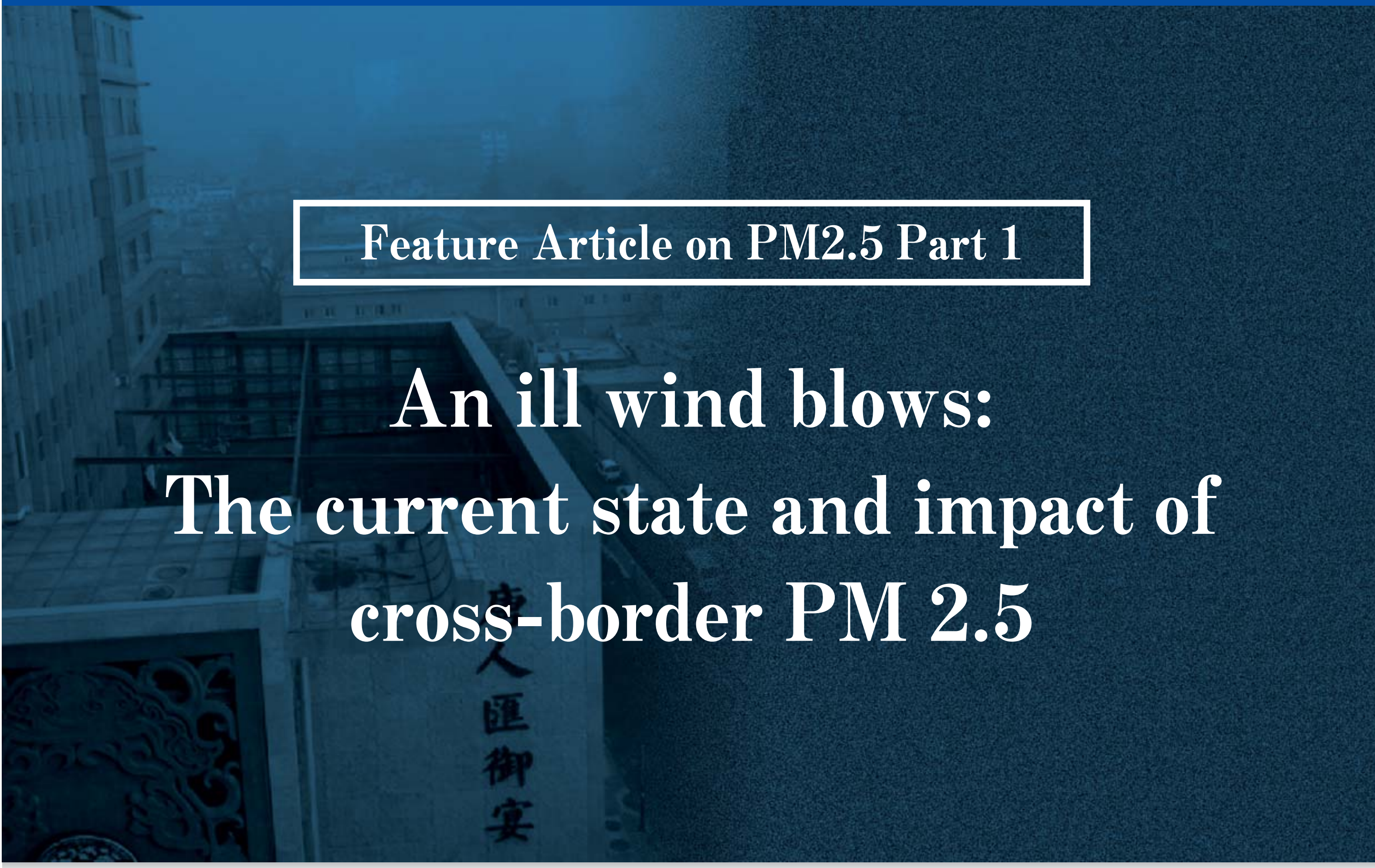


Feature Article on PM2.5 Part 1

An ill wind blows: The current state and impact of cross-border PM 2.5

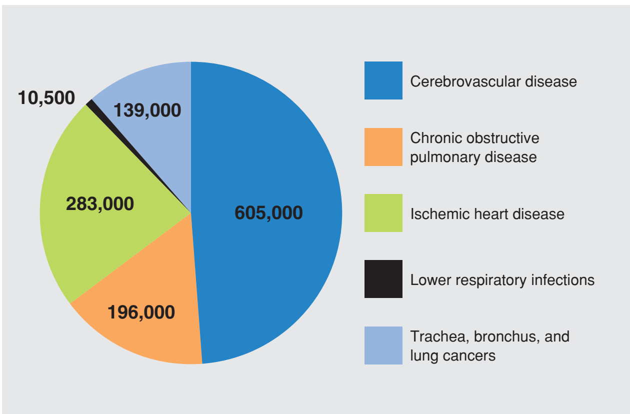
PM2.5 pollution causes to more than 1.2 million premature deaths in China

On the 31st of March, 2013, an astonishing analysis was released at the Air Pollution and Public Health Workshop in Beijing, China. The analysis says that, in 2010, there were 1.2 million premature deaths in China. Outdoor air pollution was suspected as a possible factor. This made up about 15% of the total deaths in China in the same year. The breakdown highlighted that the leading cause of death was cerebrovascular disease (600,000 persons), followed by ischemic heart diseases (280,000), chronic obstructive pulmonary (200,000), trachea, bronchus and lung cancers (140,000) and lower respiratory infections (10,000) (Fig. 1). The study was based on the 'Global Burden of Diseases Study 2010 (GBD 2010)' and was given coverage in the papers in China and Japan as a study which indicated how serious the health risk posed by PM2.5 pollution was becoming.

What is PM2.5?

Airborne particulates are known as PM (Particulate Matter). In the field of studies in air pollution, fine particles with a diameter of 10 μm or less are called Suspended Particulate Matter (SPM). SPM can be divided into 'coarse' particles with a diameter of 2.5-10 μm and 'fine' particulate matter with a diameter of less than 2.5 μm, the latter being known as PM2.5. Particulate matter includes sulphur oxides (SOx), nitrogen oxides (NOx) and volatile organic compounds (VOC) which are emitted during combustion, and secondary products generated from reactions in the atmosphere caused by gaseous air pollutants. Particulate matter such as PM2.5 is characterized by a high proportion of materials generated through chemical reactions. Among many suspended substances (aerosols) in the air, PM2.5 or nanoparticles raise particular concern for their adverse effects on health because of the extremely high possibility of their accumulating in the body.

