OCARINA通信

The OCU Advanced Research Institute for Natural Science and Technology

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−Special Feature−

As Humans and as Scientists in Pursuit of Truth
Disseminating to the World from the City of Osaka

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VOL.1

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■ Special Feature

As Humans and as Scientists in Pursuit of Truth Disseminating to the World from the City of Osaka

A year and a half since the official launching of the Advanced Research Institute for Natural Science and Technology, we are now initiating the publication of a public newsletter, OCARINA News which will report on our activities and research results over time. In this the first issue, as a special edition we are bringing you a dialogue between the Institute's Director, Professor Isamu Kinoshita, and Project Leader Professor Hideki Hashimoto.

Beginning from jointly undertaken projects, the Advanced Research Institute for Natural Science and Technology has been established as a base.

Prof. Kinoshita: Out of the idea that research which cuts across the boundaries of existing disciplines and research fields is indispensable for solving our contemporary problems, we began some joint research projects, and that was the starting point, wasn't it? Since then, not only in our research, but in building our organization and in raising funds, it feels as if we have been continuously running at full speed.

Prof. Hashimoto: Research in the natural sciences is advancing day by day, so if we don't move forward decisively we will be left behind.

Prof. Kinoshita: That's right. We couldn't wait for a couple of years for our new headquarters building to be finished, so we made our first base here in Building No. 2. This building was formerly used by the 'Yokaren,' the Naval Aviation preparatory students, so the beams are thick and the structure itself is quite sturdy, giving us a sense of security. The structure of this building is virtually the same as that of this school's Building No. 1, which has been designated as a tangible cultural property by the Cultural Affairs Agency. I'm proud of the fact that a building with such a long history can also be used as the base for our research.

Prof. Hashimoto: We just altered the interior, and that has made it into a modern space. On top of that, isn't it interesting that in this university with a 130 year history, in the oldest building the most advanced research is being carried out? I hope we can disseminate to the world the results of the research on disaster prevention and the renewal of the urban environment that have been based here.

Forerunners who thought about the future of Osaka City University.
Making a research institute that turns their ideas into reality…

Prof. Kinoshita: This Advanced Research Institute for Natural Science and Technology was born from the incisive thought of now deceased Professor Shohachi Kakuno (former professor of Osaka City University and Special Vice President of the university). At that time, Professor Kakuno and Professor Hata, who served as director of the first generation institute, envisioned an institute somewhat larger than the present one.

In the new natural sciences building complex as well, now under construction and scheduled for completion in Heisei 24, another base for the Advanced Research Institute for Natural Science and Technology can also be created. We hope that there as well new research projects will be advanced.

Prof. Hashimoto: Yes, the new facility will provide us with 1,000 square meters of space. Since we will have that much more space, we hope people who want to locate there will prepare research programs and raise the funding. We will welcome them!

Prof. Kinoshita: For certain, self-reliant efforts are necessary. It has become that way for ourselves as well.

Prof. Hashinoto: That's right. We have received research funds from CREST (Strategic Creative Research Promotion Project) as well as various enterprises, and from the supplementary budget of the Ministry of Education and Science. We have made all kinds of efforts at self-reliance. In order to assert our rights, we also have to fulfill our obligations.

Without the arrangement of somehow providing a third of research funds on one's own, getting a third form the university, and a third from the national budget, it is pretty difficult. It's natural, in doing one's own research, that you should have to provide something extra, and that can be fairly daunting.

Prof. Kinoshita: If I can add one more thing, in drawing a third of research funds from the university, I think that the content of the research and whether or not it is persuasive are also being questioned.

Prof. Hashimoto: It has been quite a struggle just getting to this point. It started with a virtual organization from the time of former university president Kaneko, and it was able to progress into a real organizational structure due to the foresight of President Nishizawa. If everything turns out well, I feel that the energy of the researchers will be explosive.

Absorbing 203 gigatons of CO_2 annually:
The wonder of photosynthesis

Prof. Kinoshita: Just mentioning the words photosynthesis and carbon dioxide reduction may not convey the fascination and interest of photosynthesis research, but when you hear that "nature absorbs annually 203 gigatons (1 gigaton = 1 billion tons) of CO_2," aren't you surprised? That is the power of photosynthesis. However hard we may try, human beings cannot manage 203 gigatons of CO_2.

