Atmospheric Pollution Due to Mobile Sources and Effects on Human Health in Japan

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Following the rapid economic growth after World War II, diseases associated with environmental pollution frequently occurred due to delayed implementation of countermeasures against environmental pollution. These diseases are exemplified by Minamata disease, Itai-itai disease, chronic arsenic poisoning, and Yokkaichi asthma. After multiple episodes of these pollution-related diseases were experienced, the government and the private sector made joint efforts to reduce environmental pollution. As a result of these efforts and because of changes in the industrial structure, pollution-related diseases have declined. Instead, however, air pollution from automobile exhaust and the health effects of automobile exhaust on people living along roads with heavy traffic began to attract the public’s attention after an increase in the use of automobiles. The epidemiological surveys carried out by the Environmental Agency and the Tokyo Metropolitan Government also have suggested unfavorable effects of automobile-caused air pollution on people living in large cities or along major roads. To solve this problem, it seems imperative to promote the reasonable use of automobiles and to work toward more efficient transportation of goods based on analyses of city structure, the life-styles of city dwellers, and the socioeconomic composition of cities. In addition, the discharge of pollutants from automobiles could be controlled. — Environ Health Perspect 102(Suppl 4):93–99 (1994).

Key words: atmospheric pollution, automobile exhaust, health effects

Introduction

The rapid and high economic growth after World War II brought environmental destruction and serious health damage because of environmental pollution in several severely polluted areas of Japan. There were many pollution-related diseases, Itai-itai disease related to cadmium pollution created by the effluent from the Mitsu Mining and Smelting Company (1,2), Minamata disease caused by the ingestion of fish and shellfish contaminated with mercury compounds discharged from the Minamata Factory of the New Japan Chisso Fertilizer Company (1,3), Yokkaichi asthma related to the sulfur oxides (SOx) discharged by the petrochemical industry (1,4), and chronic arsenic poisoning resulting from environmental pollution in the areas around the Toroku and Sasagadani mines (1). To provide prompt and fair protection and relief to the sufferers of this pollution-related health damage, the Pollution-Related Health Damage Compensation Law, which charges the polluters with the necessary expenses, has been in force since 1974. However, the onset of pollution-related health damage was prevented later by countermeasures against environmental pollution as a result of joint efforts by government and industry and changes in industrial structure.

Air pollution because of automobile exhaust and especially the health effects of auto exhaust on people living along roads with heavy traffic have become big environmental health issues in Japan. Due to the excessive concentration of population and industry accompanying high economic growth, there has been an increase in traffic volume.

Environmental Pollution Problems and Prevention in Japan

In accordance with the Basic Law for Environmental Pollution Control, environmental quality standards (EQS) were set up for sulfur dioxide (SO2) in 1969 (revised in 1973), carbon monoxide (CO) in 1970, suspended particulate matter (SPM) in 1972, and nitrogen dioxide (NO2) (revised in 1978) and photochemical oxidants (O3) in 1973 (5) (Table 1). To ensure compliance with these standards, emission and effluent regulations came into force (Figure 1).

| Substance | Standard values |
|-----------|----------------|
| Sulfur dioxide | 1-hr 0.1 ppm, 24-hr 0.04 ppm |
| Carbon monoxide | 8-hr 20 ppm, 24-hr 10 ppm |
| Suspended particulate matter | 1-hr 0.20 mg/m3, 24-hr 0.10 mg/m3 |
| Nitrogen dioxide | 24-hr 0.04–0.06 ppm |
| Photochemical oxidants | 1-hr 0.06 ppm |

Health Effects from Major Pollutants

Tokyo is the capital of Japan, the most densely populated area of Japan, and the area with the most automobile exhaust pollution. Table 2 shows the maximum 1-hr and 24-hr values of major pollutants and the maximum number of hours or days that the 1-hr and 24-hr values were above a certain level among 22 general air pollution monitoring stations and 30 automobile monitoring stations along Tokyo roadsides in 1990 (6,7).

SO2 levels have been improved remarkably, compared with the peak value of 0.059 ppm in 1967, because countermeasures against SOx, including the importation of low-sulfur content fuel, the desulfurization of heavy oil, and flue-gas desulfurization (Figure 1). In spite of several kinds of countermeasures such as emission controls on stationary sources and automobile exhaust (Figure 1), NO2 levels have not improved. Problems involved in controlling SPM because of their origin from multiple sources have caused SPM levels to remain unimproved. Automobiles are the main source of CO air pollution. As a result of gradually intensified restriction of CO emitted from automobiles since 1966, the annual average concentrations of CO have dropped rapidly, as shown in Figure 1. In the case of photo-

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chemical oxidants, the number of days of issuing an oxidant warning when the hourly oxidant concentration level exceeds 0.12 ppm is strongly influenced by meteorologic conditions and fluctuates considerably from year to year (Figure 1). Measures to control hydrocarbon emission from stationary sources and automobiles have been promoted to prevent photochemical air pollution.