Fig. 1: A breakdown of the causes of premature death thought to be caused by air pollution in China in 2010



Source: Health Effects Institute

. Outdoor air pollution was suspected as

Reasons for the mass generation of PM2.5

On the one hand, since the Air Pollution Control Law was put into force in Japan, the annual average concentration of PM2.5 has been decreasing (Fig. 2)[*1]. But on the other hand, air pollution in China has been worsening over the last dozen years or so. The US Embassy in China has made observation data on PM2.5 public on Twitter, which has led to the seriousness of the air pollution problem in China becoming known to the world. According to the website, the concentrations of PM2.5 in the air in China reached 516 $\mu g/m^3$ on the 27th of February and 510 $\mu g/m^3$ on the 7th of March in 2013. The United States Environmental Protection Agency (US EPA) has developed the Air Quality Index (AQI, $\mu g/m^3$) which indicates levels of health concern as follows: 151-200 = 'Unhealthy', 201-300 = 'Very Unhealthy' and 301-501= 'Hazardous'. A risk assessment has not even been given for an AQI over 500.

Emissions from power plants, factories, coal heating systems and cars are thought to be the main causes of the increase of PM2.5 in China. The Chinese government set an aim to reduce SOx emissions by 10% as a binding target of 'The National 11th Five-year Plan for Environmental Protection' (2006-2010) and has been tackling the air pollution problem. This has resulted in a reduction in SOx emissions by 14.29% in 2010 compared to 2005.