In contrast, through their own activities, humans are generating

7 gigatons of CO_2 per year. We are exerting all of our effort just to somehow cope with 20% of that or about 2 gigatons.

Well then, what is the mechanism by which 203 gigatons of CO_2 are absorbed? I think it is appropriate for even an organization of modest scale such as our Advanced Research Institute for Natural Science and Technology to do research focused on this problem.

Prof. Hashimoto: That's because those 203 gigatons are not in a concentrated form. The concentration of CO_2 in the earth's atmosphere averages about 400 ppm (1 ppm = 0.0001%). From that small a concentration of CO_2, it has the ability to dispose of 203 gigatons. How such a thing can be done is really a great mystery.

How can 130 million people live in Japan, an island country surrounded by the sea?

Prof. Kinoshita: However you cultivate the land of Japan, it can only support 30 million people. This number comes form the population during the Edo period. Society at that time was the most beautifully developed self-subsistence cyclic system. However, when you consider the Japan's climate and cultivatable land area, with a population of 130 million people, self-subsistence is out of the question.

Prof Hashimoto: In other words, there are too many people. But, we can't just say let's reduce the number of people, can we?

Prof. Kinoshita: If we want to do something about this, in the case of Japan we have to turn our eyes to the sea. And when we do, we see that a very strange life form is there. Normally, from seeds there are sprouts, flowers bloom, and thus plants multiply. But in this case that doesn't happen, and we find that the organism multiplies while still in the form of seeds.

Prof. Hashimoto: You're talking about Okinawan mozuku seaweed, right? The seeds of this mozuku seaweed swim through the ocean riding on sea currents, and when they become attached to a place where it is easy to grow then they sprout. However, because it wouldn't do for them to die off while they are swimming, during that time the seeds themselves split apart and multiply. Thus, they have two different ways to multiply.

These seeds have a simple structure, and they are easy to cultivate artificially, so they are adaptable to experiments. The ironclad rule of experimentation is altering only one factor at a time. That is because if one alters two factors at the same time, people cannot judge which of the factors caused a change.

Prof. Kinoshita: In Okinawa they are raising 20,000 tons of mozuku annually.

Prof. Hashimoto: Even so, with those 20,000 tons, they can't absorb 203 gigatons of CO_2, can they? We have to think about this on a global scale. Something that is done in a test tube, what happens when we think about it on a global scale? In place of the test tube, we have only the ocean, right?

Special Feature

profile

Hideki HASHIMOTO

Osaka City University Advanced Research Institute for Natural Science and Technology
Professor, Graduate School of Science

M.S. and Ph.D., Kwansei Gakuin University Graduate School of Science. After serving as assistant professor at Osaka City University's Faculty of Engineering and associate professor at Shizuoka University's School of Engineering, became professor at Osaka City University's Graduate School of Science in 2002. Has served as Project Leader at the Advanced Research Institute for Natural Science and Technology since its founding in 2008. Full-time professor in the Advanced Research Institute for Natural Science and Technology since 2010 (with a joint appointment in the Graduate School of Science).

The results of what we do now will affect our grandchildren's generation That is precisely why basic research is indispensable.

Prof. Kinoshita: A wide variety of policy measures and research are being carried out on CO_2 reduction and on biofuels. "Aren't those measures overlooking something? Are they really correct?" In order to make such judgments, I think it is really necessary to thoroughly carry out basic research of the kind that we are involved in.

Prof. Hashimoto: Ultimately it is our grandchildren's generation who are the target. Human beings basically only think about the period of time in which they themselves live, don't you think? But the ones who will have to bear the consequences are in their grandchildren's generation. We ourselves now are in just this situation. All kinds of things that people did during the period of high economic growth have become problems for their grandchildren's generation, and we are really suffering from them. I think that essentially research is something where one has to think that far ahead.

Imagining not only one's own specialized discipline, but the things it is connected to…

Prof. Kinoshita: For example, in plant factories, red LEDs are used because they are more efficient. And even more recently, strobes are used for illumination that is only on in coordinated timing with photosynthesis.

Prof. Hashimoto: What is important in photosynthesis is the alternation between light and dark. It has been demonstrated that when the light reaching plants is turned on and off, they produce about ten times as much oxygen as when they are continuously illuminated.