In 1968, the health problems related to lead pollution from motor vehicles in Ushigome Yanagi-cho, Tokyo, drew public attention. However, it was found later that the analysis of lead in blood was not correct, and there were actually no cases of lead poisoning among the inhabitants of that area. Although the expert committee on EQS for lead concluded in 1976 that it was unnes-

**Table 2.** Concentrations of major air pollutants in the Tokyo metropolitan area in 1990 (6,7).

(A) At general air pollution monitoring stations

| Pollutant | 1980 | 1990 |
|-----------|------|------|
| SO₂ ppm   | 0.12 | 0.19 |
| NO₂ ppm   | 0.04 | 0.16 |
| SPM, mg/m³| 0.888| 1.96 |
| CO ppm    | 16.6| 6.3  |
| O₃ ppm    | 0.200| 0.10 |

Number of hr (days) that the 1-hr value is over 0.1 ppm: 1-hr/year

Number of days that the 24-hr value is over 0.06 ppm: 60 days/year

(B) At automobile exhaust emissions stations

| Pollutant | 1980 | 1990 |
|-----------|------|------|
| SO₂ ppm   | 0.097| 0.208|
| NO₂ ppm   | 0.045| 0.094|
| SPM, mg/m³| 0.888| 0.307|
| CO ppm    | 23.9 | 6.6  |
| O₃ ppm    | 0.132| 0.010|

Number of hr (days) that the 1-hr value is over 0.1 ppm: none

Number of days that the 24-hr value is over 0.06 ppm: 140 days/year

Abbreviations: SO₂, sulfur dioxide; NO₂, nitrogen dioxide; SPM, suspended particulate matter; CO, carbon monoxide; O₃, photochemical oxidants.

**Evaluation of Health Effects Due to Exposure to Combined Air Pollution**

**Contribution of Nitrogen Oxides from Automobile Exhaust to General Air Pollution**

Automobile exhaust accounted for 67% of the total NOₓ emissions in Tokyo, 32% in Yokohama and, 47% in Osaka in 1985 (9). This suggests that automobile exhaust...
contributes more than 50% to general air pollution in large cities in Japan.

Recent Epidemiological Surveys of Health Effects Caused by Air Pollution

Surveys by the Environment Agency. The following two surveys (10) conducted by the Environmental Agency (EA) served as important sources of data used by the expert committee (10) to assess the health effects of current air pollution, as discussed later.

Survey A with Adults. From 1982 to 1983, the EA surveyed 33,090 parents and grandparents of children attending elementary schools in 28 districts of nine prefectures who had been living for more than 3 years in districts where the annual average levels of NO₂, SO₂, and SPM were 3.0 to 38.0 ppb, 4.0 to 13.5 ppb, and 20.0 to 63.0 μg/m³, respectively. (Data for the years concerned were measured at the regular ambient air monitoring locations.) This survey revealed significant correlations between the prevalence of persistent cough and phlegm in males or females and the annual average SO₂ and SPM levels (Table 4). The prevalence of persistent phlegm was significantly correlated with the levels of NO₂, SO₂, and SPM (10).

When the examined schools were divided into three groups, group U (schools located in districts with a population density over 5000 persons/km²), group S (density of 1000–5000 persons/km²) and group R (density below 1000 persons/km²), the prevalence of persistent cough and phlegm proved highest in group U and lowest in group R (10). When the prevalence of persistent cough and phlegm for each year and each sex was compared among the three groups, hardly any significant intergroup differences were found. The prevalence of persistent cough and phlegm was analyzed in relation to the number of family members, house size, indoor air pollution level, anamnesis, occupation, and smoking. This analysis revealed a significant correlation between anamnesis and the prevalence of persistent cough and phlegm, a slightly significant correlation with smoking, and hardly any significant correlation with indoor air pollution (10).

When the crude prevalence of persistent cough and phlegm was analyzed in relation to NO₂ levels over 10 ppb intervals, the prevalence in both males and females increased as the NO₂ level rose (Table 5). The current prevalence of asthmatic symptoms in males and females was not significantly correlated with any air pollutant (Table 4).

