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Atmospheric & Environmental Chemistry

from Keio's Faculty of Science and Technology

A new perspective for study of atmospheric & environmental chemistry

Tomoaki Okuda

Associate Professor
Department of Applied Chemistry

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.

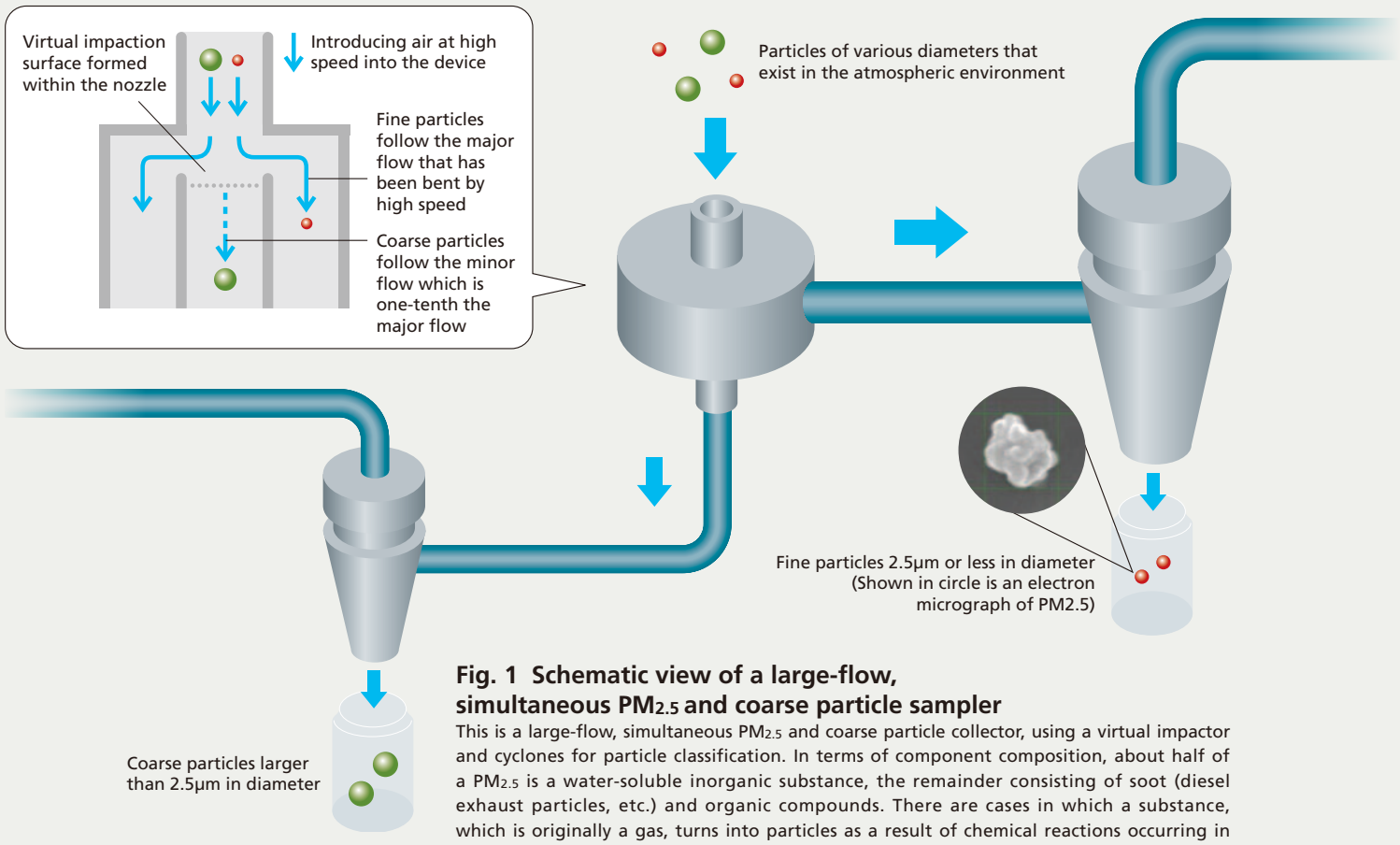


Fig. 1 Schematic view of a large-flow, simultaneous $PM_{2.5}$ and coarse particle sampler

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.

