirement often could not be met.

Still another problem is faced in the Netherlands where measures against summer smog episodes would be ineffectual because much of the photo-oxidant pollution originates from the long-range transport of nitrogen oxides from outside the country.

Relevance of Smog Alarm Systems to Central and Eastern European Cities

Returning to the original theme of this paper, we can suggest several objectives for smog alarm systems in Central and Eastern European cities.

First of all, even in the absence of any measures, a smog alarm itself can fulfill an educational role by bringing air pollution problems to the attention of city residents. In principle, it can be used by local and provincial authorities to gain support for a needed (and expensive) program to reduce air pollution permanently. This educational aspect may be particularly important in Central and Eastern Europe because of the especially tough competition between pollution control and other public services for available public funds.

Second, a smog alarm system can reduce the exposure of an urban population to air pollutants by providing warnings to parents and educational and health authorities regarding children and other sensitive members of the population;

Third, in cities where the source of pollution during an episode is primarily local (usually the case for highly polluted cities of Central and Eastern Europe), a smog alarm system has the potential to actually reduce the severity of an air pollution episode by controlling local pollutant sources in the hours preceding an episode. The benefits of this are large because temporary measures during an episode can be quickly implemented and are likely to be much less costly than permanent air pollution controls. However, to realize this potential, the following steps are recommended:

1. A relatively complete inventory of air pollution emissions is necessary.

2. A computer modeling study is needed to identify the sources that have the greatest impact on ambient pollutant levels.
3. Parallel to this study, it is necessary to conduct an engineering analysis to identify the sources *most feasible to be reduced* during an episode.
4. Results of steps (2) and (3) should be combined to develop a plan to implement reductions before an episode occurs. Good communication and enforcement procedures must be set up far in advance of an episode to accomplish these reductions during an episode.
5. Reducing sources *before* an episode occurs also requires an accurate prediction of episodes. This can be obtained by using a computer model which combines data on the trend of real-time air quality (as provided by a monitoring network) with meteorological forecasts. This type of model has been used in Milan for episode prediction (see previous text).

Although the costs of a smog alarm system (with temporary measures) are likely to be quite a bit less costly than permanent air pollution controls, they are still rather considerable and should be minimized where possible. Since monitoring systems require the largest capital investment in a smog alarm system, it is recommended to design the network as efficiently as possible. This means giving the greatest amount of coverage to the greatest number of people within financial or other constraints. As a rule of thumb, most existing systems have about one station per 100,000 inhabitants, but a computer model can be used to determine a more exact figure for the needs of a particular city.

Costs can also be reduced by substituting labor for capital where possible. One example of this is given by Zürich where the high capital costs of automatic real-time monitors are avoided by using manual measurements. Of course it is difficult to monitor a rapid increase in air pollutants using manual measurements as compared to automatic devices.

Apart from possible financial barriers, there may also be formidable institutional barriers to setting up smog alarm systems in Central and Eastern European cities. Opposition to a local government's smog ordinance may come from a different level of government which resents the local government taking on additional authority or from industry opposed to countermeasures which may temporarily curtail its output, or from citizen groups who feel that a smog alarm system is ineffectual in dealing with the root cause of a city's air pollution problems (which is correct in most cases.) Experience in many cities has shown that this opposition can be avoided if these groups and their concerns are included in the planning process of a smog alarm system. Moreover, the chance of success of countermeasures, such as reducing temperatures in private homes and curtailing vehicle usage, will be increased if they have the support of citizen and other groups.

As a final point, we recommend that international actions be taken to promote and support the rapid and proper establishment of smog alarm systems in Central and Eastern European cities. One such action would be the development and adoption of an *international smog alarm protocol.* This document would lay out guidelines for developing and implementing smog alarm systems. The protocol would recommend:

- the types of pollutants to be covered by alarms;
- pollutant thresholds and other criteria for calling an alarm;
- basic design features of an air monitoring network;
- a "prototype" emergency action plan and smog ordinance;
- basic features of an emergency action center.

We believe that the World Health Organization would be an appropriate institution to lead in developing this protocol, together with experts from IIASA and other international institutions and various national governments.

Such a protocol would at least be a starting point for cities in Central and Eastern Europe on their way to the emergency air protection of their citizens.

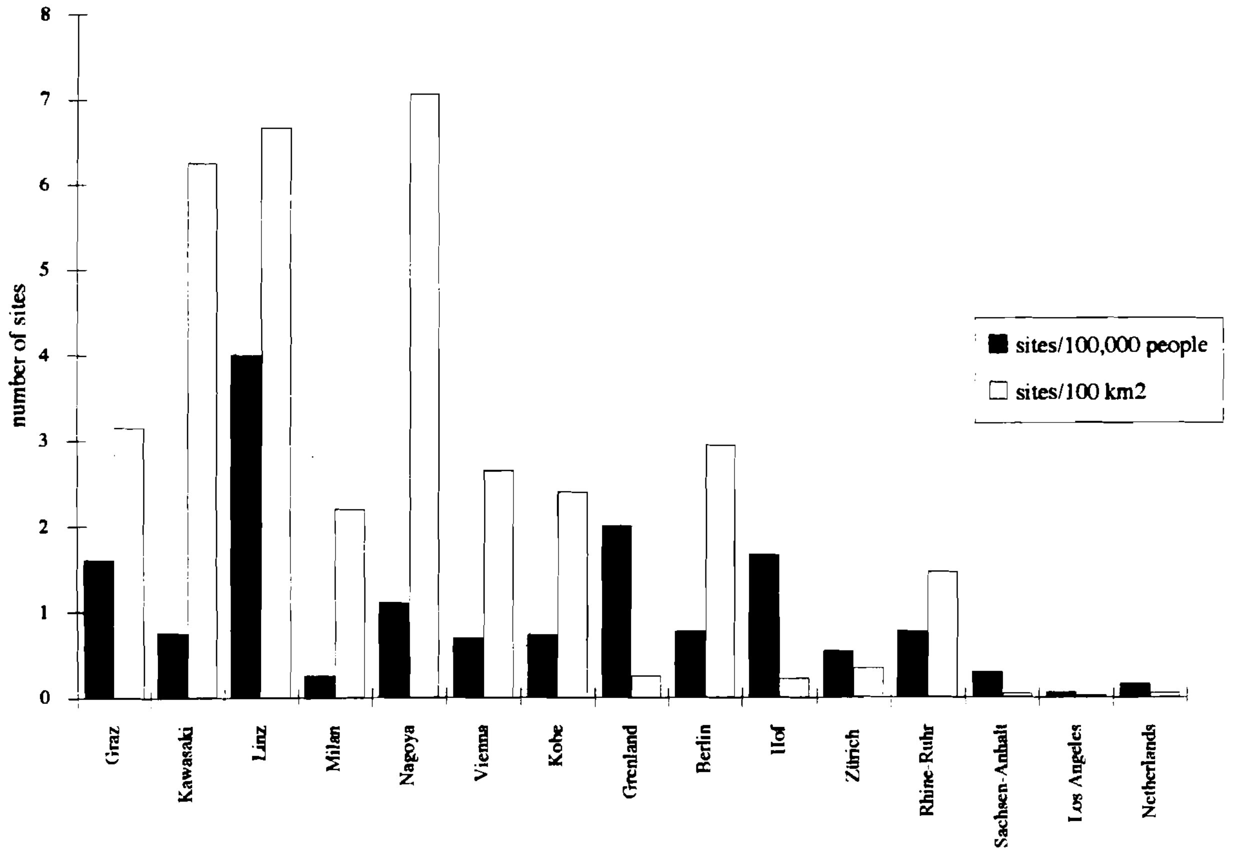

Figure 11.1. SO_2 measurement sites per 100,000 people and 100 km^2.