Survey A with Children. From 1981 to 1983, a survey was made of 43,682 elementary schoolchildren who lived in districts where the annual average levels of NO₂, SO₂, and SPM were 3.5 to 34.0 ppb, 4.0 to 16.0 ppb, and 13.0 to 69.0 μg/m³, respectively. This analysis revealed significant correlations between the prevalence of asthmatic symptoms in both sexes and the level of NO₂, between their prevalence in females and the level of SO₂, and between their prevalence in males and the level of SPM. The prevalence of chest congestion and phlegm was correlated significantly with levels of NO₂, SO₂, and SPM in males and with the level of NO₂ in females (Table 4). When the prevalence of asthmatic symptoms was analyzed in relation to levels of NO₂ examined over 10 ppb intervals, the prevalence of symptoms in both males and females increased significantly as the level rose, although the prevalence of symptoms for a given NO₂ level varied greatly among the different districts (Table 6) (10).

When children were divided into three groups (U, S, and R) in the same way as above, the prevalence of asthmatic symptoms and the prevalence of chest congestion and phlegm were highest in group U and lowest in group R. This intergroup difference was statistically significant. When the prevalence of these symptoms was paired with physical constitution, past medical history, current illness, past nutri-
tion, family composition, house size, indoor air pollution, genetic predisposition, and living environment, significant correlations were detected for physical constitution, past medical history and current illness. Following this discovery, an assessment was made to whether the differences in the prevalence of symptoms among the three above-mentioned regional groups could be explained by these three factors. In the case of all three factors, the order of the prevalence of symptoms from highest to lowest was U>S>R, in children for whom the factor was positive and in children for whom the factor was negative. This suggests that other factors are responsible for the regional differences in the prevalence of symptoms. However, when analyzed for each year and each sex, regional differences were not always significant. Factors related to indoor pollution had virtually no significant correlation with the prevalence of symptoms (10).

**Survey B with Adults.** From 1980 to 1984, a survey was conducted involving 167,165 parents and grandparents of children attending elementary schools in 51 districts of 28 prefectures who had lived in the districts for more than 3 years. In districts where the annual average levels of NO₂, SO₂, and SPM in the years concerned were 5 to 43 ppb, 5 to 24 ppb and 20 to 90 μg/m³, respectively. Significant correlations were found between the age-adjusted prevalence of persistent cough and phlegm in females and the levels of NO₂ and SO₂, although no significant correlations were detected in males (Table 4) (10).

When the age-adjusted prevalence of persistent cough and phlegm was analyzed in relation to the level of NO₂ over 10 ppb intervals, the prevalence of symptoms in females increased as the level of NO₂ rose, although no such correlation was observed in males (Table 5). The prevalence of persistent phlegm was significantly correlated with levels of NO₂, SO₂, and SPM. When the prevalence of asthmatic symptoms was analyzed in relation to air pollutants, a significant correlation was observed between their prevalence in females and the level of NO₂, and between their prevalence in males and the level of SPM (10).

**Survey B with Children.** In the same districts mentioned above, a survey was carried out from 1980 to 1984 involving 98,695 elementary schoolchildren who lived in those districts for more than 3 years. When the prevalence of asthmatic symptoms was analyzed in relation to the levels of air pollutants, significant correlations were found between the level of NO₂ and prevalence in males and females and between the level of SO₂ and prevalence in females (Table 4). When the prevalence of chest congestion and phlegm was analyzed in relation to the levels of air pollutants, a significant correlation was found between their prevalence in males and females and the levels of NO₂ and SO₂ (Table 4) (10).

When the prevalence of asthmatic symptoms was analyzed in relation to the level of NO₂ over 10 ppb intervals, the prevalence in males and females was significantly higher at NO₂ levels over 31 ppb than at NO₂ levels below 30 ppb, although the prevalence for each 10 ppb interval varied greatly among the different districts (Table 6). Part of the results of Survey B were published by Tunerishi et al. (11).

**Survey by the Tokyo Metropolitan Government**

The Tokyo Metropolitan Government (12) conducted a survey of the health effects of composite air pollution in schoolchildren from 1978 to 1984. When pulmonary function was measured monthly during a 2-year period in 153 third-grade children (9 to 10 years old) attending an elementary school in Nakano Ward, the growth-related increase in pulmonary function was significantly lower in these children than in schoolchildren in a clean-air district in Chiba Prefecture. In Nakano Ward, Tokyo, the annual average level of SO₂, SPM, and NO₂ in 1983 was 0.008 ppm, 0.052 mg/m³ and 0.030 ppm, respectively.