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)

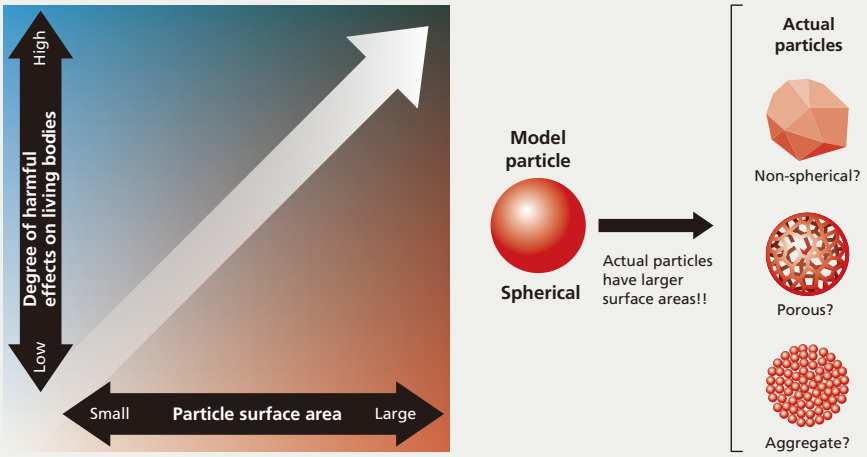


Fig. 2 How the surface area of particulate matter affects living bodies?

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.

Associate Professor Tomoaki Okuda

In studies, basketball and piano . . . my power for persistent, unwavering continuation has produced achievements.

Dr. Okuda took up playing the piano and basketball as pursuits under the influence of his elder brother and sister. Although he took up neither pursuits on his own will, he was able to experience joys that could be appreciated only through continually engaging in them. The power to persistently continue pursuits was nurtured through piano and basketball. This combined with the power to look at things objectively – a capacity developed through constant changes in his environment – led to his worthy achievements.

What was your childhood like?

I was born in Fussa City of Tokyo as the youngest child of three – a brother seven years older and a sister five years older than me. Under the influence of my brother and sister, I began to take lessons on the piano at the age of four and continued the pursuit until 27 years of age when I found employment. Since both my brother and sister had been playing the piano since childhood, I took playing the piano for granted.

After having served as a high school teacher, my father became a university teacher, teaching sociology of education at the faculty of literature of a private university. In his daily life he made it a rule to come back home at 6:00 p.m. He often invited his students for a reading circle or drinking party; he looked really happy.

Watching my father's behavior as an example, I came to make up my mind to become a universithy teacher at some time. In reality, the lifestyle as a science/engineering course faculty member is much different from that of a humanities course. Contrary to my initial expectations, I'm now leading an extremely busy life.

Let me ask you about your school studies.

My parents told me to study mathematics and Japanese closely because both subjects are fundamental. However, I don't remember them forcing me to study too hard. If I remember correctly, I had little difficulty in school studies from elementary through junior high school years. I was admitted to the Tokyo Metropolitan Tachikawa High School. Soon after that I decided to choose the science and engineering course.

When I was a junior in high school, I began to think about what I should do in the future. I wanted to do something useful for people, such as solving environmental problems. So I was inclined to choose the industrial chemistry course at a college. It was when Mr. Ohmachi, my chemistry teacher, advised me, saying "If you want to advance to the applied chemistry course, you should seriously study the basics at your college." Accepting his kind advice, I entered the Department of Chemistry, Faculty of Science, of Tokyo Metropolitan University.

Upon entering the university, I belonged to the basketball team. Basketball was a pursuit I had engaged in from junior high through senior high school. Day after day of hard practice made me so exhausted that I somehow attended classes but was always sleeping at the front row of the classroom.