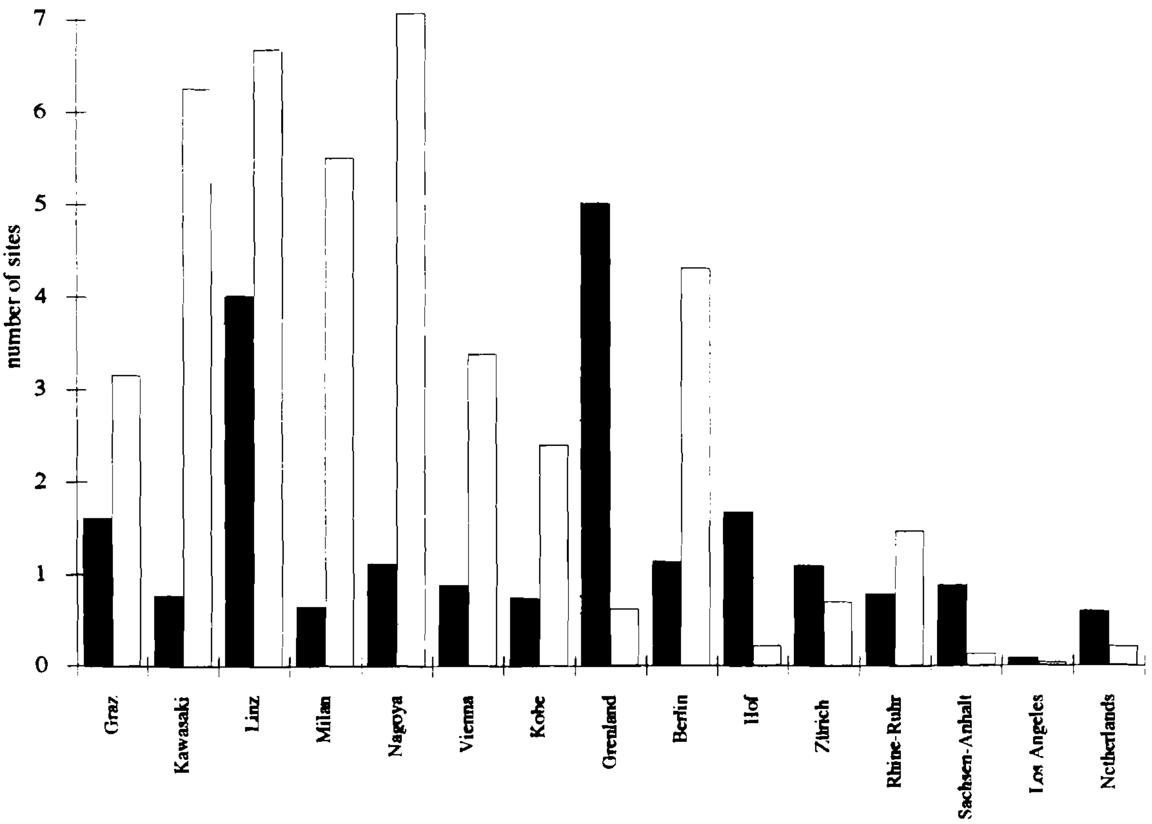

Figure 11.2. SPM measurement sites per 100,000 people and 100 km^2.

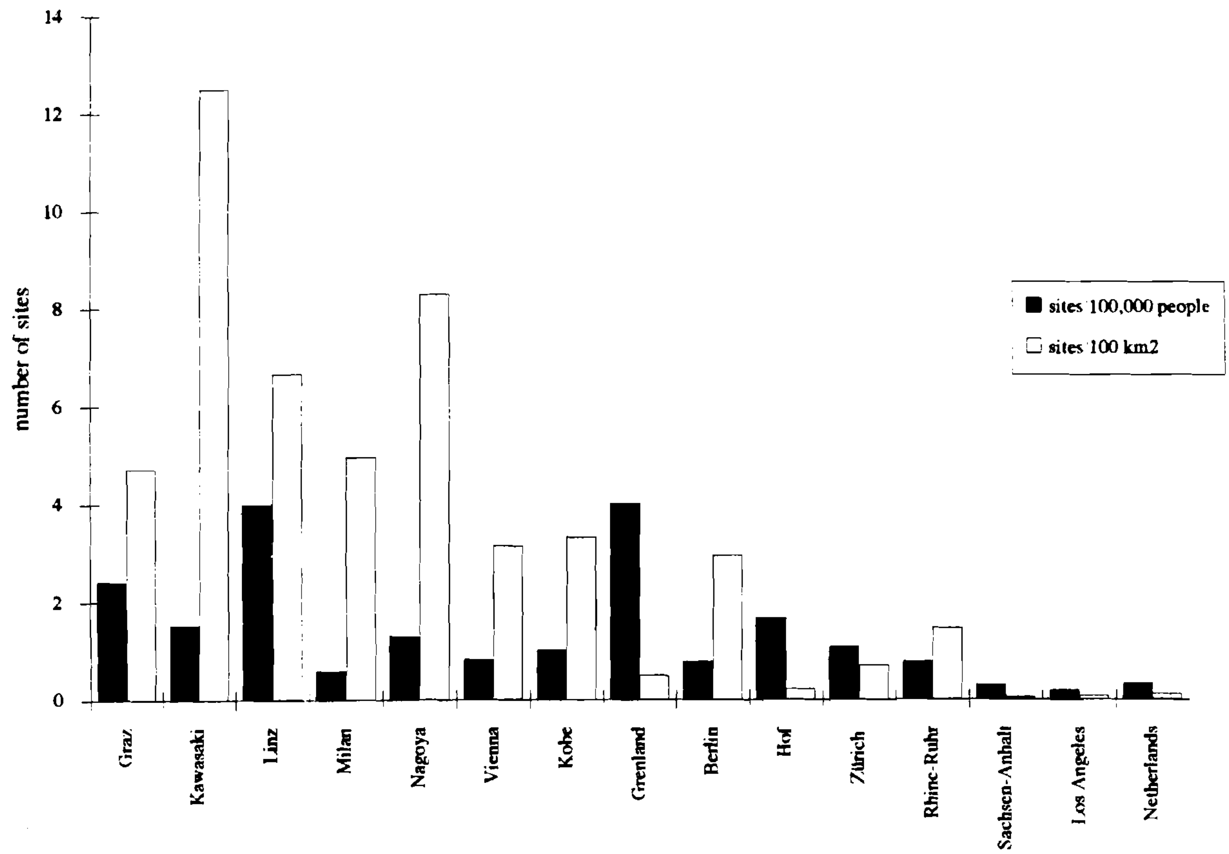

Figure 11.3. NO_2 measurement sites per 100,000 people and 100 km^2.