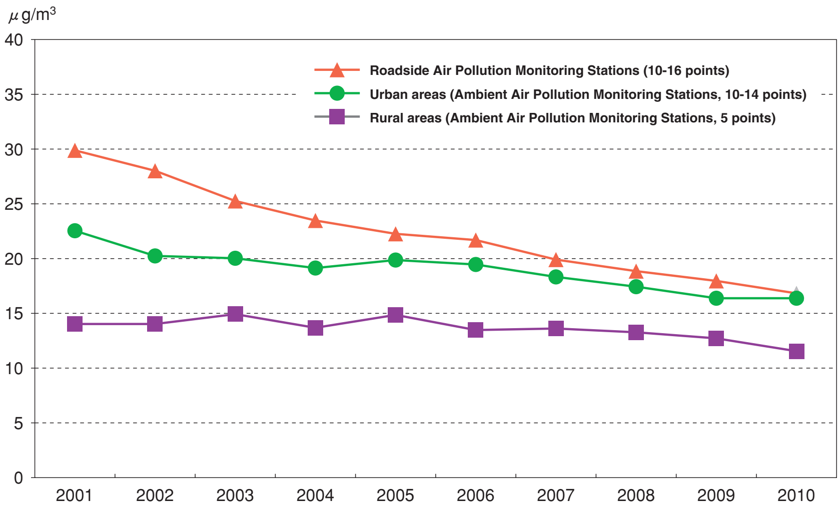
'Although some say that SOx emissions from coal power plants are the dominant cause of air pollution, this view is not correct. Actually, since installation of desulfurization equipment in newly built factories and power plants has been promoted, SOx emissions have been decreasing. However, NOx emissions from coal power plants and factories have been increasing (Fig. 3 and Fig. 4). In addition, emissions from private cars have also increased. Thus, it could be said that the increase in the total volume of pollutants is responsible for the degradation of the atmospheric environment,' Hajime Akimoto, Director General of the Asia Center for Air Pollution Research (ACAP) postulated.

In Beijing, a new vehicle emission standard which is equivalent to 'Euro 5' in EU vehicle emission standards, has been in force since February 2013. This is forecast to reduce NOx car emissions by a further 40%. In Jiangsu province, the Pearl River Delta region (Guangdong province) and in Shanghai, the 'Grade IV' standard, one rank below, was enacted to keep sulphur content down to 50ppm or less. 'Grade III', which allows sulphur content to be up to 150ppm has been adopted in other areas. Those standards, however, apply only to new vehicles and not used vehicles. As a result, about 75% of privately owned cars in China do not meet the standard, 'Grade III' (Fig. 5. According to the China Annual Report on the Prevention and Control of Vehicle Pollution (2010), 50% of the total volume of air pollutants is discharged by cars which comply with the 'Grade I' national vehicle emission standard, and pollutants from vehicles conforming to 'Grade III' or higher account for less than 5% of total emissions. This shows that exhaust gases from outdated vehicles meeting the old standard only are a substantial cause of air pollution in China.

In addition to vehicle emissions, particles emitted from coal heating systems are thought to be another factor in air pollution. Coal-burning heating systems are still widely used in many regions in China today and a lot of fine particles including particulate matter are dispersed in the winter. The result of a joint research project undertaken by the National Institute for Environmental Studies and China Medical University on air pollution and its health effects in Shenyang, Fushun and Tieling showed that the concentration of pollutants in the air increased in winter, and lung function of children deteriorated as a consequence[*2].

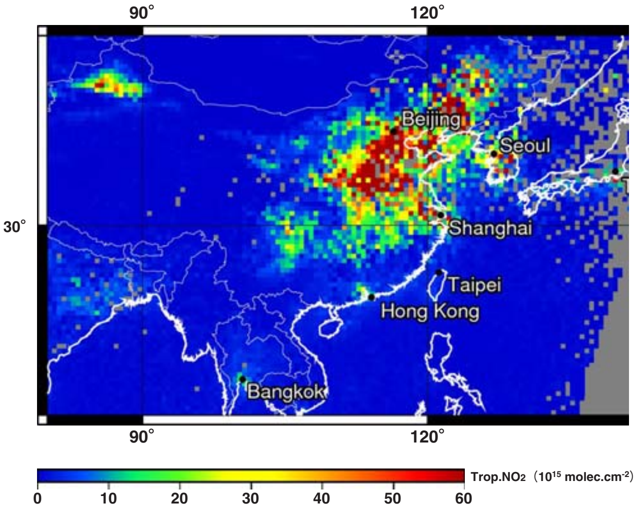
Furthermore, the lack of desulfurization and denitrification