To tell the truth, I took up basketball also thanks to the influences of my brother and sister. My true interest was in baseball, but I chose basketball after all. Whether playing the piano or basketball, I didn't choose them on my own will. But it was by the power of my will that I have continued the pursuits for years to date, of which I'm a bit proud.

As a member of an adult team, I'm still continuing this sport at a pace of once a week. I also have an experience of teaming up with students of the Department of Applied Chemistry and winning the Keio Gijuku Presidential Cup in a Keio-wide basketball tournament.

As for piano, up until 27 years of age I had performed in a piano concert three times a year. Later I joined a jazz band and a fusion band, where I was responsible for the keyboard part. I continued these activities up to the age of 32 before leaving Japan to study in the United States. Our original band even released two CDs from an indie label. Furthermore, I performed several times on live house stages and on the occasion of our Yagami Campus Festival. Due to my extremely busy work schedule, I'm now suspending these musical activities.

Influences of my brother and sister are extending to my research activities. My elder brother is an X-ray system engineer working for an analytical equipment manufacturer. As such, he once offered a suggestion for my studies. Instead of the conventional acid decomposition/ICP-MS system, I successfully developed an analytical method based on "energy-dispersive X-ray fluorescence (EDXRF) spectroscopy." This is a multi-element simultaneous X-ray spectrometry system to analyze metallic constituents in $PM_{2.5}$, which enables accurate analysis easily and quickly. He suggested the use of this system in my research.

Due to its relatively low sensitivity, this system had been deemed inappropriate for microanalysis until then. To overcome this drawback, I exerted my ingenuity for improvements. The

resultant system was found well capable of dealing with 15-or-so elements, exhibiting the efficiency of analyzing one sample in approximately 15 minutes. Thanks to this research achievement, I was honored with the "Research Paper Award 2014" from the Japan Association of Aerosol Science and Technology and the "Technological Development Award" which is the 4th Steel Foundation for Environmental Protection Technology Award for grant-in-aid research results.

About when did you put research work into full gear?

As a senior I belonged to a lab specializing in environmental and analytical chemistry. But I was an active member of the basketball club up to October the same year. So it was only after I advanced to the master's course that I got down to research work seriously.

However, the theme was not atmospheric research. I began by analyzing pollutants taken from deposits on a lake bottom. By boring cores (cylindrical samples of sediments) and examining them, it was possible to follow changes in contamination in time series. I actually went to a lake at the foot of Mt. Akagi, where I used a rowboat to collect cores.

But I gradually found it somewhat irritating to focus on analyzing contamination that took place in the past. I wish to really contribute to the health of people – this enthusiasm urged me to investigate into what's going on NOW. Because of this motivation, I also took up research into the atmosphere when I was in the second year of the master's course.

Since I was aiming to become a university teacher, I advanced to the doctor's course instead of looking for private employment. It was just about then that my advising teacher was retiring, so for my doctor's course I chose Tokyo University of Agriculture and Technology (TUAT). That said, most of the vitally needed measuring instruments were available only at Tokyo Metropolitan University (TMU). Therefore, I had to shuttle between TUAT and TMU frequently.

The target research theme during my doctor's course was harmful compounds found in the soil and atmosphere, which consist of benzene ring (a hexagonal ring arrangement consisting of six carbon atoms). I worked to identify their sources and pathways, among others.

Why and how did you come to teach at Keio?

I applied for a position in response to Keio University's public recruitment call in 2001 when I was in the third year of my doctor's course. Since I had no relations whatsoever with Keio, I thought I would never be employed.

Then I went over to the United States to study at the University of Wisconsin-Madison from 2007 to 2008. At Wisconsin, I engaged in research relating to purification of diesel engine exhaust gas. As the very first overseas study for me, I had difficulties with English, but studying there was a truly challenging and rewarding experience. At the same time I was able to appreciate good aspects of Japan as a very livable country with highly advanced social systems. It also seems to me that Japanese students are superior when it comes to basic scholastic ability.