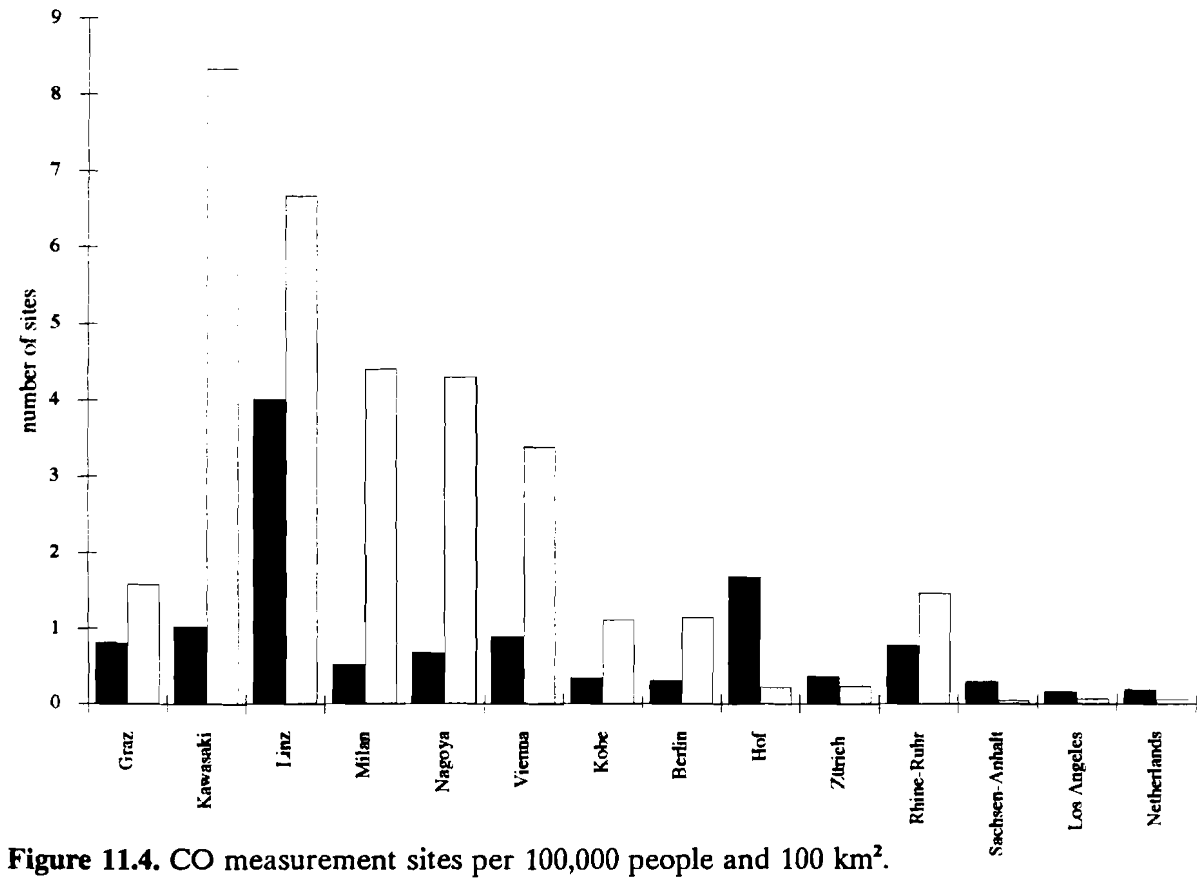

Figure 11.4. CO measurement sites per 100,000 people and 100 km^2.

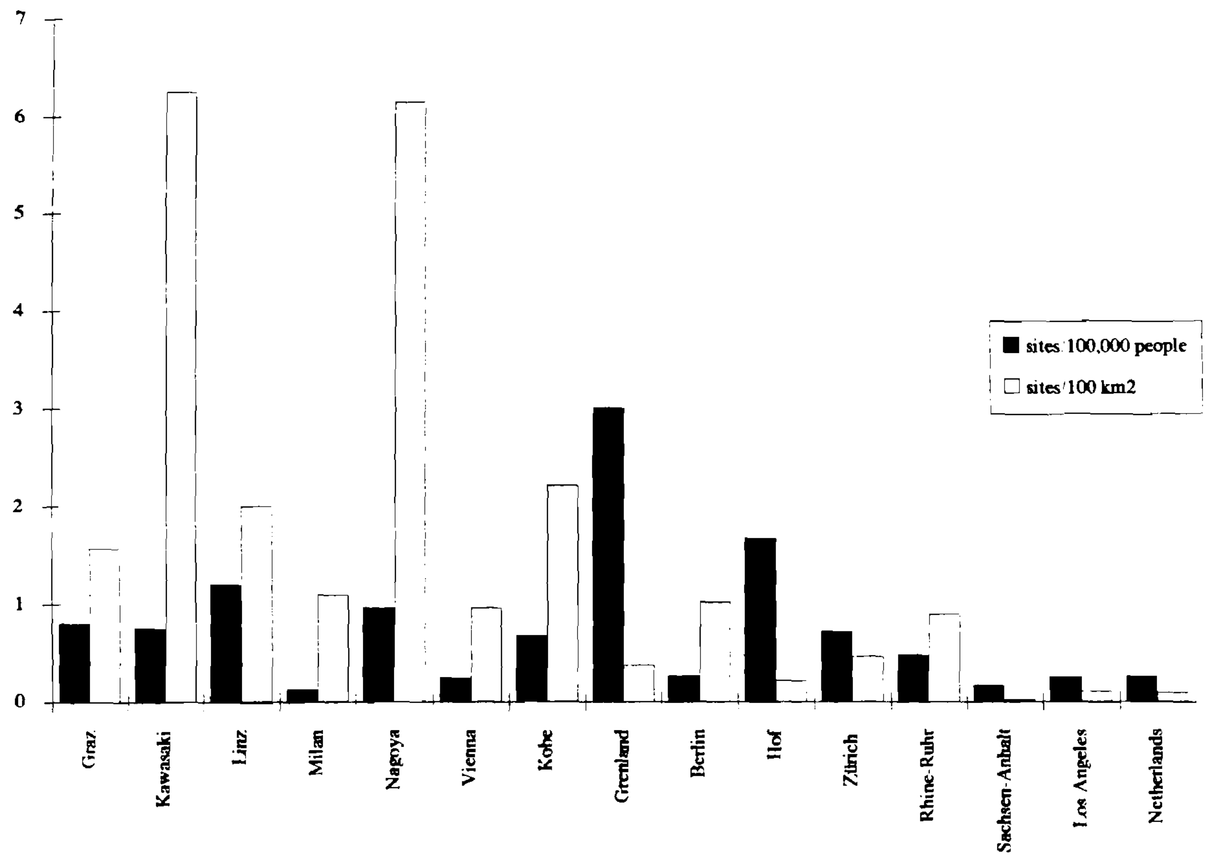

Figure 11.5. O_3 measurement sites per 100,000 people and 100 km².

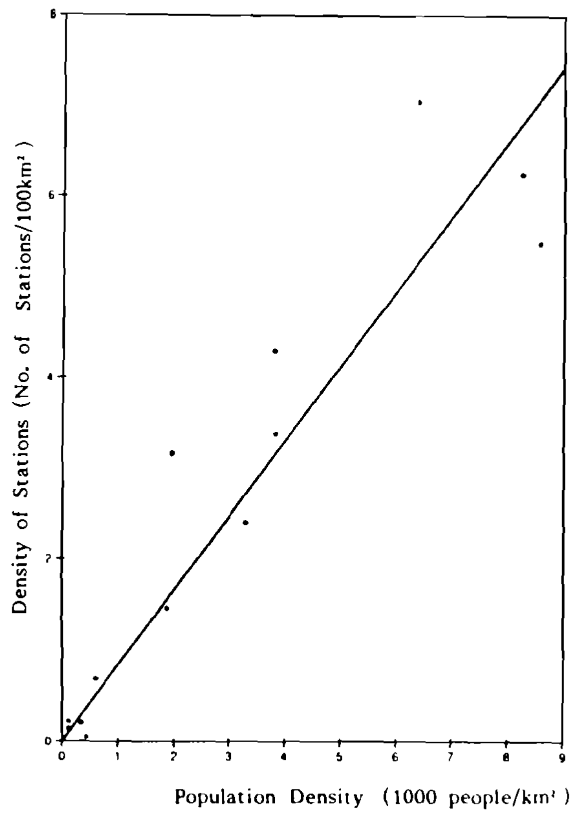

Figure 11.6. Density of population vs density of SO_2 stations for smog areas survey in report (Grenland, Linz excluded). Data derived from Table 11.1.

