Current Status of Wind Environmental Issues and Strategy for Environmental Conservation in Japan

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ABSTRACT: This paper describes the present status of wind environmental issues and a strategy for environmental conservation in Japan. The attainment ratio of environmental quality standards at ambient air pollution monitoring stations is as follows: 0.5% for photochemical oxidants, 99.1% for nitrogen dioxides, 52.5% for particulate matter, 99.8% for sulfur dioxides, and 100% for carbon monoxide. At roadside air pollution monitoring stations, the attainment ratio of environmental quality standards has decreased to 83.5% for nitrogen dioxides and to 34.3% for particulate matter. This indicates that air pollution due to automobile exhaust gas is still a severe problem. There is an urgent need to find measures to combat mobile emission sources in Japan. Furthermore, because of the increase in heat discharge emitted by human activities and in the area of artificial ground cover in urban areas, a heat island is occurring in most large cities. This further increases air pollution caused by photochemical oxidants in summer and nitrogen oxides in winter. To determine indoor air quality, a national survey was carried out of more than 5000 houses. This survey revealed that formaldehyde concentration was more than 0.08 ppm in 27.8 % houses and was not proportional to building age. For assessment of pedestrian wind environment, CFD simulations have been rapidly increasing. The Architectural Institute of Japan is scheduled to make a practical guideline for CFD prediction in the wind environment in 2005.

KEYWORDS: Outdoor air pollution, Indoor air quality, Pedestrian wind, Air quality standards, Criteria, Environmental white paper, Japan

1. Increase in Energy Consumption

There are now more than 35,000,000 privately owned automobiles in Japan and this contributes to the convenience of our daily lives. However, energy consumption increases with combustion of fuels and causes a heavy environmental load. The increased number of electrical appliances in households has caused a further rise in energy consumption. The electric power demand in private houses has shown a large increase, from 1,410.8 billion kWh in 1990 to 1,930.7 billion kWh in 2001. The total discharge of carbon dioxide in 2002 was 1,248 million tons. Compared with those in 1990, this is an increase of 11.2% in the total discharge amount and 7.8% in the discharge amount per person. The increase in discharge amount of carbon dioxide due to energy consumption is one of the main factors causing global warming [1].

2. Air Quality Standards for Outdoor Air Pollutants

Fig.1 indicates governmental regulations and academic standards concerning outdoor and indoor pollution. The Air Pollution Control Law enacted in 1967 enforced restrictions on emission of harmful substances from factories and facilities. In areas where factories are concentrated it was difficult to maintain environmental quality standards for nitrogen dioxides in accordance with discharge restrictions on facility units. Total load control was enforced for factory units according to the total amount reduction program in 1974. The total Air Pollutant Control Law was newly revised in 1992 into the Basic Environmental Law to establish sustainable society with a low environmental load. Table 1 summarizes the air quality standards for major air pollutants.

3. Present Status of Atmospheric Environment

This is described, referring to the Environmental White Paper 2004 [1].

3.1 Heat island

The heat island phenomenon, which indicates that air temperature in urban areas is higher than in suburban areas, is now found in most large cities. According to the Third Assessment Report of the Inter-governmental Panel on Climate Change (IPCC) in 2001, it is estimated that the average surface temperature on the globe increased by 0.6°C ± 0.2°C during the 20th century. However, in major cities such as Tokyo and Nagoya, the average temperature increased by 2 - 3°C during the same period. Fig. 2 shows high temperature areas in the Tokyo district. The area where the temperature exceeds 30°C is extending widely. Compared with the mean change of the global climate, the increasing trend of heat island in urban areas is extremely remarkable. The main cause of this trend is thought to be the increase in heat emission from human activities such as from air-conditioning units, electrical devices, combustion facilities and motor vehicles. The second cause is the change of ground cover conditions. Areas of open green space and water have decreased with construction of concrete buildings and paved roads. The heat load from solar radiation is kept inside the canopy layer and causes tropical nights. There were more than 50 days of tropical nights in downtown Tokyo this summer. This leads to frequent usage of air-conditioners, causing a vicious cycle of increased energy consumption. It is also pointed out that air pollution is accelerated by photochemical oxidants in summer and by nitrogen oxides in winter.

