Title	Scientific approach to elucidating the atmospheric environment and its health effects : Making the most of the latest methods and new perspectives to get to the bottom of PM2.5
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Author	田井中, 麻都佳(Tainaka, Madoka)
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Associate Professor Tomoaki Okuda is featured in this issue, whose field of research focuses on collection technology for and physico-chemical properties of airborne particulate matter.

Scientific approach to elucidating the atmospheric environment and its health effects

Making the most of the latest methods and new perspectives to get to the bottom of $PM_{2.5}$

$PM_{2.5}$, a particulate matter 2.5μm or less in diameter, is an issue of growing concern of late due to its potential threat to health. Associate Professor Tomoaki Okuda of the Department of Applied Chemistry strives to establish a collection technology for $PM_{2.5}$ and larger particles while also shedding light on their physico-chemical properties such as surface area concentrations and electrostatic characteristics. Instead of being stuck in preconceived ideas, he boldly employs the latest methods to investigate into unknown properties of substances and elucidate what the atmospheric environment really is – endeavors for the promotion of people's health.

Collecting $PM_{2.5}$ by means of cyclone system

$PM_{2.5}$ concentration in the atmosphere over China showed a sudden rise in 2013, the negative impact of which was feared to cause a serious social concern in Japan. While the problem of air pollution itself dates back as early as the 19th century, it was much later – in the 1970s onward – that particulate matter 2.5μm or less in diameter came to the fore as a likely culprit of serious threat to health.

Smaller particles mean that pollutants not only enter the nasal cavity and trachea but can also reach as deep as alveolus in the lung, thus causing respiratory and/or cardiovascular diseases, which is said to be the real problem. To address this problem, the United States established its environmental standards in 1997 and Japan in 2009.

The ensuing years have seen a number of countries move forward with research efforts on $PM_{2.5}$ and take countermeasures. As a research scientist, Dr. Okuda is engaged in studies of $PM_{2.5}$ collection technology and its physico-chemical properties.