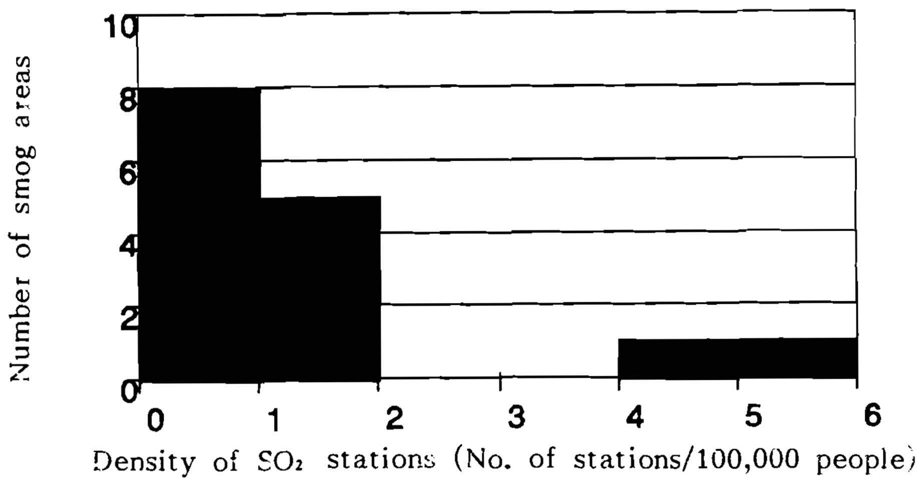

Figure 11.7.a. Distribution frequency of SO_2 measurement sites per 100,000 people.

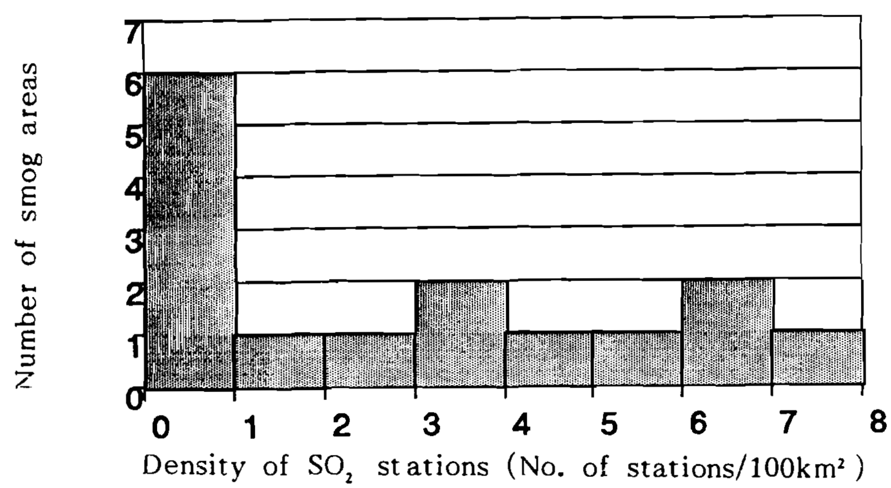

Figure 11.7.b. Distribution frequency of SO_2 measurement sites per 100 km^2.

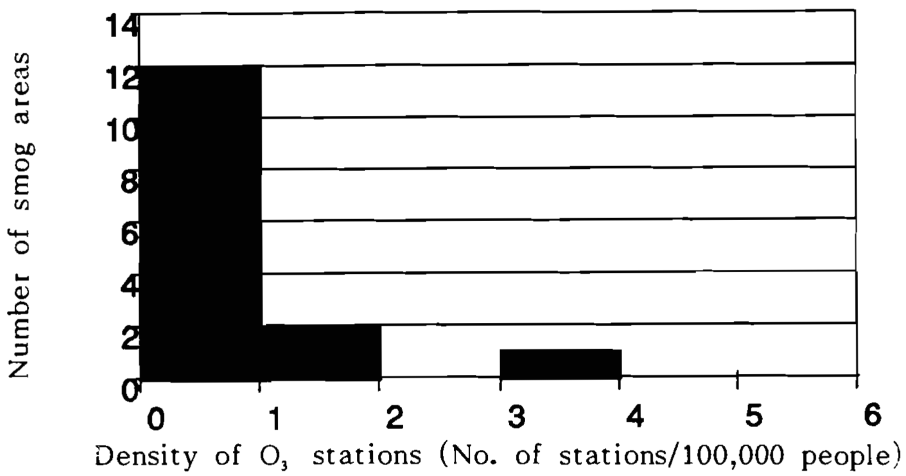

Figure 11.8.a. Distribution frequency of O_3 measurement sites per 100,000 people.

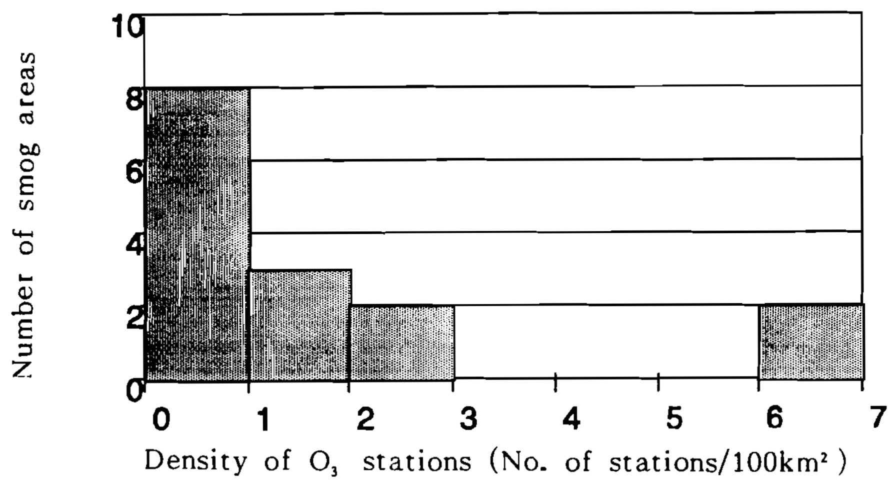

Figure 11.8.b. Distribution frequency of O_3 measurement sites per 100 km^2.