Fig. 2: The change in mass concentrations of PM2.5



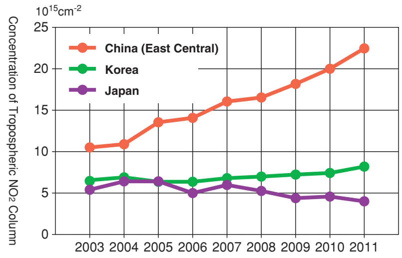
Source: Observational study of the influence of exposure to fine particulate matter conducted by Japan's Ministry of the Environment, 2010

Fig. 3: The map shows the high concentration of NOx in urban areas of China



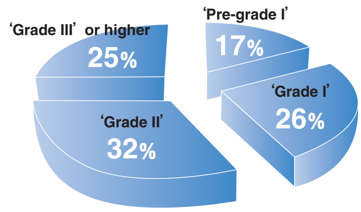
Source: Center for Environmental Remote Sensing at Chiba University

Fig. 4: The concentration of NO2 has been increasing over the past decade in Central East China



Source: Center for Environmental Remote Sensing at Chiba University

Fig. 5: The composition of in-service cars by vehicle emission standards grade



Source: The China Annual Report on the Prevention and Control of Vehicle Pollution (2010)

equipment in outdated power plants, the quality of gasoline, smoke from factories and dust from construction sites are also thought to be the causes of air contamination.

The Chinese government set a binding target to reduce SOx emissions by 8% and NOx emissions by 10% below 2000 levels in 'the National 12th Five-year Plan for Environmental Protection (2011~2015) and has been taking measures to deal with the air pollution problem. However, as far as can be seen from the observed data on PM2.5 released by the US Embassy in China, those measures have not yet achieved significant results.

The current state of cross-border pollution

In 2012 and 2013, PM2.5 concentrations of 70 μ g/m^3 in Kumamoto prefecture and 50 μ g/m^3 in Fukuoka and Yamaguchi prefectures were obserbed, with both levels exceeding Japan's environmental quality standard of 35 μ g/m^3. Cross-border pollution from China was suspected as a source of the increase in PM2.5 concentration.

Dr. Hitoshi Irie, an associate professor at the Center for Environmental Remote Sensing at Chiba University, explained the situation like this: 'Satellite observation data confirms that aerosols originating from the Eurasian mainland are carried to Japan by air currents (Fig. 6). However, it is impossible to identify the nature of those aerosols only by satellite observations, so it is difficult to determine whether they are 'yellow sand' (originating naturally from desert regions) or PM2.5.'

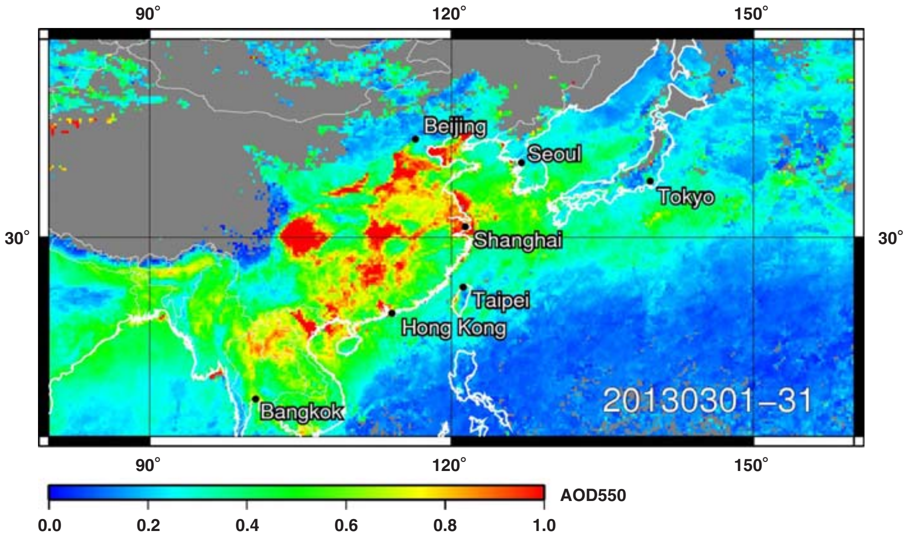
In addition, as there are no geosynchronous satellites to observe fixed points over the skies of Asia, twenty-four-hour monitoring is not possible. Therefore, it is not possible to prove objectively only by satellite observation data whether the increase in PM2.5 is because of particulates generated in Japan or due to cross-border pollution.