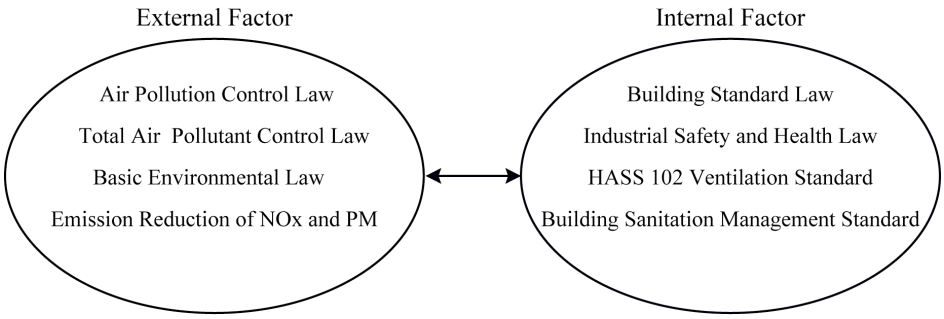


Figure 1. Governmental regulations and standards concerning air quality in Japan

Table 1. Summary of air quality standards for major air pollutants

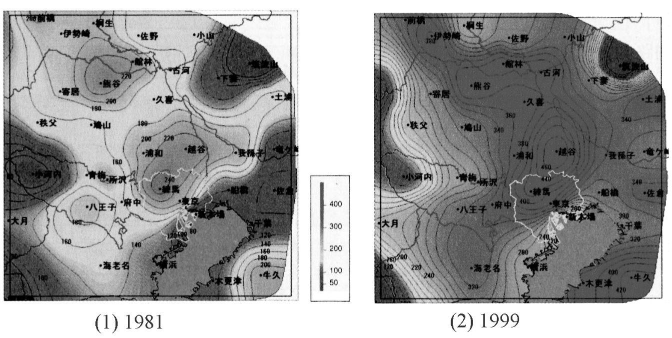
Types of air pollutants	Standard		Units
Total suspended particles (TSP)	hour	0.20	mg/m^3
	day	0.10	
Sulfur oxides (SO_2)	hour	0.10	ppm
	day	0.04	
Nitrogen oxides (NO_2)	day	0.04-0.06	ppm
Carbon monoxide (CO)	8 hours	20.00	ppm
	day	10.00	
Photochemical oxidants	hour	0.06	ppm

3.2 Acid rain

After being emitted into the atmosphere, sulfur dioxides and nitrogen dioxides are turned to sulfuric acid and nitric acid, respectively, causing rain with high acidity. It is feared that acid rain seriously influences fish through acidification of lakes and rivers, forests due to acidification of soil, and buildings and cultural properties. As acid rain may be transported several thousands of kilometers from the original source and generate causative substances, it causes trans-boundary air pollution. From fiscal year 1983 to fiscal year 2000, the first to the fourth acid rain monitoring surveys were performed and revealed that at 48 monitoring stations all over Japan, the annual average pH was found to be 4.72 - 4.90, indicating almost the same acidity as in Europe and America. In the coastal areas on the Sea of Japan, the deposition amount of sulfuric acid ions and nitric acid ions tended to increase in winter. This suggests the influence of acid rain transported from the Asiatic continent. From August 2000, the increased deposition of sulfuric acid ions was found in some areas in the Kanto and Chubu regions, and this was regarded as the result of a volcanic eruption at Mt. Oyama on Miyake Island.

3.3 Photochemical oxidants

Photochemical oxidant is widely known as the main cause of photochemical smog and is secondarily generated when primary pollution substances such as nitrogen oxides and volatile organic compounds are subjected to photochemical reaction under sunlight. As photochemical oxidants have strong acidifying power, high concentrations of oxidants may strongly irritate the eyes and throats, and seriously influence respiratory organs. The influence of these substances is also extended to agricultural products. The environmental quality standard for photochemical oxidants indicates that the one-hour concentration must be kept less than 0.06 ppm. The attainment ratio in fiscal year 2002 was found to be as low as 0.5% at ambient air pollution monitoring stations (hereinafter referred as " ambient station"). The number of days with warnings issued on photochemical oxidants was up to 108, extending over 19 prefectures. The warning was issued most frequently in August, i.e. 47 days in total, followed by June with 24 days. There were 254 persons who reportedly suffered discomfort caused by photochemical air pollution. When the number of days with warning was classified by area blocks, the Kanto area was the highest with 68 days, accounting for about 63% of the total, as shown in Fig. 3.