From 1987 to 1989, the Metropolitan Government (13) repeated pulmonary function measurements in a larger number of children attending two elementary schools in center city and one elementary school in a control district selected on the basis of 10-year cumulative NO₂ data obtained at regular ambient air monitoring stations. This survey disclosed a significant difference in the prevalence of wheezing and asthmatic symptoms between center city and the control district. The growth-related increase in pulmonary function tended to be lower in center city than in the control district (13).

**Epidemiological Surveys of Health Effects of Air Pollution around Roads with Heavy Traffic**

In the report by the expert committee (10), the necessity of considering the influence of regional air pollution, which appears to be more severe than general ambient air pollution, was pointed out. This suggestion is based on the following surveys in roadside districts conducted in several areas.

The EA conducted a respiratory questionnaire survey on the health effects of air pollution on residents living along heavy-traffic roads (traffic volume about 150,000 automobiles per day) from Osaka to Kobe in 1975 in cooperation with Hyogo Prefecture Environmental Pollution Research Institute and Watanabe et al. (14). The subjects of this survey were housewives between 30 and 60 years old who lived in any of the following areas for more than 2 years: within 50 m of the edge of a national road (area A) and in more remote areas (150 to 250 m away from the edge of a national road [area B]). There were 420 subjects in area A and 429 in area B. The prevalence of persistent cough and acute bronchitis tended to be higher in the area A group than in the area B group. No significant difference was observed in pulmonary function. In this survey, the one month average levels of SO₂, NO₂, CO, and lead in area A were 0.025 ppm, 0.045 ppm, 2.7 ppm, and 0.31 μg/m³, respectively. The levels in area B were almost half the levels in area A.

Nagira et al. (15) investigated the prevalence of respiratory symptoms and diseases in 2,677 schoolchildren attending two elementary schools facing a national road linking Osaka and Kobe. Prevalence was analyzed in terms of the distance between children's homes and the road (within 100 m, 100 to 300 m, and over 300 m away from the edge of the road). A close relationship was found between the prevalence of persistent cough or phlegm, wheezing, acute respiratory infection, recurrent respiratory infection, or allergic rhinitis and distance from the road: the closer the children lived, the greater the prevalence rate.

Matuki et al. (16) investigated the usefulness of the urinary hydroxyproline/creatinine ratio (HOP ratio) as a new biochemical index of the adverse health effects of passive smoking and air pollution. A total of 4,964 schoolchildren 6- to 11-year old were studied from 1977 to 1980. The area investigated was a typical residential region of Tokyo with three main roads (each with a traffic volume of 40,000 to 80,000 automobiles per day). The HOP ratio was analyzed in terms of the distance between the children's homes and the main road (within 50 m, 51 to 100 m, and over 101 m from the main road) and the number of cigarettes smoked per day in their house- hold. The HOP ratio increased with increasing numbers of cigarettes smoked in their household and with shortening of the distance between their homes and the main road. A significant positive correlation...
Table 7. Percentage of prevalence of respiratory symptoms and past history of disease in residents living along roadsides and in more remote areas.

| Respiratory symptoms          | Roadside | Remote districts | Level of significance |
|-------------------------------|----------|-----------------|-----------------------|
| Persistent cough              | 7.5      | 5.2             | 0.049                 |
| Persistent phlegm             | 12.7     | 10.0            | 0.069                 |
| Persistent cough and phlegm  | 4.5      | 3.4             | 0.231                 |
| Wheezing                      | 2.0      | 1.7             | 0.836                 |
| Asthmatic attack              | 7.0      | 6.7             | 0.896                 |
| Dyspnea                       | 1.8      | 0.8             | 0.075                 |
| Past history of disease       |          |                 |                       |
| Pneumonia                     | 9.9      | 8.0             | 0.164                 |
| Allergic rhinitis             | 14.3     | 15.0            | 0.614                 |
| Chronic bronchitis            | 4.3      | 4.4             | 1.000                 |
| Bronchial asthma              | 0.7      | 0.7             | 1.000                 |

*Level of significance was tested by the chi-square test.*

between the HOP ratio and these factors was found.