However, some research reports founded on ground-based fixed observation claim that the probability of cross-border pollution coming from China is extremely high. The Japan Agency for Marine-Earth Science and Technology (JAMSTEC) analyzed data from year-round measurements of the concentration of particulate matters in the air on Fukue Island in Nagasaki prefecture. The study revealed that Fukue Island was ordinarily less likely to be artificially contaminated, but most of the days when high concentrations of aerial particulate matters were registered did not correspond to days when 'yellow sand' was observed, and a high black carbon concentration was also recorded with PM2.5. These results suggest an influence of cross-border pollution from the mainland on the increase in PM2.5 in Japan.

The health risks of PM2.5

Dr. Douglas Dockery, a professor at Harvard University, conducted an epidemiological survey with his colleagues in 1993 which indicated a significant correlation between the concentration of PM2.5 and mortality rates*3. PM2.5 particles are very fine and have a high probability of reaching and accumulating in the alveoli of the lung. In the alveoli, PM2.5 particles are digested by macrophages (a kind of white blood cell which eats foreign substances in the body) or go through into blood vessels and are carried throughout the body in the blood, which can have various impacts on health. The following health risks are thought to exist, while many of them remain

Fig. 6: Satellite observation data show the route of aerosols carried by the air current across the sea



Source: Center for Environmental Remote Sensing at Chiba University

unexplained.

Effects on the respiratory system

PM2.5 might trigger an inflammatory response in the air passage and the lungs, which can induce bronchitis and pneumonia. Additionally, allergic reactions in the air passage are triggered and the symptoms of asthma, allergic rhinitis and other allergic reactions are aggravated. Therefore, there will be an increased risk of respiratory infection.

Effects on the circulatory system and the immune system

There is a risk that particulate matter that passes through lung tissue could cause direct damage to blood vessels and the circulatory system. In addition, as for indirect effects, there is also a danger that lesions of angiostenosis such as a myocardial infarction or a cerebral brain infarction could be caused as PM2.5 passing through to lung tissues might stimulate blood platelets and the blood coagulation system or induce thrombosis. Furthermore, active oxygen or cytokines generated by biological reactions such as inflammations could exert an influence on the circulatory system, stimulate the sensory nerves in the respiratory system, causing an irregularity in the autonomous nervous system, in turn bringing about an irregular pulse or inducing changes in cardiac function. With respect to the effect on the immune system, allergic symptoms could become worse and the immune capability of macrophages could be impaired, reducing resistance to infection.

Effect on cancer risk

It is said that PM2.5 could cause to cancer incidence since DNA could be damaged by macrophages while they attack PM2.5 accumulated in lung tissues. However, there is insufficient supporting evidence to prove a causal link between the accumulation of PM2.5 and cancer incidence.

Mr. Takahiro Kobayashi, the Program Officer of the Environmental Research and Technology Development Fund at the Association of International Research Initiatives for Environmental Studies, said ‘although the number of reports on the health risks of PM2.5 has increased in recent years, the mechanism and chemical nature of the causal relationship between PM2.5 and health damage still remains to be definitively elucidated. The chemical composition of PM2.5 differs from area to area and source to source. Aside from this, even if the primary product could be identified as having been generated from a particular source, it is impossible to determine the nature of the secondary products which would be created as a result of chemical reactions with other matters in the air, since these can differ from area to area as well as with differing meteorological conditions. Therefore, in order to mitigate the health risks of PM2.5, it is essential to carry out detailed field studies on the chemical nature and mechanism of PM2.5 from area to area, to undertake impact assessments of PM2.5 on health and to conduct long-term epidemiological studies so that the causes of health damage from PM2.5 can be revealed.’