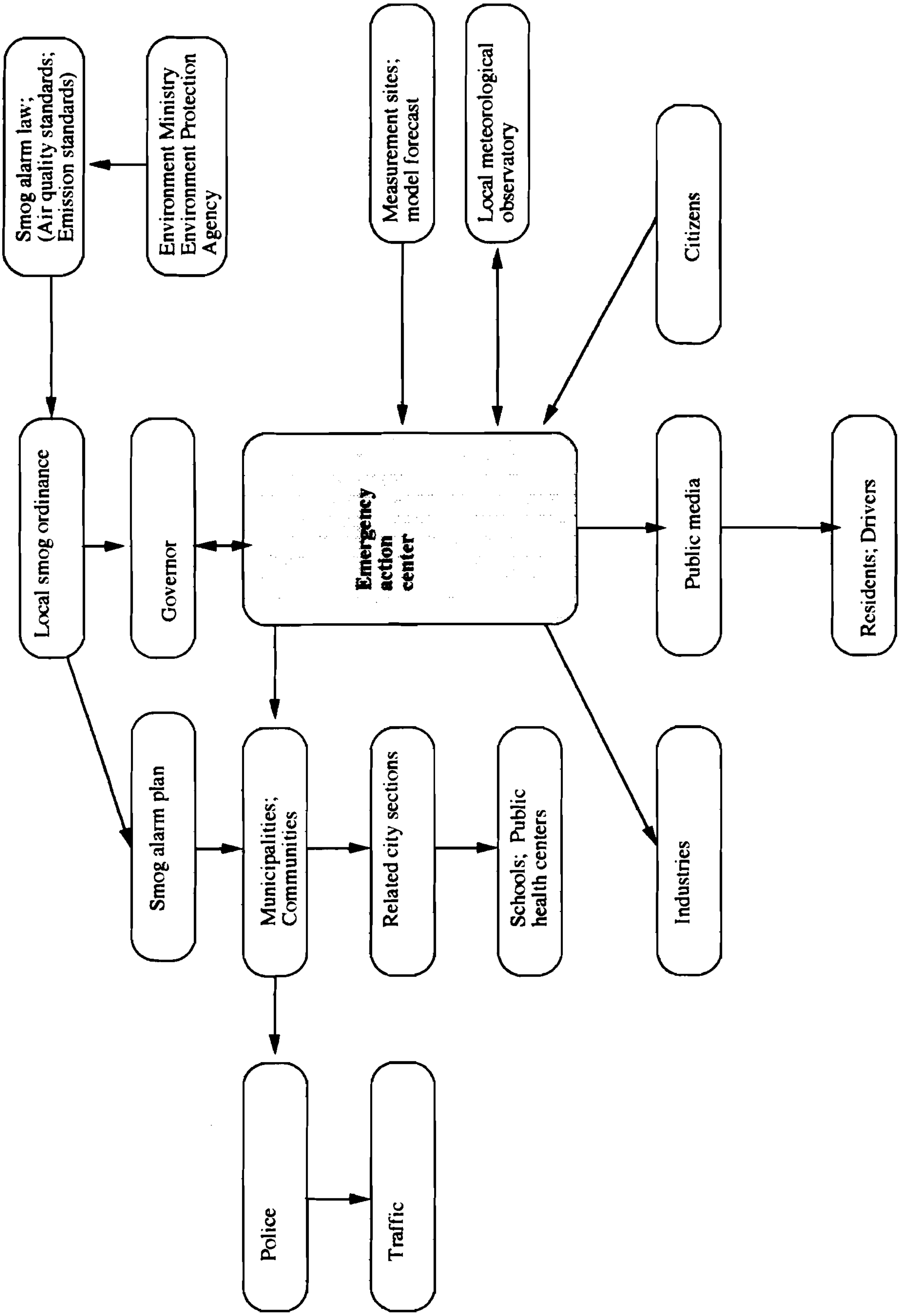

Figure 11.9. Typical smog alarm communcation.

Table 11.1. Description of smog areas.

Smog area	Smog areas according to size				Number of measurement sites[a]					
	Population (× 1000)	Population density (people/km^2)	Smog areas (km^2)	Urban area (>1000 people /km^2)	Multi[e]	SO_2	SPM	NO_x	CO	O_3[b]
Cities										
Graz	249	1,960	127	yes		4	4	6	2	2 (17)[c]
Kawasaki[d]	1,188	8,250	144	yes		9	9	18	12	9
Linz	250	1,667	150	yes		10	10	10	10	3 (11)[c]
Milan	1,561	8,577	182	yes		10	4	9	8	2
Nagoya	2,080	6,380	326	yes		23	23	27	14	20
Vienna	1,590	3,831	415	yes		14	11	13	14	4 (20)[c]
Kitakyushu[e]	1,065	2,285	466	yes	14					
Kobe	1,777	3,279	542	yes		13[d]	13	18	6	12
Grenland	100	125	800	no		5	2	4		3
Berlin	3,350	3,794	883	yes		38	27	27	10	9
Hof (district)	120	133	903	no		2	2	2	2	2
Zürich (canton)	1,110	642	1,729	no		12	6	12	5	6
Smog alarm districts										
Osaka (region)[e]	7,750	4,160	1,863	yes	121					
Rhine Ruhr (district)	7,000	1,892	3,700	yes		54	54	54	54	33
Sachsen (state)[e]	5,100	288	17,713	no	33					
Leipzig (district)[f]	1,400	283	4,966	no		14	2	1		
Dresden (district)[f]	1,810	268	6,738	no		32	3			
Sachsen-Anhalt (state)	3,100	153	20,292	no		27	9	9	9	5
Halle (district)[g]	1,700	194	8,771	no		35	4		1	6
Los Angeles (region)	13,000	433	30,000	no		11	7	23	21	33
Netherlands (entire country)	14,400	353	40,844	no		85	23	45	26	38

[a]These refer to automatic measurement sites, except for Leipzig, Dresden, and Halle.
[b]In some cases other oxidants are also measured.
[c]Number of entire county that is relevant as summer smog area.
[d]NO_2, CO with emission exhaust stations.
[e]The number of total multicomponent measurement sites, number for constituents might be less.
[f]Since October 1990 part of Sachsen. These districts of Sachsen are presented separately because data were available for them.
[g]Since October 1990 part of Sachsen-Anhalt. This district of Sachsen-Anhalt is presented separately because data were available for it.

Table 11.2. Smog alarm threshold values, in micrograms per cubic meter.

Smog area	Pre-alarm SO_2	SPM	NO_2	CO	O_3	Level 1 alarm SO_2	SPM	NO_2	CO	O_3	Level 2 alarm SO_2	SPM	NO_2	CO	O_3
Graz	400	600[a]	350	20,000	200	600	800[a]	600	30,000	300	800	1,000[a]	800	40,000	400
Kawasaki[b]	534	—	—	—	240	1,335	—	—	—	480	1,869	—	—	—	800
Linz	400	600[a]	350	20,000	200	600	800[a]	600	30,000	300	800	1,000[a]	800	40,000	400
Milan[h]	250	—	200	10,000	—	500	—	400	30,000	—	—	—	—	—	—
Nagoya[b]	—	—	—	—	240	—	—	—	—	480	—	—	—	—	800
Vienna	400	600[a]	350	20,000	200	600	800[a]	600	30,000	300	800	1,000[a]	800	40,000	400
Kitakyushu[b]	—	—	—	—	240	534	—	—	—	—	—	—	—	—	800
Kobe[b]	267	—	—	—	240	534	—	—	—	—	—	—	—	—	800
Grenland	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Berlin[c]	600	1,100[d]	600	30,000	—	1,200	1,400[d]	1,000	45,000	—	1,800	1,700[d]	1,400	60,000	—
Hof[c]	600	1,100[d]	600	30,000	—	1,200	1,400[d]	1,000	45,000	—	1,800	1,700[d]	1,400	60,000	—
Zürich[e]	200	—	—	—	240	350	—	—	—	—	—	—	—	—	—
Osaka[b]	534	2,000	960	—	240	1,335	—	—	—	480	1,869	3,000	1,920	—	800
Rhine Ruhr[c]	600	1,100[d]	600	30,000	—	1,200	1,400[d]	1,000	45,000	—	1,800	1,700[d]	1,400	60,000	—
Sachsen[c]	600	1,100[d]	600	30,000	—	1,200	1,400[d]	1,000	45,000	—	1,800	1,700[d]	1,400	60,000	—
Sachsen-Anhalt[c]	600	1,100[d]	600	30,000	—	1,200	1,400[d]	1,000	45,000	—	1,800	1,700[d]	1,400	60,000	—
Los Angeles[b]	720	300	960	20,000	480	275	138	1,320	27,500	660	400	200	1,920	40,000	960
Netherlands[f]	150	450[g]	—	—	240	350	700[g]	—	—	360	[f]	[f]	—	—	[f]