(1) 1981 (2) 1999

Figure 2. High temperature areas in Tokyo district

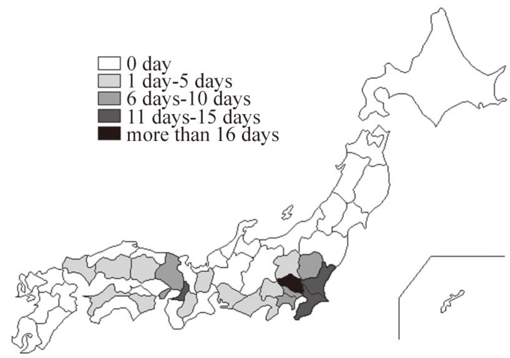


Figure 3. Number of days with photochemical oxidants warning

3.4 Nitrogen oxides

Nitrogen oxides such as nitrogen dioxide are generated when various substances are burnt. Major sources of generation include stationary sources and mobile emission sources. NOx is a causative substance of photochemical oxidants, airborne particles and acid rain. In particular, NO_2 in high concentration strongly irritates respiratory organs. The environmental quality standards for nitrogen dioxides indicate that the daily mean of one-hour values must be within the range of 0.04 - 0.06 ppm or lower than this level. Fig. 4 shows the variation of annual concentrations at ambient air pollution monitoring stations and at roadside air pollution monitoring stations (hereinafter referred to as “roadside stations”). The average values at ambient stations continue to remain almost the same, while those at roadside stations show gradually decreasing values. The attainment ratio of the environmental quality standards was 99.1% at ambient stations and 83.5% at roadside stations, both showing improving trends. However, the concentrations in large cities, as shown in Fig. 5, still show high values with ratios in the range of 43.1 - 69.3% at roadside stations from 1998 to 2002.

3.5 Suspended particles

Airborne particles drifting in the atmosphere seriously affect respiratory organs when high concentrations are precipitated in the lungs and trachea. These particles include primary particles and secondary particles. The primary particles are discharged directly from the generating sources into the atmosphere. The secondary particles are generated when gaseous substances such as sulfur oxides, nitrogen oxides, or volatile organic compounds are converted to particles in the atmosphere. The environmental quality standards for airborne particles indicate that the daily mean of one-hour values and the one-hour value must not be more than 0.10 mg/m^3 and 0.20 mg/m^3, respectively. The annual average value is 0.027 mg/m^3 at ambient stations and 0.035 mg/m^3 at roadside stations. In recent years, the values have tended to be at almost the same level or gradually decreasing, as shown in Fig. 6. Based on the long-term monitoring evaluation, the attainment ratio of environmental standards for airborne particles has been 52.5% at ambient stations and 34.3% at roadside stations, both showing some decrease compared with the ratio in 2001. Monitoring stations not attaining the environmental quality standards are located in 42 prefectures all over Japan.

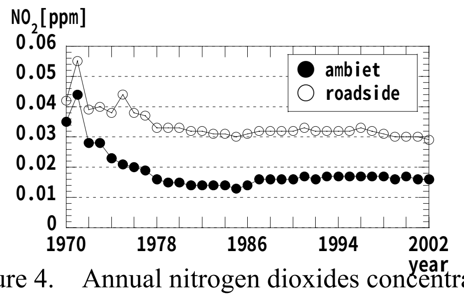


Figure 4. Annual nitrogen dioxides concentration

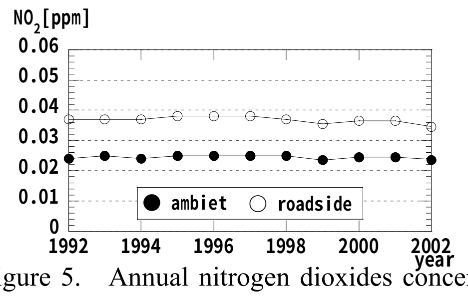


Figure 5. Annual nitrogen dioxides concentration in specified areas

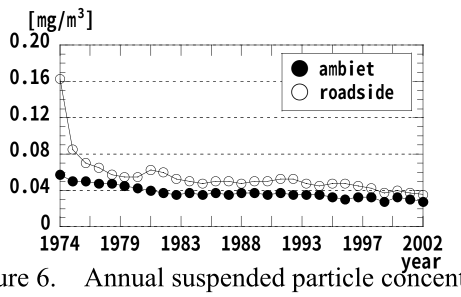


Figure 6. Annual suspended particle concentration

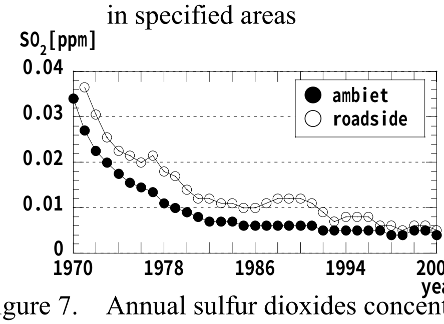


Figure 7. Annual sulfur dioxides concentration

3.6 Sulfur oxides

The environmental quality standards for sulfur dioxides indicate that the daily mean one-hour value and the maximum one-hour value must not be more than 0.04 ppm and 0.1 ppm, respectively. As shown in Fig. 7, the annual average value in 2002 was 0.004 ppm at ambient stations and 0.005 ppm at roadside stations, both being continuously at almost the same levels over the past several years. The attainment ratio of the environmental quality standards for sulfur dioxides has been 99.8% at ambient stations and 99.0% at roadside stations, showing satisfactory conditions in recent years.

3.7 Carbon monoxide

The environmental quality standards for carbon monoxide indicate that the daily mean one-hour values and 8-hour average one-hour value must not be more than 10 ppm and 20 ppm, respectively. Fig. 8 indicates that the annual average value in 2002 was 0.4 ppm at ambient stations and 0.7 ppm at roadside stations, showing a gradual decrease in recent years. These environmental quality standards have been attained at all monitoring stations.