How to protect against the invisible threat

According to the results of an acute exposure test to PM2.5 conducted on healthy adults, changes in the blood biochemical index were observed when the test subjects were exposed to PM2.5 at a concentration of 72.2 μ g/m^3 over two hours. In contrast, some research suggests that, in some cases, no change in blood pressure and heartbeat was observed even after being exposed for two hours at an average concentration of 190 μ g/m^3. No consistent relationship between exposure concentration and health damages has been found. However, when exposure tests were conducted on children who had respiratory or circulatory conditions, or adults whose immune system was weakened, some health damages were seen in the results even though they were exposed to PM2.5 at an average daily concentration of 69 μ g/m^3. That is to say, PM2.5 has a low impact on healthy people, but there is a necessity for those with a high susceptibility to avoid going out and to use masks as well as take other measures to protect themselves against PM2.5. Also, since PM2.5 is very small particulates, normal hay fever masks are not effective. In order to protect oneself against PM2.5, masks that have passed PFE (particle filtration efficiency) testing and are certificated by 'N95' in American standard or 'DS2' in Japanese standard should be used.

The data of the concentration of PM2.5 in all areas in Japan are released on websites of every prefecture or on the web page of the Atmospheric Environmental Regional Observation System, which is operated by the Ministry of the Environment (http://soramame.taiki.go.jp/). Also, the Ministry of the Environment aims to attract people's attention by defining, based on knowledge thus far gained, a 70 μ g/m^3 average for a day and 85 μ g/m^3 for an hour as 'tentative guideline values' for exposure at which we are more likely to suffer from health damages from PM2.5.

International cooperation essential to tackling cross-border pollution

In March 2013, Li Keqiang, Premier of China, gave a media briefing and said as follows: 'in the recent period not just Beijing but in extensive part of eastern China, there's been hazy weather. [⋯]. First we shouldn't incur any new problems and we need to raise our environmental threshold. Second we need to speed up efforts to overcome long standing problems which include phasing out backward production facilities. We need to face the situation and punish offenders with no mercy and enforce the law with an iron fist (Thomson Reuter Foundation)' and he announced that the government is going to spend 328.6 CNY billion (about 5 trillion JPY) on measures to counter environmental degradation, an increase of 12% over the previous year.

Cross-border pollution is an environmental problem which is not solvable just by those countries directly affected. On the 5th and the 6th of May 2013, at the 15th Tripartite Environment Ministers Meeting among Japan, Korea and China, the attendants issued a joint statement about measures to tackle cross-border pollution including PM2.5. In addition, the Government of Japan on the 6th of April announced an initiative aiming to strengthen technical cooperation in East Asia on policy measures against air pollution such as PM2.5. Also, the provision of observation equipment and dispatch of engineers and researchers to mainland China and surrounding countries has been put forward. In order to implement the plan, 13 countries including Russia, Korea, China and Mongolia have formulated a policy to utilize the strength of a network called Acid Deposition Monitoring Network in East Asia (EANET) in which Japan has played a leading role.

Hajime Akimoto, Director General of ACAP said, 'EANET launched its activities in 2001 and has been monitoring and assessing acid rain recorded on observation equipment in various areas of East Asia for more than 10 years. Since PM2.5 is one kind of causative substance of acid rain, it makes sense to observe, monitor and assess PM 2.5 by expanding the scope of our observational activities. However, intergovernmental agreements are extremely important in order to ensure the effectiveness of our activities.'

Cross-border pollution cannot be resolved by only providing technology – intergovernmental cooperation is essential. However, in the midst of the dispute over the Senkaku/Diaoyu Islands threatening a good relationship between Japan and China, how in-depth a discussion can be held remains unknown. Based on the experiences of pollution issues in the past such as the Yokkaichi asthma or Kawasaki pollution lawsuits, Japan has become rich in accumulated know-how, technology and human resources. Maximizing those resources would enable an early resolution of the air pollution problem. Many experts point out that restoring the relationship between Japan and China is indispensable for the realization of an early resolution.

This volume of SAFE is focused on featuring the current state of PM2.5, cross-border pollution and health risks posed by PM2.5. In the next volume, the roles of technology, regulations and international cooperation in resolving air pollution will be considered in greater depth.

*1: Observational study of the influence of exposure to fine particulate matter conducted by the Ministry of the Environment, Government of Japan

*2: The National Institute for Environmental Studies. Urban Air Pollution in China and Its Health Effects.
http://www.nies.go.jp/kanko/kankyogi/21/02-03.html

*3: Dockery, Douglas and Pope, Arden. Epidemiology of Chronic Health Effects: Cross-Sectional Studies.

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