The Tokyo Metropolitan Government (17) examined the effect of air pollution on residents living along heavy-traffic corridors where traffic volume during daytime 12-hr is about 40,000 automobiles per day from 1982 to 1984. The prevalence of symptoms was compared in 816 housewives living along roadsides (within 20 m of the road) and 1100 housewives living in more remote areas (20 to 150 m away from roads). As shown in Table 7, the prevalence of respiratory symptoms tended to be higher in the roadside group than in the remote group. A similar tendency also was observed when subjects were analyzed by age, duration of residence in the district, and smoking. A simultaneous environmental survey revealed that levels of air pollutants decreased as distance from the road increased, suggesting the involvement of automobile exhaust in the high prevalence of respiratory symptoms in the roadside group. In that survey, the 7-day average levels in Itabashi Ward were as follows: NO, 0.071 ppm at the roadside, 0.011 ppm at 20 m from the roadside, and 0.009 ppm at 150 m from the road; NO<sub>2</sub>, 0.041 ppm at the roadside, 0.021 ppm at 20 m from the roadside and 0.019 ppm at 150 m from the road; SPM, 136.6 at the roadside, 113.4 at 20 m from the roadside, and 98.0 μg/m<sup>2</sup>/m<sup>2</sup> at 150 m from the roadside.

Nitta et al. (18,19) published the results of these studies conducted from 1982 to 1984. The Mantel–Haenszel odds ratios for distance from the roadway, adjusted for age and smoking status, ranged from 0.80 to 2.57 for chronic phlegm, chronic cough, chronic wheezing, shortness of breath and chest cold with phlegm. Both reports suggest that exposure to automobile exhaust is associated with increased risk of respiratory symptoms.

Ono et al. (20,21) surveyed residential SPM and NO<sub>2</sub> concentrations along the major roadways (traffic volume during the daytime 12-hr: about 35,000 automobiles per day) in Tokyo and conducted a health survey on respiratory symptoms and distance from roadways in 1987. Environmental monitoring was conducted five times, every three or four months. Using a newly developed SPM sampler and NO<sub>2</sub> filter badge, continuous 4-day (96-hr) measurements were conducted in 200 residential homes for 4 weeks. NO<sub>2</sub> was measured in the living room, kitchen, and outside each home, while SPM was monitored only in the living room. Health information from 805 homes was collected using self-administered respiratory questionnaires. SPM and NO<sub>2</sub> concentrations showed large variations. Indoor pollution levels depended mostly on indoor sources such as cigarette smoking and unventilated space heaters, and the effect of those indoor sources were influenced by the building structure with respect to airtightness. An association between an increase in pollutant levels and distance from roadways was observed. However, its effect is small compared to the effects of indoor sources. The prevalence rate of respiratory symptoms was higher in children and adults in areas nearest roadways with heavy traffic. These findings suggest the presence of a relationship between automobile exhaust and health effects.

To examine the health hazards of roadside air pollution in more detail, the Tokyo Metropolitan Government (22) conducted a questionnaire survey of respiratory symptoms from 1987 to 1989. The subjects of this survey were women between 30 and 60 years old who lived in one of the following areas for more than 3 years: (a) within 20 m of the edge of any major road in Sumida Ward (the roadside group), (b) 20 to 150 m away from the edge of major roads in Sumida Ward (the remote group), and (c) Higashiyama Ward excluding areas within 20 m of the edge of a road (the Higashiyama group). There were 489 subjects in the roadside group, 800 in the remote group, and 821 in the Higashiyama group. The prevalence of persistent cough, persistent phlegm, wheezing, and shortness of breath from highest to lowest was in the following order: roadside > background > Higashiyama. When the data were corrected for age, duration of residence in that location, occupation, smoking, method of indoor heating, and house structure, the prevalence of wheezing and shortness of breath was found to differ significantly among the different districts. An environmental survey in these districts revealed the gradients of NO and SPM levels. When exposure levels were examined in about 20 subjects each from the roadside group and the remote group and about 10 subjects from the Higashiyama group, the levels of air pollutants during the nonheating period of the year decreased in the following order: roadside > background > Higashiyama. The outdoor levels of air pollutants showed no area-related gradient during the indoor heating season.