3.8 Harmful air pollutants

Various types of chemical substances have been detected in the atmosphere although at low concentrations. There is deep concern that these substances may influence health conditions of inhabitants with long-term exposure to them. According to the monitoring of harmful air pollution substances in 2002, the concentration in the atmosphere for nickel compounds (25 $ngNi/m^3$) exceeded the guideline value at 2.9% of all monitoring points. The average concentration at all monitoring points showed a decreasing trend. For acrylonitrile, vinyl chloride monomer, and mercury and their compounds, the measured values were lower than the guideline values at all points.

4. Strategy for Environmental Conservation in Atmosphere

This is described, referring to the Environmental White Paper 2004 [1].

4.1 Measures against heat island

The governmental liaison council on countermeasures against heat island effect stipulated a general guideline in March 2004. This was based on four major policies: reduction of artificial heat discharge, improvement of ground cover conditions, improvement of structure mode in urban areas, and better modification of life style.

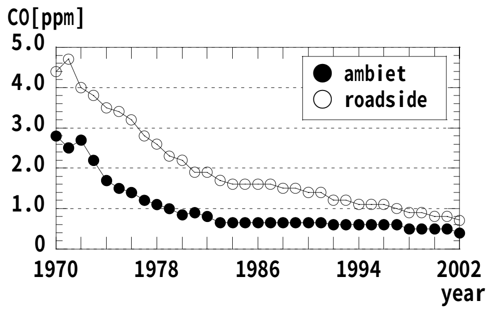


Figure 8. Annual carbon monoxide concentration

To reduce artificial heat discharge, it is effective to promote energy-saving, to take measures to improve traffic distribution and to utilize unused energy. Specific measures are as follows: production of high-efficiency energy-consuming equipment; construction of houses and buildings with high energy-saving effects; development of low-emission vehicles; taking of measures to improve traffic distribution and encouragement of the use of public transportation.

The improvement of ground surface conditions may effectively reduce evaporation of water from ground surfaces and prevent high temperatures on the ground surface. The final target is to achieve public open space in urban areas such as water and green areas from 12 m^2 per person in 2002 to 13 m^2/person in 2007, i.e. an increase of about 10%.

To improve the construction mode in urban areas, the ventilation path from green belts and water surfaces is thought to be very effective. While conserving green spaces in urban areas, it is necessary to establish a firm network of water and green areas, and to encourage the buildup of cities with lower environmental load.

To alleviate the heat island phenomenon closely associated with social and economic activities in urban areas, the life style must be modified. Specifically, it is aimed to bring down the discharge amount of carbon dioxide (440,000 tons - 850,000 tons) by the year 2010 by setting the level of air-conditioning temperature to 28°C in summer and the heating temperature to lower than 20°C in winter.

4.2 Measures against acid rain

Long-term monitoring of acid rain has been carried out to attain early detection of this kind of rainfall, to identify trans-boundary substances causing acid rain, and to predict the influence of acid rain on forests and lakes in the future.

4.3 Measures against yellow sands

In recent years, a large quantity of yellow sands has been coming to Japan from China and Mongolia. A common concern for China, Korea and Japan now is to take effective countermeasures against yellow sands. An investigation has been carried out in Japan to clearly identify the actual approach of yellow sands at 8 points all over the country. To establish a reliable monitoring system, a yellow sand observation system using rader was installed in Toyama Prefecture, and observation was initiated.

4.4 Measures against photochemical oxidants

(1) Emergency measures against photochemical oxidants

At 19 local weather stations all over the country, analysis and prediction have been performed to identify the weather conditions that are most likely to generate photochemical oxidants. Information is given to local public communities, and smog weather information is announced when necessary. Based on this information and on data obtained from atmospheric monitoring stations, local public communities issue photochemical oxidants warnings and reports in accordance with general principles of emergency measures against photochemical oxidants. At the same time, factories and other facilities emitting soot are requested to reduce their discharge amounts of air pollutants, and users are requested to voluntarily restrict unnecessary driving of automobiles.

(2) Measures for reducing discharge of hydrocarbons

Air pollution due to photochemical oxidants is expected to be improved by restricting the emission of nitrogen oxides and volatile organic compounds. To reduce hydrocarbons discharged from automobiles, restriction of exhaust gas has been enforced since 1973 in accordance with "the Air Pollution Control Law" issued in 1968. Subsequently, restrictions have been successively renewed.