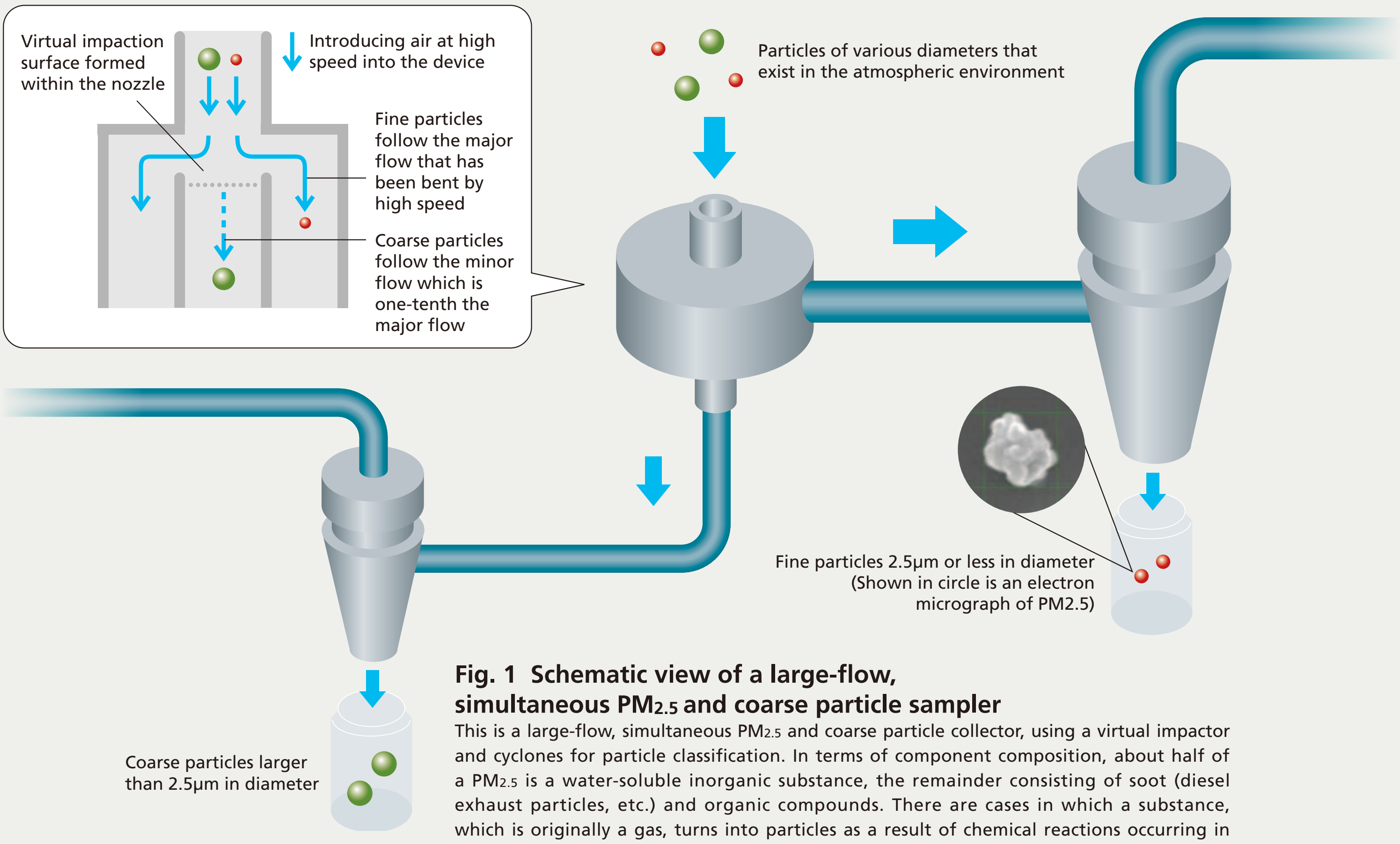

Fig. 1 Schematic view of a large-flow, simultaneous $PM_{2.5}$ and coarse particle sampler

This is a large-flow, simultaneous $PM_{2.5}$ and coarse particle collector, using a virtual impactor and cyclones for particle classification. In terms of component composition, about half of a $PM_{2.5}$ is a water-soluble inorganic substance, the remainder consisting of soot (diesel exhaust particles, etc.) and organic compounds. There are cases in which a substance, which is originally a gas, turns into particles as a result of chemical reactions occurring in the atmosphere. These cases are viewed as problematic because conventional regulations are often unable to deal with them. Meanwhile, pollen and dust are classified into coarse particles. For example, there is a possibility that yellow sand particles, which have adsorbed pollutants, fly over to Japan. We can expect to apply the technique of collecting $PM_{2.5}$ and coarse particles – simultaneously and in large quantities – to cell exposure experiments and various other fields of research.

"Why did I begin with the collection technology? Because I thought it would be impossible to elucidate the true impact of $PM_{2.5}$ on the human body unless we conducted experiments on substances actually collected from the atmosphere. This is why I began my research by collecting a lot of particulate matter in the air."

In the past, filtering systems were the main technology used to collect $PM_{2.5}$ in the atmosphere. What Dr. Okuda adopted was a cyclone system based on centrifugal force. To tell the truth, until recently the cyclone system has been regarded as inappropriate for collecting ultrafine particulate matter.

"As it is used, a filter gets clogged. Moreover, some substances stuck to the filter cannot be taken out. So I dared to choose a cyclone system instead. In the past, cyclones were used mostly for collecting large-diameter particles; in fact, there were very few papers that mentioned the use of a cyclone for collecting $PM_{2.5}$. Once I tried the cyclone system, however, I could collect most of $PM_{2.5}$. Even today, most cyclone specialists won't believe this very fact," Dr. Okuda added laughingly.

In the first place, airborne particulate matter is something that contains, along with $PM_{2.5}$, large particles slightly less than 10μm in diameter, such as pollen that adversely affects the nose and throat. So Dr. Okuda exhibited ingenuity to modify the air passage designed to draw in the air at a rate of 1,200 liters per minute. What he did was the creation of what is known as a "virtual impactor" designed to create separate airflow channels with different airflow speeds, which in turn allows two cyclones installed downstream to sort and collect large and small particles simultaneously.

"This development enjoyed unexpectedly great response from interested users so much so that devices modelled after my creation are being installed here and there," he proudly remarked.