Prof. Kinoshita: The current efficient system used in plant factories originated from that kind of photosynthesis research.

Prof. Hashimoto: And also, recently I have seen in the news that demonstration experiments have begun in which the lithium ion batteries that GS Yuasa and others have used in electric cars are being used a second time to store the electricity of solar batteries that are installed on the rooftops of Lawson convenience stores. Seeing this news, I though it would be interesting if in the future instead of 'Lawson' we could have 'noson' or agricultural villages. Using the electricity from solar batteries we could put out LED illumination in a regular cycle, fix CO_2, and raise crops that grow ten times faster than normally. Beyond that, if we were able to produce the hydrogen used in fuel cells using photosynthesis, that would be extremely efficient. In order to foster the people and the researchers who can understand and manage that kind of multifaceted working, organizations like the Advanced Research Institute for Natural Science and Technology are necessary. Just doing research on photosynthesis alone will not result in ideas like the 'noson.'
Doing the research that can be done here because this is Osaka…
That is our mission.

Prof. Kinoshita: There is also the question of how can we transform and transmit efficiently the electricity generated by the sun, wind, and other natural energy sources.

Prof. Hashimoto: The electricity that comes from solar generation, etc. is direct current, but we have to go to the trouble of converting it to alternating current and transmitting it, don't we?

Prof. Kinoshita: Direct current had the problem that along the way resistance developed and the power diminished. But recently high temperature superconductors have come into use and it has become possible to transmit direct current as it is. In the case of a superconductive line in actual use, everything within a 500 meter radius can be connected. What I want you to notice in this instance is urban transportation such as the subway. Except for the Shinkansen bullet trains, electric trains all run using direct current, so the rails can be used as they are as infrastructure for distributing direct current. The idea that we should pursue photosynthesis research arose premised on this.

Prof. Hashimoto: That's because the solar generated and hydrogen generated electric power that uses photosynthesis is direct current electricity.

Prof. Kinoshita: So, why are we doing photosynthesis research at Osaka City University? One of the reasons is because it can be connected to subway lines, etc. as they are for direct current electricity infrastructure.

Prof. Hashimoto: If we use the train lines as infrastructure, we can cover the entire city, can't we?

Prof. Kinoshita: If we are trying to cut CO_2 emissions by 20–25%, we have to use all our technology comprehensively. One example of that is thinking up innovations that will improve urban energy infrastructure and power generation that matches that. In the city of Osaka, isn't that the mission that we have?

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profile

Isamu KINOSHITA

Director, Advanced Research Institute for Natural Science and Technology
Professor, Graduate School of Science

B.S. in Chemistry, Tohoku University Faculty of Science. M.S. and Ph.D., Nagoya University Graduate School of Science. After serving as assistant professor, lecturer, and associate professor in Osaka City University's Faculty of Science, was appointed to his current positions in 2003.

Prof. Hashimoto: Yes, it's our mission. This kind of research is hard to do unless we do it on such a scale that the things we think about in one lab at the university bounce directly back to the government. In the case of Osaka, it is just the right size… the city of Osaka itself has great interest in the problems of the environment, and it is an environment that is easy to study.

From the instinctive urge of thinking, "I want to know…," research to fulfill humankind's intellectual curiosity.

Prof. Kinoshita: Here at Osaka City University, we want to be involved in research that leads to innovation from a unique perspective that exists nowhere else. However, although this is just my personal opinion, at present we seem to be sorely lacking in a philosophical outlook. Isn't it impossible to attempt innovations without a philosophy?

Prof. Hashimoto: Why do you want to do that kind of research? The problem is, people have no skill in correctly asserting themselves, they haven't even thought about it.

Prof. Kinoshita: I think that humans are instinctively consumed by the desire to know things. Even when someone is in love, they want to know whether the other person loves them or not. Wanting to know what happens after we die is where religion comes from.

Prof. Hashimoto: Ultimately, we run into that proposition, don't we? Even Faraday said that to a natural scientist, the question "what meaning does this research have?" is a silly question. Humans are animals with intellectual curiosity, and since natural science is what clarifies what we don't understand, is there anything more than that which we can do?

However, we have now entered a time when the world at large will not permit us that. When we try to connect things to something that can be useful or lead to an innovation, that's where philosophy and ethics emerge.