4.5 Measures against stationary sources

(1) Measures against nitrogen oxides

In the Air Pollution Control Law, restrictions on emission of harmful substances are enforced for factories and facilities that generate nitrogen oxides, sulfur oxides, smoke and soot. In areas where factories are concentrated and it is considered difficult to maintain environmental quality standards for nitrogen dioxides in accordance with discharge restrictions on facility units, the total load control is enforced for factory units according to the total amount reduction program prepared by the Governor of each prefecture. At the end of the year 2001, there were about 215,000 facilities discharging soot and smoke. When classified by type, as shown in Fig. 9, boiler facilities comprised the highest in number, being 137,000 facilities (64%). Next was Diesel engine facilities, being 27,000 facilities (12%). The total annual discharge amount of nitrogen oxides from stationary sources in 1999 was 408,000,000 m^3/N (837,000 tons). Fig. 10 indicates the emission ratios from stationary facilities. For nitrogen oxides discharged from these stationary sources, measures taken are based on low NOx combustion techniques or flue gas denigration techniques. At the end of the year 2001, there were 1,478 flue gas denigration systems with processing ability of 376,000,000 m^3N/h.

(2) Measures against particles

Fig. 11 indicates the emission ratio of facilities for soot and dust. Airborne particles include substances generated from gaseous substances such as nitrogen oxides and volatile organic compounds, when these substances are subjected to photochemical reaction in the atmosphere. Based on the discharge conditions of causative substances and on air pollution prediction models accounting for the creation of secondary particles, evaluation is now being made on overall measures to attain environmental quality standards.

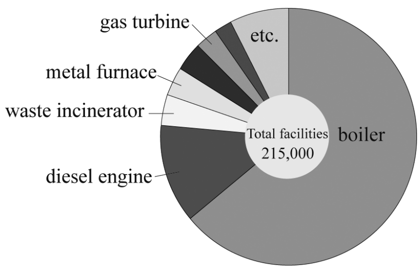


Figure 9. Facilities discharging soot and smoke

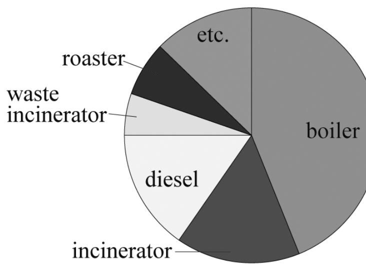


Figure 10. Emission ratio of nitrogen oxides from stationary facilities

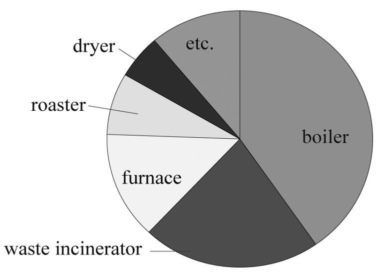


Figure 11. Emission ratio of soot and dust from stationary facilities

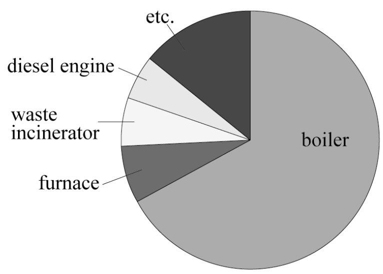


Figure 12. Emission ratio of sulfur oxides from stationary facilities

(3) Measures against sulfur oxides
In addition to discharge restrictions for facility units based on K-Value Regulation in accordance with the Air Pollution Control Law, total pollutant control loads are enforced in 24 specified areas. Fig. 12 indicates the emission ratio of facilities. Annual total discharge amount of sulfur oxides from stationary sources was 220,000,000 m^3N (629,000 tons) in 1999. Measures such as desulfurization of fuel oil or installation of flue gas desulfurization systems have been taken to restrict sulfur oxides discharged from these stationary sources. At the end of the year 2001, the total number of installed flue gas desulfurization systems was 1,908, and the total processing ability was 221,000,000 m^3N/h.

4.6 Measures against mobile emission sources

(1) Measures against automobile exhaust gas
In large cities, extensive increases of driving distances caused by increasing use of automobiles resulting in air pollution by nitrogen dioxides and airborne particles from automobile exhaust gas are still very serious problems. Vehicle unit regulation and measures on automobile fuel are being taken.
(2) Promotion to propagate low emission vehicles
In accordance with "Action Plan to Develop and Propagate Low Emission Vehicles" prepared in July 2001, electric vehicles, natural gas vehicles, methanol vehicles, hybrid electric vehicles, fuel cell vehicles and vehicles with high fuel efficiency and low exhaust gas emission are defined as low emission vehicles in the development stage. It is aimed now to propagate more than 10,000,000 such vehicles as early as 2022. About 5,750,00 low emission vehicles were actually in practical use all over Japan at the end of September 2003.
(3) Measures for traffic distribution
Measures are taken on dispersion and smoothing of traffic distribution and on restriction and reduction of traffic amount.

4.7 Measures against harmful air pollutants

Benzene, trichloroethylene and tetrachloroethylene are designated substances in accordance with the Air Pollution Control Law. Facilities that discharge these substances are specified. At the same time, restriction standards for them are set to reduce their discharge.