Regardless of being a researcher or not, I strongly suggest you to go overseas at least once in order to have another, objective look at our home country. Currently I'm serving as a member of the International Committee at Keio, strongly encouraging our students to study abroad.

What do you think are good points of Keio University?

The philosophy of the Keio founder Yukichi Fukuzawa is thoroughly shared by all teachers, administrative staff and even by senior alumni. This allows Keio as a whole to always keep the proper, desirable direction. For example, Keio has an established system to offer satisfactory support to those who study abroad. I'm especially grateful to our administrative staff for their dedicated support. Keio really has an excellent environment, where all of us can work and learn unrestrictedly and comfortably. As a person who came from outside Keio, I may be able to see these merits clearly more than anyone else. The importance of "looking at things from different viewpoints" comes home to my heart.

◎ Some words from students . . . ◎

● Dr. Okuda is a very earnest teacher. But when we are wrong, he is reasonable enough to criticize us. I think there are few teachers like Dr. Okuda who guide us as to how to speak and how to make presentations – considerations to ensure that we can do well when we go out into the world. On the other hand, when we are OFF, he joins us for a drinking party, enjoying sports and the like. This positive, lively atmosphere is a great asset to all of us.

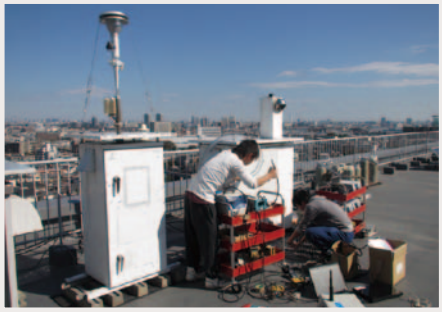
(Reporter & text writer : Madoka Tainaka)

For the full text of this interview
http://www.st.keio.ac.jp/kyurizukai

Studies, hobbies . . . no matter what I do, I'll do my best. A breakthrough will come in sight in due time. I'd like to follow my own path, believing in myself and not making compromises.

Tomoaki Okuda

Dr. Okuda specializes in environmental chemistry, atmospheric chemistry and aerosol engineering. He pursues research work by developing new-concept methods of his own to shed light on harmful physico-chemical properties of atmospheric aerosols relative to living bodies. He graduated from the Department of Chemistry, Faculty of Science, of Tokyo Metropolitan University in 1997, and then completed the master's course. In 2002, he obtained a doctor's degree (Dr. Agr.) at the United Graduate School of Agricultural Science, Tokyo University of Agriculture and Technology. The same year saw him become a research associate at Keio University Department of Applied Chemistry, Faculty of Science and Technology, and assistant professor in 2007. From 2007 to 2008, he served as visiting lecturer at University of Wisconsin-Madison. In 2015, he was promoted to the current position as associate professor of Keio University Department of Applied Chemistry, Faculty of Science and Technology. Among the awards he received is the Asian Young Aerosol Scientist Award (June 2015).



Experiment on the rooftop

Engaging in atmospheric environment studies means many experiments being conducted on the rooftop. So we install various pieces of equipment rooftop for continuous observation and bring in measuring apparatuses as necessary to obtain detailed data. Carrying in these materials requires muscle power and is often affected by weather conditions. However, success in obtaining intriguing data, using equipment originally designed and manufactured by myself, gives me exceptional delight.

Basketball

In my student days, I belonged to the basketball club. Even today, once-a-week basketball exercise is a must for me. Once I formed an ad hoc team with juniors of the Applied Chemistry Department to take part in Keio's basketball tournament, where we won the Keio Gijuku Presidential Cup. I also enjoy this sport with my friends. I'm looking forward to the annual training camp with them.

Musical activities

I began to take classical piano lessons at age 4, appearing on piano recital stage three times a year thereafter. After coming of age, I even formed bands. The band named "almi" released two CDs. On the occasion of Yagami Festival (our campus festival), our band performed on the main stage. Although I was also active as a member of the "Okotamura" jazz fusion band, I had to suspend my activities with this band because I became very busy with both work and child rearing.