**The Relationship between Air Pollution and Chronic Obstructive Pulmonary Disease**

The expert committee for evaluating the relationship between air pollution and health damage (23) (an organization set up within the framework of the Central Council for Environmental Pollution Control) drew the following conclusion about the relationship between current air pollution levels and the prevalence of chronic obstructive pulmonary disease (COPD) in Japan, based on comprehensive assessment of the available evidence from animal experiments, experimental human exposure studies, epidemiological studies and clinical findings in 1986. (a) As was true of air pollution in the past, present-day air pollution is mostly attributable to the combustion of fossil-derived fuels. Therefore, it would not be a significant error if the present air pollution in Japan is dealt with in terms of three major air contaminants, SO<sub>2</sub>, NO<sub>2</sub>, and SPM. Of these three, the latter two seem to warrant particular attention, considering the current status of fuel consumption, countermeasures against air pollution and changes in the source of pollutants (especially changes in the structure of traffic systems). (b) It cannot be denied that air
pollution as a whole has had some influence on the natural history of COPD. From 1955 to 1965, COPD in individuals living in certain areas of Japan was chiefly attributable to air pollution, on the grounds that its prevalence was considerably higher in districts with high air pollution levels. However, it appears to be impossible to attribute COPD to air pollution alone. c) Based on an assessment of the present level of air pollution in Japan in relation to COPD, we would like to call attention to the following points: What we studied was primarily the effects of environmental air pollution on the population. Therefore, the effects of air pollution in particular areas, especially those with higher air pollution levels than the average, must be considered separately. Also, the existence of a group of people with increased sensitivity to air pollution has been attracting attention. If the number of individuals belonging to this group is not large enough, this group may be overlooked during epidemiological studies on the general population. This possibility must be borne in mind.

**Future Topics**

The Japanese Expert Committee (23) affirmed the possibility that air pollution in Japan is affecting the natural history of COPD. In its opinion, the levels of air pollution in Japan are not high enough to clearly demonstrate a cause-effect relationship between air pollution and COPD, but they also are not low enough to rule out a causal relationship. The committee added that the influence of automobile exhaust on residents living along roadsides requires special consideration.

During the period when coal was a major source of energy, \( \text{SO}_2 \) and particulate matter were major air pollutants. Because these pollutants affect the large airways that are rich in mucus-producing cells, the health effects of air pollution in those days was represented by chronic bronchitis-like symptoms (e.g., cough and phlegm). Following the replacement of coal with petroleum and the increase in automobiles, \( \text{NO}_x \) and fine particulate matter (containing nitrates and sulfates) began to act as major air pollutants. In this situation, the peripheral airways seem to be the major site affected by air pollution. The peripheral airways are referred to as a silent zone where abnormalities are less likely to become apparent. For this reason, the effect of air pollution on the peripheral airways is difficult to assess.

The data obtained by general ambient air pollution surveys conducted by the Environment Agency and the Tokyo Metropolitan Government do not demonstrate clearly the health effects of air pollution but also do not rule out an effect as discussed above. When roadside residents who are thought to be exposed to high levels of automobile exhaust were surveyed, the prevalence of respiratory symptoms tended to be higher than in more remote inhabitants. It is an open question, however, whether the residents with respiratory symptoms were exposed to higher levels of automobile exhaust than symptom-free inhabitants.

To evaluate the contribution of automobile exhaust to health hazards, it is necessary to evaluate the percentage of the total amount of air pollution to which individuals are exposed that is attributable to automobile exhaust. The effect of a given level of automobile exhaust exposure differs in individuals who are also exposed to air pollutants from other sources and in individuals who are not exposed to air pollutants from any other source. When city dwellers are exposed to air contaminated with pollutants from fixed and mobile sources to a degree close to the minimal exposure level presenting a health hazard, health effects appear likely to become manifest as they are exposed to indoor air pollutants or to automobile exhaust by living along roads with heavy traffic (Figure 2).

More research, including assessment of individual exposure to auto exhaust and assessment of health effects among roadside residents more highly exposed to auto exhaust, is necessary before any definitive conclusion concerning a causal association between exposure to auto exhaust and increased risk of respiratory symptoms and

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**Figure 2.** Evaluation of the health effects of automobile exhausts on residents living along heavy traffic roads. The scale of each item does not necessarily indicate the exact strength of the effect of each item.
diseases can be drawn. The process of health risk assessment (RA) on the health effects of environmental pollution due to auto exhaust may demand scientific research involving performance of RA, without regard to risk management (RM). However, environmental pollution must not be allowed to increase while we attempt to perform scientific RA instead of RM. RM should satisfy public requirements for foreknowledge and prevention of risk evaluated by incomplete RA. Furthermore, it is necessary to construct a comprehensive and prescient environmental policy, not only to prevent local pollution and preserve the natural environment, but also to promote human health and to create a comfortable urban environment.

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