5. Indoor Air Environment

5.1 Present status of indoor air environment in residential buildings

For energy conservation and protection against global warming, thermal requirements of newly constructed residential buildings in Japan have become very high. In these houses, the building envelope is airtight, so the air infiltration rate is very low. However, many kinds of building materials, furniture and utensils that include chemical compounds are used in present houses. Therefore, indoor air is easily polluted with such volatile organic compounds. Houses where occupants are suspected of sick building syndrome are called "sick houses" in Japan.

A national survey on indoor air quality was carried out by the Japanese government in 2000 [2]. More than 5000 dwellings were selected nationwide. The concentrations of the chemical compounds formaldehyde, toluene, xylene and ethylbenzene were measured for 24 hours. Fig. 13 shows that formaldehyde concentration in over 27.8 % houses exceeded the guideline of 0.08 ppm. Fig. 14 shows the relationship between formaldehyde concentration and building age, indicating that formaldehyde concentration does not decrease much with increasing building age.

5.2 Air quality standards for indoor air pollutants

Due to sick building syndrome in houses caused by chemical compounds, the building standard law was partially revised in July 2002. Following this revision, in July 2003, a building construction technical code for preventing sick buildings was issued. Table 2 shows the guideline concentration of indoor air pollutants regulated by the Ministry of Health, Labor and Welfare. In this guideline, 13 pollutants are specified and as for TVOC, interim concentration levels are designated.

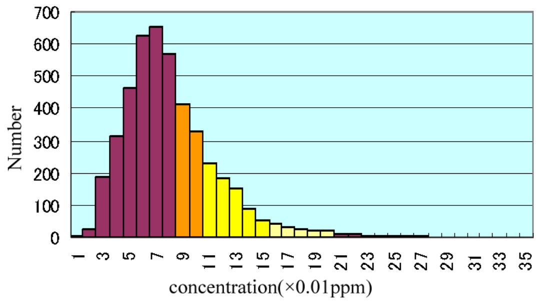


Figure 13. Distribution of formaldehyde concentration in Japanese houses

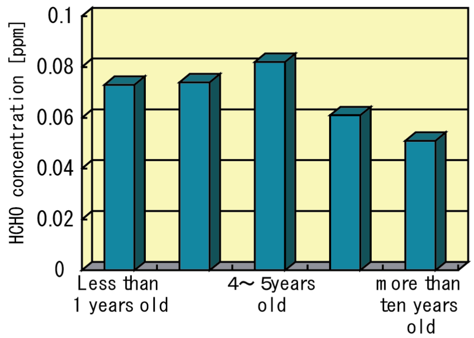


Figure 14. Relationship between formaldehyde concentration and building age

5.3 Design criteria for acceptable concentration of CO_2

For a general indoor environment, CO_2 has been used for a long time as an index of indoor air quality. The law for Building Sanitation Management Standard by The Ministry of Health and Welfare states that the CO_2 concentration should be under 1000 ppm. This is not based on the health effect of CO_2 alone but on the environmental experience that other pollutant concentration is proportional to CO_2 concentration. As a result, it was decided that the design criteria for an acceptable concentration of CO_2 should be 1000 ppm as a general indoor quality index. However, in Canada the acceptable concentration of CO_2 is 3500 ppm for residential buildings. Thus, the value of 3500 ppm is adapted provisionally for the design criteria for an acceptable CO_2 concentration.

Table 2. Guideline concentrations of indoor air pollutants regulated by Ministry of Health, Labor and Welfare of Japan

Pollutants	Guideline concentration of indoor air
Formaldehyde	100μg/m^3 (0.08 ppm)
Acetaldehyde	48μg/m^3 (0.03 ppm)
Toluene	260μg/m^3 (0.07 ppm)
Xylene	870μg/m^3 (0.20 ppm)
Ethylbenzene	3800μg/m^3 (0.88 ppm)
Stylene	220μg/m^3 (0.05 ppm)
Paradichlorobenzene	240μg/m^3 (0.04 ppm)
Dibutyl Phthalate	220μg/m^3 (0.02 ppm)
Tetradecane	330μg/m^3 (0.04 ppm)
DEHP	120μg/m^3 (7.6 ppb)
Diazinon	0.29μg/m^3 (0.02 ppb)
BPMC	33μg/m^3 (3.8 ppb)
Chlorpyrifos	1μg/m^3 (0.07 ppb)

6. Wind Environment at Pedestrian Level Around High-rise Buildings

6.1 Present situations of wind environment at pedestrian level

Strong wind around high-rise buildings has been a social issue for over 30 years in Japan. Conflicts between constructors and residents are not unusual, and occasionally develop into lawsuits. Although Japanese law does not regulate the assessment of the pedestrian wind environment, some local governments oblige developers to make preliminary investigations, estimates, and assessments regarding the environmental impact of their development projects. For example in Tokyo, developers who plan to build a high-rise building over 100 meters high and a total floor area of over 100,000 square meters must carry out procedures according to the "Environmental Impact Assessment Ordinance of the Tokyo Metropolitan Government". The investigation of wind environment is required not only for such mandatory cases but also for cases when residents demand that. Thus, wind tunnel experiments or CFD simulations are often carried out in Japan.