Tomoaki Okuda's ON and OFF time

Whether in ON or OFF time,
I love to be with many others.

Exhaust gas purification experiment in U.S.A

While studying in the United States, I conducted diesel exhaust gas purification experiments by adding a catalyst to the fuel. I carried the test equipment, which is larger than our body, put it on a vehicle, assembled it and took samples – all by myself. I contributed the research results in the form of a research paper while in the U.S., which was accepted and published after I returned to Japan.

Academic prize awarding ceremony

Fortunately enough, I was able to receive five academic awards in the past three years. Any academic results cannot be achieved solo. Fruit of research can only be published thanks to students' ceaseless efforts, cooperation from businesses and discussions with other researchers from within and outside Keio. I'm determined to devote myself to research with gratitude to all these people around me always in mind.

Child rearing

Small children are leading their daily lives with all their power. I feel there are many things I can learn from them. They are too active for me to handle. So I occasionally invite some students to my home to deal with my small ones. As their father, I think I should set an example by making all-out efforts from day to day so that they will grow into healthful, reliable citizens.

Sports in U.S.A.

In the early days of my stay in the U.S., I had difficulty in communicating with others due to my poor English speaking ability. But the golden saying "Sports are a universal language!" came to my mind. Through soccer, basketball, snowboarding and other sports, I became friendly with many people from many parts of the world.

Public lectures and media interviews

Because atmospheric environment issues are a focus of public interest, I'm often asked to deliver public lectures and respond to mass media interviews. To the extent possible, I accept these requests so that our research results will be used to benefit society. In doing so, I explain environmental issues facing us based on the latest scientific knowledge.

私の本棚

My favorite books

Aerosol Measurement: Principles, Techniques, and Applications

This book provides comprehensive explanation of aerosol science, my specialty, from the viewpoint of "measurement." While the book shown here is the second edition, the third edition is already available now. This voluminous book, well over 1,000 pages, allows readers to use it like an encyclopedia. Every time I come up with a new idea for research, I first check this book to find whether or not the problem was already resolved in the past.

Points at Issue Facing the Japanese

More than half of environmental problems are problems of human society. As such, it's essential that we keep an eye on the latest developments in the state of society. Though I may not be so well conscious as Dr. Kenichi Ohmae, the author of this book, I myself maintain an interest in environmental problems, thinking about how we can make our society a better one.

Two music CDs (as mementos of my band)

The 1st album "Rise in the Rainbow" and the 2nd album "From the Center of Fountain" are here. These CDs continue to be a good memory although the band itself was dissolved upon release of the second album. In addition to performance including chorus, to create the CDs I played the role of a recording engineer and was even responsible for mixing and jacket design.

Fundamentals of Aerosol Science

Besides the atmospheric environment, aerosol science is closely related to diverse fields, such as industrial health, clean rooms, powder transport and pharmaceutical engineering. This book focuses on vital elements underlying these fields relative to aerosol science. In terms of volume, it is only 200 pages or so, but it's not an easy task even for researchers to fully understand its content.

Introduction to Atmospheric Chemistry (translated Japanese version available)

Aerosol science is a discipline dealing with particles as constituents found in the atmosphere (medium). But the understanding of the atmosphere as the medium is of equally crucial importance. While the original book is written in English, its translated Japanese version is available, which is highly recommended to Japanese beginners.

A Technique for Producing Ideas

This book was once used as a textbook at a study meeting for working members of society. Despite its volume of only 58 pages and its first edition dating back as early as 1940, it's a great book worthy of reading. Though originally written for business and marketing as targets, the approaches suggested here can be applied as is to research and scientific pursuits. A remark at the end of the book is very impressive: "By way of conclusion, I'd like to call your attention to crucial advice, 'You should set about your task immediately without getting too particular about methods and means."

Learning from Wisdom of Zen – for Mannerly and Beautiful Life

It is often the case that we face difficulties in the course of our life. Knowing how to calm the mind would be helpful if we become uneasy. It is widely known that Steve Jobs was deeply influenced by Zen. This book encourages us to "lead a mannerly and beautiful life."