[a] Austrian index: SPM + SO_2.
[b] Original values in ppb.
[c] After 72 hours the state of alarm is automatically advanced one level.
[d] German index: 2 × SPM + SO_2.
[e] Swiss pre-alarm values are twice the ambient standard.
[f] Decision of Councillor of the Queen.
[g] Dutch index: SPM + SO_2 − 10.
[h] After 120 hours pre-alarm is advanced to level 1 alarm.

Table 11.3. Number of hours for which a threshold must be exceeded before an alarm is called. (In some cases these are averaging times, in other cases duration of instantaneous measurements.)

Smog area	Pre-alarm					Level 1 alarm					Level 2 alarm				
	SO_2	SPM	NO_2	CO	O_3	SO_2	SPM	NO_2	CO	O_3	SO_2	SPM	NO_2	CO	O_3
Graz	3	3[a]	3	3	3	3	3	3	3	3	3	3	3	3	3
Kawasaki	2	—	—	—	1	2	—	—	—	1	2	—	—	—	1
Linz	3	3[a]	3	3	3	3	3	3	3	3	3	3	3	3	3
Milan[g]	1	—	1	1	—	1	—	1	1	—	—	—	—	—	—
Nagoya	—	—	—	—	1	—	—	—	—	1	—	—	—	—	1
Vienna	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Kitakyushu	3	—	—	—	1	3	—	—	—	—	—	—	—	—	1
Kobe	3	—	—	—	1	3	—	—	—	—	—	—	—	—	1
Grenland	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Berlin[b]	3	24[c]	3	3	—	3	24	3	3	—	3	24	3	3	
Hof[b]	3	24[c]	3	3	—	3	24	3	—	—	—	—	—	—	—
Zürich[d]	24	—	—	—	1	24	—	—	—	—	—	—	—	—	—
Osaka	2	2	1	—	1	2	—	1	—	1	2	3	1	—	1
Rhine Ruhr[b]	3	24	3	3	—	3	24	3	3	—	3	24	3	3	—
Sachsen[b]	3	24	3	3	—	3	24	3	3	—	3	24	3	3	—
Sachsen-Anhalt[b]	3	24	3	3	—	3	24	3	3	—	3	24	3	3	—
Los Angeles	24	24	1	8	1	24	24	1	8	1	24	24	1	8	1
Netherlands[e]	24	24	—	—	1	24	24[f]	—	—	1	—	—	—	—	[e]

[a]Austrian index: SPM + SO_2.
[b]After 72 hours the state of alarm is automatically advanced one level.
[c]German index: 2 × SPM + SO_2.
[d]Swiss pre-alarm values are twice the ambient standard.
[e]Decision of Councillor of the Queen.
[f]Dutch index: SPM + SO_2-10.
[g]After 120 hours pre-alarm is advanced to level 1 alarm.

Table 11.4. Additional criteria to smog alarms.

	% of meas. sites exceeding threshold					Forecast of met. conditions (hours)[a]					Model support to predict episodes				
Smog area	SO_2	SPM	NO_2	CO	O_3	SO_2	SPM	NO_2	CO	O_3	SO_2	SPM	NO_2	CO	O_3
Graz	33	33	33	33	2	12	12	12	12	—	—	—	—	—	—
Kawasaki	22	—	—	—	1	—	—	—	—	—	—	—	—	—	—
Linz	33	33	33	33	2	12	12	12	12	—	—	—	—	—	—
Milan	50	—	50	50	—	—	—	—	—	—	model[b]	—	—	—	—
Nagoya	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—
Vienna	33	33	33	33	2	12	12	12	12	—	—	—	—	—	—
Kitakyushu	[c]	—	—	—	1	—	—	—	—	—	—	—	—	—	model
Kobe	[c]	—	—	—	1	—	—	—	—	—	—	—	—	—	model
Grenland	—	—	—	—	—	—	—	—	—	—	model	model	model	model	model
Berlin	33	33	33	33	—	24	24	24	24	—	—	—	—	—	—
Hof	[c]	[c]	[c]	[c]	—	24	24	24	24	—	—	—	—	—	—
Zürich	[c]	—	—	—	1	24	—	—	24	—	—	—	—	—	—
Osaka	[c]	—	[c]	—	1	—	—	—	—	—	model[d]	—	—	—	model
Rhine Ruhr	33	33	33	33	—	24	24	24	24	—	—	—	—	—	—
Sachsen	33	33	33	33	—	24	24	24	24	—	—	—	—	—	—
Sachsen-Anhalt	33	33	33	33	—	24	24	24	24	—	—	—	—	—	—
Los Angeles	[c]	[c]	[c]	[c]	[c]	—	—	—	—	—	—	—	model	model	model
Netherlands	[c]	[c]	—	—	[c]	—	—	—	—	—	—	—	—	—	model

[a]Numbers of hours unfavorable meteorological conditions forecasted to continue.
[b]Currently not in use.
[c]At least one station.
[d]Nonnumerical model based on a flowsheet diagram.

Table 11.5. Sources of episodes and constituents relevant to smog ordinances.

	Expected sources of local air pollution episodes[a]					Constituents relevant to smog ordinances					
Smog area	SO_2	SPM	NO_x	CO	O_3	No. of sub-districts	SO_2	SPM	NO_x	CO	O_3
Cities											
Graz	h,i	h	t,i	t	t		•	•	•	•	•
Kawasaki	i	—	t,i	t	t,i		•	—	—	—	•
Linz	i	i	—	—	t,i		•	•	•	•	•
Milan	h	h	t,h	t	—		•	—	•	•	—
Nagoya	—	i	t,i	t	t,i		•	—	—	—	•
Vienna	h	h	t	t	t,i		•	•	•	•	•
Kitakyushu	i	—	t,i	t	t,i		•	—	—	—	•
Kobe	i	—	t,i	t	t,i		•	—	—	—	•
Grenland	—	i	t,i	—	t,i		—	—	—	—	—
Berlin	ii,h,t,i	ii,h,i	t	t	—		•	•	•	•	—
Hof	ii	ii	—	—	—		•	•	•	•	—
Zürich	—	—	t	t	t		•	•	—	—	•
Smog alarm districts											
Osaka	i	—	t,i	t	t,i	7(3 SO_2)	•	•	•	—	•
Rhine Ruhr	i,h,ii	i,h,ii	t	t	t,it	5	•	•	•	•	—
Sachsen	i,h	i,h	i,t	—	—	10	•	•	•	•	—
Sachsen-Anhalt	i,h	i,h	i,t	—	—	10	•	•	•	•	—
Los Angeles	—	—	t,i	t	t,i	34	•	•	•	•	•
Netherlands[b]	ii	ii	t,i	t	t,it	12	•	•	—	—	•

[a]Opinion of local experts noted during July 1991 and April 1992.
[b]Not a smog area.
i = local industry
t = local traffic
h = local heating
ii = regional industry
it = regional traffic

Table 11.6. Number of recent smog alarms.