6.2 Assessment of pedestrian wind environment by wind tunnel experiments

For wind tunnel experiments for these assessments, multi-channel thermister anemometers are widely used in Japan to measure wind velocities. Because the anemometers are relatively strong and hard to break, they can be set from under the turntable as shown in Fig. 15. Once the anemometers are set at the measuring points, the wind velocities at all points can be measured at the same time. Therefore, it does not take much time to measure the wind velocities for many wind directions and for several experimental cases. However, the frequency response of the anemometer is low (lower than 1Hz). The gust wind speed can not be evaluated with this type of the anemometer. This is one of the problems in estimating the occurrence frequency of maximum gust speed as described later.

6.3 Assessment of pedestrian wind environment by CFD simulations

The application of CFD to the prediction of the wind environment has been rapidly increasing. Despite its widespread use, the accuracy of the prediction and many factors that affect the simulation results are not yet thoroughly understood. In order to clarify such ambiguities and make a practical guideline for the CFD prediction of the wind environment, a working group was organized by the Architectural Institute of Japan (AIJ). This group consists of researchers from several universities and private companies. The working group has conducted various comparative studies as follows.

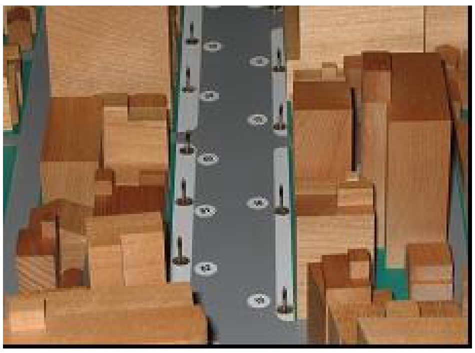


Figure 15. Multi-channel thermister anemometers installed in building models

・Flow field around a high-rise building without neighboring buildings, as shown in Fig. 16
・Flow field around a high-rise building within a model city block, as shown in Fig. 17
・Flow field around high-rise buildings in actual urban areas, as shown in Fig. 18

The results of the CFD were compared with those of wind tunnel experiments, and many factors such as computational domain, grid, boundary conditions, numerical scheme for advection terms, and turbulence models were examined to clarify their influence on the simulation results [3], [4]. The practical guideline for CFD prediction based on these investigations will be published by the AIJ next year. The English version will also be available on the AIJ website.

6.4 Criteria for assessment of wind environment at pedestrian level

The occurrence frequencies of wind velocities at pedestrian level can be calculated using the statistical wind data of the nearby meteorological observatory and the results of the wind tunnel experiment or CFD simulation. One of the most widely used methods for assessing the wind environment is based on the occurrence frequency of daily maximum gust speed proposed by Murakami, Iwasa and Morikawa as shown in Table 3 [5].