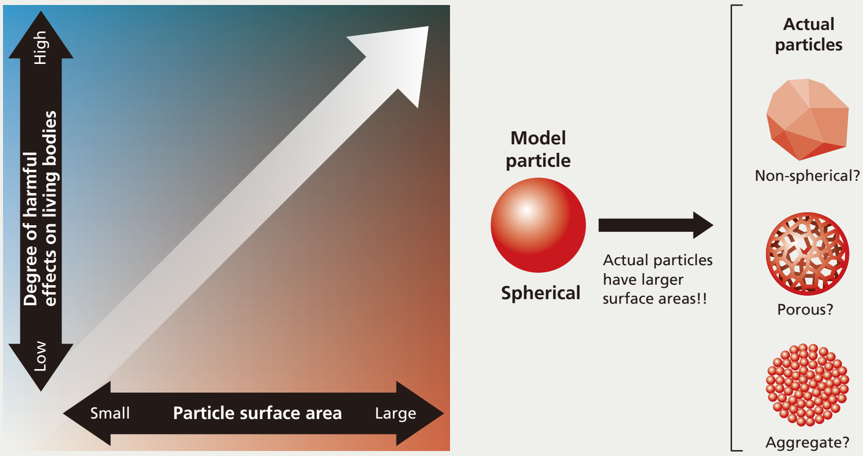

Fig. 2 How the surface area of particulate matter affects living bodies?

Even substances of identical chemical component composition can affect living bodies in different ways if their surface areas differ. As the surface area becomes larger, there is a possibility of its hazard to living bodies getting greater due to chemical reactions taking place on the particle surface and/or promotion of pollutant adsorption. In the actual atmosphere, particles are not spherical. When it comes to non-spherical particles or an aggregate of fine particles stuck to each other, their surface areas increase, but virtually no measurement has been made to date.

Measuring surface area concentration in real-time

Another research theme of Dr. Okuda is real-time measurement of surface area concentration of particulate matter.

"Over the years, the main interest of $PM_{2.5}$ research scientists had been in shedding light on its chemical component composition. Not to be missed here is the fact that the impact of a given substance on living bodies varies according to the state of matter. For example, most $PM_{2.5}$ particles exist as an aggregate of fine particles stuck to each other. The surface of this aggregate is rough and uneven. As such, it has a surface area larger than that of a spherical body, which is known to have adverse effects on living bodies."

In a particle exposure experiment using a carbon nanotube and mice, it was confirmed that inflammation of the mice's respiratory tract tissue was promoted as the particle surface area became larger. It was also known that in proportion to surface area, particles were liable to adsorb pollutants in the atmosphere onto their surface. This led Dr. Okuda to use equipment designed to measure the surface area concentration in real-time. Based on the "diffusion charging method," this equipment allows a sample to pass through an ion-generating chamber, charges particles and measures the current value downstream. He has been collecting data in this manner since 2013.

"From March 2015 on, we are collaborating with Fukuoka University, the National Institute of Advanced Industrial Science and Technology and the National Institute for Environmental Studies, measuring in real-time more chemical component concentrations and particle surface areas and observing differences in terms of time series. Although the current environmental standards require us to determine mass concentration only, sooner or later surface area concentration may be added as a new metric."

Examining the charge state of fine particles

Recent studies reveal that when particles are inhaled into a living body, particle deposition amount increases in proportion to the particles' number of charges.

"In an experiment using a human respiratory tract replica, it became clear that charged particles were sticking to the respiratory tract about six times more than non-charged ones. This interprets that the concentration of harmful substances in the atmosphere is six times higher, doesn't it? However, there are virtually no researchers who have noticed this fact."

So Dr. Okuda is also engaged in real-time measurement of charged-state particles by means of the "electrical mobility method" which allows particles to pass between electrode plates and uses a particle counter to determine the number of particles downstream where the air stream passage is branched off.

"What's intriguing to me is that the balance between positively- and negatively-charged particles changes frequently. Since influences of cosmic rays alone cannot explain this drastic change, there must be one or more other causes, such as exhaust gas and high-voltage power cables. But virtually no studies about this phenomenon have been made to date. Naturally, I've had to make necessary devices all on my own. Given this is an uncharted territory of research, it's all the more challenging and rewarding."

A seemingly known world can be a vast untapped world the moment you get rid of your stereotypes. We would like to expect Dr. Okuda's unique perspective and approach to produce more and more creative research results.

(Reporter & text writer : Madoka Tainaka)