Smog area	Period years	Pre-alarm SO_2	Pre-alarm SPM	Pre-alarm NO_2	Pre-alarm CO	Pre-alarm O_3	Level 1 alarm SO_2	Level 1 alarm SPM	Level 1 alarm NO_2	Level 1 alarm CO	Level 1 alarm O_3	Level 2 alarm SO_2	Level 2 alarm SPM	Level 2 alarm NO_2	Level 2 alarm CO	Level 2 alarm O_3
Graz	1987–1992	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—
Kawasaki	1981–1990	—	—	—	—	30	—	—	—	—	—	—	—	—	—	—
Linz	1980–1992	—	9	—	—	2[b]	—	—	—	—	—	—	—	—	—	—
Milan[a]	1987–1991	—	—	100	—	—	—	—	15	—	—	—	—	—	—	—
Nagoya	1990	—	—	—	—	4	—	—	—	—	—	—	—	—	—	—
Vienna	1975–1992	—	—	—	—	6[b]	—	—	—	—	—	—	—	—	—	—
Kitakyushu	1974–1991	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Kobe	1967–1991	97	—	—	—	4	16	—	—	—	—	—	—	—	—	—
Grenland	No regulation	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Berlin	1980–1991	12	4	—	1	—	4	4	—	—	—	1	2	—	—	—
Hof (district)	1985–1991	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Zürich (cantone)	1985–1991	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Osaka (region)	1965–1990	45	—	—	—	461	66	—	—	—	324	1	—	—	—	1
Rhine Ruhr	1979–1990	2	—	—	—	—	—	—	—	—	—	1	—	—	—	—
Leipzig(county)[c]	Nov–Dec 89	1(286)[d]	—	—	—	—	108[d]	—	—	—	—	45[d]	—	—	—	—
Dresden(county)[c]	Nov–Dec 89	1(68)[d]	—	—	—	—	6	—	—	—	—	—	—	—	—	—
Halle(county)[e]	Nov–Dec 89	1(72)[d]	—	—	—	—	>1	—	—	—	—	1	—	—	—	—
Los Angeles (region)	1980–1990	—	—	56	82	844	—	—	—	—	34	—	—	—	—	—
Netherlands (country)	May–June 89	—	—	—	—	13[f]	—	—	—	—	—	—	—	—	—	—

[a]No statistics available, approximate values for NO_2.
[b]Number of pre-alarm levels since May 1992 (May 1 to August 10, 1992).
[c]Currently part of Sachsen.
[d]Hours in excess.
[e]Currently part of Sachsen-Anhalt.
[f]Value from Noord-Brabant; pre-alarm levels occurred on from 4 to 13 days in 7 of 12 smog districts.

Table 11.7. Episode countermeasures at different alarm levels.

Smog area	Health advisory	Pre-alarm Industry	Pre-alarm Heating	Pre-alarm Traffic	Level 1 alarm Industry	Level 1 alarm Heating	Level 1 alarm Traffic	Level 2 alarm Industry	Level 2 alarm Heating	Level 2 alarm Traffic
Graz[a]	•	—	—	—	•	•	•	•	•	•
Kawasaki	•	•	—	—	•	—	—	—	—	—
Linz[a]	•	—	—	—	•	•	•	•	•	•
Milan	•	—	—	—	—	—	•	•	—	•
Nagoya	•	•	—	—	•	—	—	•	—	—
Vienna[a]	•	—	—	—	•	•	•	•	•	•
Kitakyushu	•	•	—	—	•	—	—	•	—	—
Kobe	•	•	—	—	•	—	—	•	—	—
Grenland	•	—	—	—	—	—	—	—	—	—
Berlin	•	—	—	—	•	•	•	•	•	•
Hof	•	—	—	—	•	—	—	•	—	—
Zürich	•	—	—	—	—	—	—	—	—	—
Osaka	•	•	—	—	•	—	—	•	—	—
Rhine Ruhr	•	—	—	—	•	•	•	•	•	•
Sachsen	•	—	—	—	•	•	•	•	•	•
Sachsen-Anhalt	•	—	—	—	•	•	•	•	•	•
Los Angeles	•	•	—	•	•	—	•	•	—	•
Netherlands	•	—	—	—	•	—	—	•	—	—

[a]Currently only for winter smog alarm. Summer smog alarm systems scheduled to be operating by 1994.

•Measures implemented by local authorities.

Table 11.8. Summary of most common smog countermeasures.

	Pre-alarm	Level 1 alarm	Level 2 alarm
Industry	Lower capacity Use low-sulfur fuel Voluntary enforcement of reduction plan	Further capacity reduction Use low-sulfur fuel Enforcement of reduction plan	Close some plants Further capacity reduction Enforcement of reduction plan
Domestic heating	Reduce heating Reduce room temperature Advise use of low-sulfur fuel	Reduce heating Further reduction of room temperature Use low-sulfur fuel	Reduce heating Further reduction of room temperature Use low-sulfur fuel
Traffic	Use public transportation Avoid using private cars Organize car pools	Enforce traffic plan Restrict private car use Ban cars in certain areas on certain days	Weekend schedule Allow only emergency vehicles Ban all cars
Others			Ban public gatherings

Information Sources

Alcamo, J. 1992. Emergency care needed in Central and Eastern Europe. *Environment.* **34**(3):44–45.

Austria, Smogalarmgesetz, 1 Jun. 1989.

Austrian Academy of Science, A.B.f.A.M.f.E., Youth and Family, Photooxidantien in der Athmosphäre — Luftqualitätskriterien Ozon, Executive Summary, 1989.

Bavaria, B., Smog Verordnung, 17 Oct. 1985.

Berlin, Smogverordnung, 1990.

Berlin Municipality, S.f.S.u.U., Luftverschmutzung in Berlin und Umgebung im Jahr 1989, 1990.

Burkhard, H.P., Maßnahmen des Kantons Zürich zur Reduktion der Ozonbelastung, in Medienseminar der Kantone Zürich und Schaffhausen, May 1991, Meilen.

Cassmassi, J.C., Development of an Objective Ozone Forecast Model for the South Coast Air Basin, presented at 80th Annual Meeting of APCA, New York, 21-26 June, 1987.

CONCAWE, Motor Vehicle Emision Regulations and Fuel Specifications: 1990 update, The Oil Companies´European Organization for Environmental and Health Protection.

De Leeuw, F.A.A.M, H.J.v.Rheineck Leyssius; Calculations of Long-Term Averaged and Episodic Oxidant Concentrations for the Netherlands, *Atmospheric Environment* 1991, **25A** (9):1809–1818.

Dutch Ministry of Housing, Air Pollution Act, 1989.

Dutch Ministry of Housing, Memorandum Concerning 1991 Smog Abatement Regulations, 1991.

Dutch Ministry of Housing, Smog Alert System in the Netherland, 1991.

Dutch National Institute for Public Health RIVM, National Air-Quality Monitoring Network: Technical Description, 1989.

Fabian, P., Smog in Ballungsgebieten, in *Atmosphäre und Umwelt*, P. Fabian, editor, 1987, Springer-Verlag, Göttingen.

Fett, W., *Vorbelastung durch ferne Quellen bei Smogepisoden*, *Smogepisoden*, ed. K.J. Nieding, 1986, Fischer Verlag, Berlin, Stuttgart and New York.