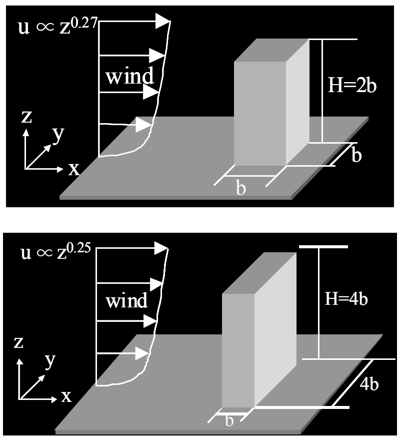


Figure16. Isolated high-rise building without neighboring buildings

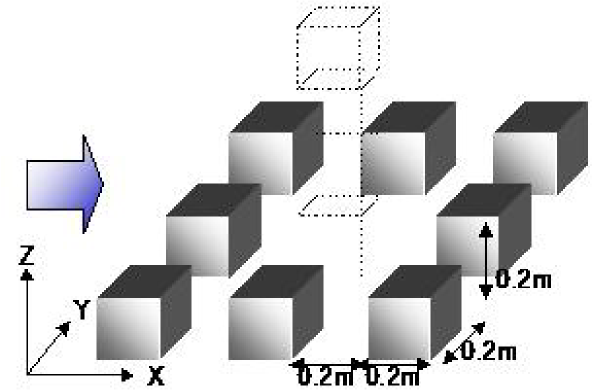


Figure 17. Isolated high-rise building within a model city block

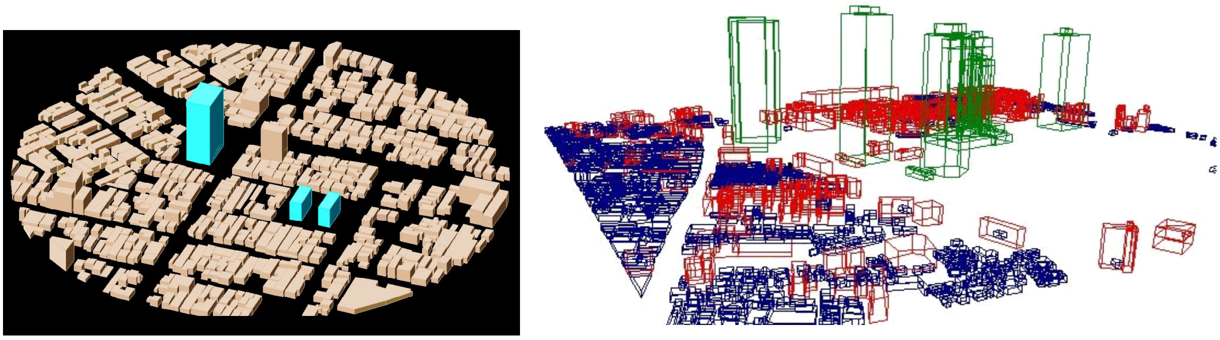


Figure 18. Computer graphics of high-rise buildings in actual urban areas

The other assessment method based on the cumulative frequency of mean wind velocities (averaging time is 10 minutes) proposed by the Wind Engineering Institute as shown in Table 4 is also widely used in Japan [6]. Murakami et al. conducted long term observations of wind speed and wind-induced problems in cooperation with many inhabitants in downtown Tokyo. The criteria were determined considering the relationships between the daily maximum gust speeds and impressions of wind environment or wind-induced problems.

As mentioned above, because multi-channel thermister anemometers with poor frequency response are used in the wind tunnel experiments, gust wind velocities can not be obtained from the experiments. Furthermore, most of the CFD simulations for the assessments are based on the Reynolds averaged turbulence models, so the obtained results are mean wind velocities not gust wind velocities. Therefore, when using Murakami's criteria, gust factor (the ratio of peak gust wind velocity and mean wind velocity) have to be assumed. However the occurrence frequency of daily maximum gust speed strongly depends on the assumed gust factor. Nishimura and Takamori [7] and Hongo and Nakayama [8] proposed gust factor estimation methods, but we have not yet reached a general consensus about the determination of the gust factor.

Table 3. Criteria for assessment of pedestrian wind environment based on occurrence frequency of daily maximum gust speed [5]

Class	Effect of strong wind	Areas applicable (example)	Level of assessment of strong wind and acceptable exceedance frequency (at height of 1.5m)		
			Daily maximum gust speed(m/s)		
			10	15	20
			Daily maximum mean speed(m/s)		
			10/G.F	15/G.F	20/G.F
1	Areas used for purposes most susceptible to wind effects	Shopping street in residential area, Outdoor restaurant	10% (37 days per year)	0.9% (3 days per year)	0.08% (0.3 days per year)
2	Areas used for purposes not too susceptible to wind effects	residential area, park	22 (80 days per year)	3.6 (13 days per year)	0.6 (2 days per year)
3	Areas used for purposes least susceptible to wind effects	office street	35 (128 days per year)	7 (26 days per year)	1.5 (5 days per year)

Table 4. Criteria for assessment of pedestrian wind environment based on cumulative frequency of mean wind velocity [6]

	Mean wind velocity at cumurative frequency of 55%	Mean wind velocity at cumurative frequency of 95%	Notes
Region A	≦1.2m/s	≦2.9m/s	Wind environment for residential area
Region B	≦1.8m/s	≦4.3m/s	Wind environment for residential area and urban area
Region C	≦2.3m/s	≦5.6m/s	Wind environment for office area
Region D	＞2.3m/s	＞5.6m/s	Wind environment around super high-rise building

7. Conclusion

Based on the Environmental White Paper 2004 and recent research results, the present status of wind environmental issues in Japan were demonstrated.

1. The attainment ratio of the environmental quality standards at roadside monitoring stations was 83.5% for nitrogen dioxides and 34.3% for particles. These figures indicate that air pollution caused by automobile exhaust gas is still a very serious problem.
2. Because of the increase in heat discharge emitted by human activities and in the area of artificial ground cover in urban areas, a heat island is occurring in most large cities, where the environmental air quality greatly worsens particularly in the hot summer season. This further enhances air pollution caused by photochemical oxidants in summer and nitrogen oxides (NOx) in winter.
3. A national survey on indoor air quality was carried out by Japanese government. More than 5000 dwellings were selected nationwide. This revealed that formaldehyde concentration was more than 0.08 ppm in 27.8 % houses and was not proportional to building age.
4. For assessment of pedestrian wind environment, wind tunnel experiments or CFD simulations are often carried out. In particular, the CFD method has been rapidly increasing. The Architectural Institute of Japan is scheduled to make a practical guideline for CFD prediction of the wind environment in 2005.

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