Prof. Kinoshita: Honestly speaking, it's not a question of making life even more convenient than it already is. Even though there's no direct connection to our daily lives, when a supernova star appears it is front page news, and when the mini-satellite explorer Hayabusa returns, everyone is moved.

Prof. Hashimoto: Everyone is moved, but they ask, "How much tax money does it consume?"

Prof. Kinoshita: Nevertheless, we want to understand. If we accept that idea as being important, then the scientific researcher should really think about that.

It's a quote from somebody, but it's said that "Science does not tell us about the future. What it tells us about is humans." That is surely true. However, many people have the misunderstanding that equates science with the future.

So that humans don't commit mistakes…
The base we should stand on is USR (University Social Responsibility)

Prof. Kinoshita: I belong to the pollution generation, so I have repeatedly asked myself the question, "Is it really alright to do chemical research?" For example, the spilling of mercury that was the cause of Minamata disease is a terrible problem. However, because of that, how would it be if we banned all use of mercury? Even though when mercury is properly disposed of, its use makes the cost cheaper and it is easier to produce, that would have shut off all those possibilities.

Prof. Hashimoto: From a safety perspective, it has been overregulated.

Prof. Kinoshita: What I'm saying is, there is no problem if it safely managed in the real sense.

Prof. Hashimoto: In other words, it's a problem with people. Because people committed mistakes, it's a manmade disaster. If you want to prevent manmade disasters, then you need philosophy and ethics.

Prof. Kinoshita: Now, a public entity's existence absolutely requires the creation of ethical guidelines. Osaka City University has its own ethical guidelines, and in them it is written that we are exerting our efforts for the welfare of humanity and for society.

Prof. Hashimoto: The Advanced Research Institute for Natural Science and Technology has its own rules, and in them it is written that our goal is to give back to the society and to the region.

Prof. Kinoshita: Such things are called USR (University Social Responsibility). In the case of a company, they are called CSR, and this is a word we hear a lot these days. The university's version of this, the USR, is I think the foundation that we should all join together in standing on, isn't it? Of course this should be a place where we disseminate research results to Osaka City, to the citizens, and to the world, but I also want it to be a place where we disseminate an ethical and philosophical image as well.

Research Introduction

Proposal for Appropriate Use of Ground Water in Osaka City and Its Metropolitan Area

Five faculty members* from the Graduate School of Science, Graduate School of Engineering, and the Graduate School of Human Life Sciences are engaged in joint research in Group B under the research topic, "Constructing a Sound Groundwater Resources Use Law for the Environmental Protection of the Metropolitan Area and Ground Disaster Prevention." Here we will hear from the Graduate School of Engineering's Professor Oshima who serves as the team leader.

* in addition to Prof. Oshima: Prof. Harue MASUDA (Biology and Geosciences, Graduate School of Science); Prof. Muneki MITAMURA (Biology and Geosciences, Graduate School of Science); Prof. Yoshinori KANJO (Urban Engineering, Graduate School of Engineering); Prof. Yoshikazu NISHIKAWA (General Science of Aging Societies, Graduate School of Human Life Sciences).

Characteristics of the 3 layers of groundwater: the shallow layer, the middle layer, and the deep layer

In looking at groundwater, we divide it generally into three layers depending on the depth. These are the shallow layer of groundwater down to 40 meters below the surface, the middle layer from about 100 to 500 meters down, and the deep layer, deeper than 500 meters below the surface. The problems involved with each layer and its means of utilization are each different.

The shallowest layer was in former times pumped up excessively, which was the cause leading to ground subsidence, and because of this in 1963 the Industrial Water Use Law and the Building Water Use Law were enforces which restricted the pumping up of groundwater. As a result, as shown in Figure 1, ground subsidence was brought to an end, but because this shallow groundwater layer is constantly replenished by rain from the mountain areas, the groundwater level rose rapidly. Along with this many kinds of problems also arose. My specialty field is research on this layer, and I will explain more in detail below.