Finzi, G., A Mathematical Model for Air Pollution Forecast and Alarm in an Urban Area, *Atmospheric Environment* **16**(9):2055–2059.

Finzi, G., R.Garcia,E.Hernandez; The SO_2 Pollution of Madrid — A Comparison between Two Stochastic Models for Real-Time Forecast Purposes, *Il Nuovo Cimento*, **6**C(6).

GDR, D.D.R., Gesetzblatt-Reinhaltung der Luft-Smogordnung, 9 Nov. 1989.

Germany, Federal Republic of Germany; Musterentwurf einer neuen Smogverordnung, 1987.

Gualdi, R., and V. Gianelle, L 'inquinamento atmosferico rilevato nel bienno 1989–1990, ed., C.d.M. Locale, 1981.

Halle District Government, Umweltbericht des Bezirk Halle, 1989.

Hanggartner, M., Ch. Meuli, R. Isler, J. Lustenberger, 1990, Vergleich von Ozonpassivsammlern mit kontinuierlichen Messgeräten, in *Umwelttechnik*, 4/90, Zürich.

Hernandez, E., and G. Finzi, The SO_2 Pollution of Madrid — A Study of Meteorological and Statistical Aspects, *Il Nuovo Cimento*, **6**C(6).
Hohmeyer, O., and A. Sieber, Systematic Presentation of the Clean Air Policy Individual OECD Member States, Synopsis, 1988, Eraunhofer-Gesellschaft zur Förderung der angewandten Forschung.
IIASA, Questionnaire on Smog Alarm Systems, 1991.
Italian Government; Leggi e Decreti — Limiti massimi di accettabilita´delle concentrazioni e limiti massimi di esposizione relativi ad inquinati dellåria nell´ ambiente esterno, 1983.
Japan Environment Agency, Quality of the Environment in Japan, 1990, EPA.
Kobe-Municipal-Government, Quality of the Environment in Kobe 1990, 1990.
Lahmann, E., Quellen, Immissionen und Trends von Luftverunreinigungen in Ballungsgebieten Berlin. Smogepisoden, ed. K.J. Nieding, 1986, Berlin.
Leutert, G., Workshop on International Exchange of Data for Smog Warning/information Systems in Europe, 14–15 May, 1992, Suisse Federal Agency for Environment, Forest and Landscape.
Löffler, H., Umweltbericht Luft, 1990, Magistratsabteilung 22.
Lübkert, B., 1989, Characteristics of the Mid-January 1985 SO_2 Episode in Central Europe: Report from an International Workshop, *Atmospheric Environment*, **23**(3):611–623.
Ministry of Nordrhein-Westfahlen, L., Empfehlungen zur bundeseinheitlichen Praxis bei erhöhten Ozonkonzentrationen, 1989, LAI, Länderausschuβfür Immissionsschutz.
Müller, W.G., 1988, *Design of an Air Pollution Monitoring Network*, IIASA Working Paper.
Munn, R.E., 1981, *The design of air quality monitoring networks*. MacMillan. London. 109 pp.
Niederösterreichische-Landesregierung, Entwurf zur Verordnung über den Smogalarmplan, 1991, Amt der Niederösterreichischen Landesregierung.
Norwegian Pollution Control Board, L.S., Årsrapport 1989 for industriforurensning i Nedre Telemark, 1990, Statens Forurensningstilsyn, Nedre Telemark.
Norwegian Pollution Control Board, B.S., S. Sivertsen, Årsrapport 1991, SFTs kontrollseksjon i Nedre Telemark, 1991, Statens Forurensningstilsyn, Nedre Telemark.
Oberösterreichischen-Landesreierung, A.d., Automatisches Luftüberwachungsnetz Oberösterreich, 1986, Landesbaudirektion Immissionsschutz.
Oberösterreichischen-Landesreierung, A.d., Verordnung über den Smogalarmplan Linz, 1989.
Oberösterreichischen-Landesreierung, A.d., Luftgüteüberwachung: Jahresbericht 1990, 1991, Abteilung Umweltschutz UA Luftreinhaltung und Energietechnik.
Nordrhein-Westfahlen; Smogverordnung, 1974.
Pleschberger, W., Vergleich des Smogalarmgesetzes von Wien und Zürich, 1990.
Prittwitz, V., Smogalarm: Fünf Funktionen der unmittelbaren Gefahrenabwehr, 1985, International Institute for Environment and Society.
Provincia di Milano, Studi per la valutazione della qualita‘ dell´aria nella provincia di Milano, 1990.
Sachsen, Umweltbericht 1991 Freistaat Sachsen, 1991.
Sachsen, Smog Verordnung, 5 Dec. 1991.
Sachsen-Anhalt, Immissionsschutzbericht 1990, 1991, Ministerium für Umwelt und Naturschutz des Landes Sachsen-Anhalt.
Sachsen-Anhalt, Smog Verordnung, 6 Dec. 1991.
SCAQMD, Regulation VII-Emergencies, in Air Quality Management Plan South Coast Air Basin: 1980, adopted May 1977, amended July 1980.
SCAQMD, Air Quality Management Plan — South Coast Air Basin, 1990.
Soeda, A. et al.; Real Time Control of Emissions in Japanese Cities, presented at IIASA Workshop on Mathematical Models for Planning and Controlling Air Quality, 1979, Laxenburg.
Steiermärkische-Landesregierung, Smogalarmplan Graz, 1989.
Suffern M., Smog Alarms in Germany, *Clean Air*, **24**(1).

Suisse-Federal-Council, Luftreinhalteverordnung (LVR), 1985, Der Schweizerische Bundesrat.
Suisse-Federal-Council, Empfehlungen für das Vorgehen bei Wintersmog, 1987.
Törnevik, H. Computerized Air Quality Surveillance — The Gothenburg Airviro Integrated Monitoring System, presented at Chemistry and the Environment Conference, Salzburg, 4–6 Sep. 1991.
UNEP/WHO-GEMS, Assessment of Urban Air Quality, 1988, Global Environmental Monitoring System.
USA-EPA, Guide for Control of Air Pollution Episodes in Medium-Sized Urban Areas, 1971.
USA-EPA, Guide for Control of Air Pollution Episodes in Small Urban Areas, 1971.
USA-EPA, § 51.150, Subpart H — Prevention of Air Pollution Emergency Episodes; App. Example Regulation for Prevention of Air Pollution Episodes, 1986.
Vienna Municipality, Landesgesetzblatt für Wien: Smogalarmplan, 1991.
WHO, Acute Effects on Health of Smog Episodes, 1992, World Health Organization, Regional Office for Europe, Copenhagen.
World Wildlife Fund, *World Atlas for the Environment — Urban Air Pollution*, 1991.
Young, J.W.S., J.M. Hewings, D.G. Kelly, J.C. Lack, R.E. Munn, H.J. Roireau, R.W. Shaw, L. Shenfeld, A Proposed Air Quality Index for Canada, presented at The Fourth Clean Air Conference, Tokyo, Japan, May 1975.
Zürich-Kanton, Luftprogramm für den Kanton Zürich, 1990, Baudirektion für den Kanton Zürich.
Zürich-Stadt, Umwelt Bericht Stadt Zürich 1989/90, 1990, Umweltschutzfachstelle, Gesundheits und Wirtshaftsamt des Kanton, Zürich.
Zürich-Stadt, Massnahmen zum Sommersmog, presented at Medienseminar Sommersmog, Schaffhausen, 16 May 1991.