The reality of the $PM_{2.5}$ problems

~ The importance of referring to primary information ~

Tomoaki Okuda

In Japan the government established environmental standards for $PM_{2.5}$ in 2009. In 2013, the outbreak in China of $PM_{2.5}$ high concentration was bandied about as an issue of serious concern. Indeed, $PM_{2.5}$ is now a major social issue. It was more than a decade ago that I became involved in $PM_{2.5}$ as a research scientist. But I could hardly imagine that my research target, $PM_{2.5}$, would come to the fore as one of the most popular keywords (The 30th "Top Ten You-Can Keywords of the Year" Awards, 2013)

However, I often feel like something is wrong with the way mass media report on $PM_{2.5}$. As far as I know, the actual state of things about $PM_{2.5}$ is as follows: ① It's not true that the average $PM_{2.5}$ concentration in Japan has been rising over the past several years; ② Admitting that in January 2013 $PM_{2.5}$ concentration in China was higher than the average for the past, that of Japan for the same period remained unchanged; ③ Except the cases of exceptionally high $PM_{2.5}$ concentration outdoors, normally there is little difference between outdoor and indoor concentrations; and ④ Wearing a mask to avoid inhaling $PM_{2.5}$ is almost nothing but a placebo because it's very difficult to use a mask closely adhered to your face. … What do you think? You may have found that my points are pretty much different from the impressions you received from mass media reports. Especially from 2013 to 2014, I was repeatedly asked to give public lectures on $PM_{2.5}$. Most of the audience appeared surprised at what I indicated.

To tell the truth, the data behind my opinion are all published by reliable public organizations. In other words, anyone can access such primary information. To our regret, mass media reports often fail to communicate primary information correctly. More than once did I say to myself, "How did they draw such an interpretation from this primary information!"

Such is not limited to $PM_{2.5}$ problems. If you have come across news you are curious about, refer to primary information as much as possible so that you can properly interpret the problem on your own. This is a very important ability given that our modern society is flooded with information of all kinds. In my classwork, therefore, my students are encouraged to develop their own opinions through discussions on environmental problems, using reliable primary information.

Science and Technology **Information**

The 16th KEIO TECHNO-MALL 2015 "More Partnerships, More Dreams"

KEIO TECHNO-MALL is an annual event to widely disseminate research results from the Keio Faculty and Graduate School of Science and Technology while also serving as a vital venue of encounters for industry-academia-government collaborations such as joint research and technological transfer.

At booths, you can see faculty members and students making presentations of their research results through real-machine demonstrations or display of posters. Every year, this event attracts many visitors – from businesses, government/public organizations, and other universities, etc.

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Date: December 4 (Fri.), 2015 10:00 ~ 18:00
Venue: Tokyo International Forum (Exhibition Hall 2, Basement 2)

Featured main event:
"Brain, Mind and Happiness" by Prof. Takashi Maeno (Graduate School of System Design and Management) and others
Round-table sessions:
"Engineering Approach to the Environment Issues" by Prof. Toshihisa Ueda, facilitator (Department of Mechanical Engineering)
"Future Society with Intelligent Robots" by Prof. Takahira Yamaguchi, facilitator (Department of Administration Engineering)

Editor's postscript

Dr. Okuda is seriously tackling problems relating to $PM_{2.5}$. I could see his devoted attitude while interviewing him. From time to time, he appeared particularly eager to let us have the correct knowledge of $PM_{2.5}$. I would like you to read the column on this page, which may drastically change your stereotype idea about $PM_{2.5}$.

The photograph on the front cover is an attempt to show Dr. Okuda collaborating with the particle sampler which is his original development and is installed outdoors. Although I couldn't imagine how the photo would work out until the front cover design was completed, the blue sky-like background was marvelously reproduced. It was a satisfactory finish that well reflected the image of his research.

(Manami Matsubayashi)

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