What has created problems in the middle groundwater layer is the fact that digging of wells that fall outside the purview of the law and the construction of exclusive private pipelines to utilize groundwater have rapidly increased. The actual conditions and extent of that water usage are not really understood, but if these private pipelines continue to increase they could potentially lead to the demise of water works projects. Also, if they continue to spread, they could dry up the groundwater and have the potential to once again create ground subsidence. The groundwater in this layer does not have as many sources of replenishment as the shallow layer, once the volume of water has been reduced, it is virtually impossible to restore it to its original condition. In the deep groundwater layer as well, there is a rising demand for water for the development of hot springs, and there is the possibility that it will dry up in the near future. In order to prevent these problems, we are conducting a survey of the actual status of groundwater utilization.

Raising the groundwater level of the shallow layer causes 4 problems.

My own research is focused on the themes of the shallow groundwater layer and disaster prevention and the environment of the ground. By the raising of the water level in this layer, four problems have arisen. The first of these is that because the groundwater level has risen higher than it was when underground structures were planned and built, buoyancy has come into play and existing structures have become unstable. The second problem is that excavations such as those for subway construction, etc. have become difficult. The third problem is the soil liquefaction that became a problem in the Great Hanshin-Awaji Earthquake. In the near future it is said that Tonankai and Nankai earthquakes will occur, and with the groundwater at the high level that it is now, one can predict that a great deal of damage will occur. And the fourth problem is contamination of the soil and groundwater. As groundwater penetrates soil that is contaminated with heavy metals and volatile organic compounds (VOC), the contaminant matter will spread along with the groundwater.

Additionally, we believe the fact that "the abundant shallow layer of groundwater is not being effectively utilized" is also one of the problems, and we are exploring ways to effectively utilize groundwater and solve these four problems.

How much groundwater can be pumped up?

Figure 2 is a cross-sectional diagram of Osaka from east to west. The shallow groundwater layer is divided between the 'loose alluvial sand formation' and the 'No. 1 Diluvial gravel formation' below it, sandwiching the 'alluvial clay formation' which is almost impervious to water. Looking at the two layers containing this groundwater, we calculated how much groundwater could be pumped up.

First of all, based on a ground database and boring survey of Osaka, we looked at the characteristics of soil and the ground in each 250 meter cell in a grid. From those characteristics, we tried to find how far the alluvial clay formation layer would sink when the groundwater level was lowered. Then, if we the amount it is possible to lower the groundwater level and have the subsidence stop below the minimum permissible amount of sinking, we can calculate the amount of groundwater that can be effectively utilized. In this research, based on architectural foundation structural planning guidelines, etc. we posited the permissible subsidence amount at 5 cm.

Figure 3 shows the case of water pumped from the alluvial sand formation layer, and Figure 4 that from the diluvial gravel formation layer. Except for some localities where the ground is loose, we found that it would be possible to pump up 2~3 meters from the alluvial sand formation and 2~4 meters of groundwater from the diluvial gravel formation.

Is lowering the groundwater level of the shallow layer effective against soil liquefaction?

Additionally, we tried to prove whether or not lowering the groundwater level would be an effective measure against liquefaction. First, we investigated the thickness and the grain sizes of sand in the alluvial sand layer, and based on that data tried to find the degree of danger of liquefaction in the case of an ocean trench type earthquake, such as the Tonankai or Nankai earthquakes, occurring. That is shown in Figure 5. The higher the PL value, the higher the degree of danger. At the present groundwater level, the alluvial sand layer in eastern Osaka is thin and it would be relatively safe, but in western Osaka the degree of danger of liquefaction has become extremely high.

Well then, what happens when the water level of the alluvial sand layer is lowered? Figure 6 shows the degree of danger of liquefaction if the water level is lowered 3 meters from its present level. The red color which shows an extreme danger condition has almost completely disappeared. In other words, by lowering the groundwater level about 3 meters, liquefaction can be prevented without causing ground subsidence.

profile

Akihiko OSHIMA

Professor, Specialist in Urban Engineering, Graduate School of Engineering, Osaka City University

B.S. Osaka City University in Engineering. M.S. and Ph.D. in Civil Engineering, Osaka City University Graduate School of Engineering. Beginning in 1988, served as assistant professor, lecturer, and then associate professor in Civil Engineering Dept. of Osaka City University's Faculty of Engineering. Appointed to present position in 2011. Field of specialization: Geoengineering

Thinking about effective groundwater utilization from a geo-engineering perspective

Based on these research results up till now, we are at present pursuing research on the effective use of the groundwater that is pumped up. For example, there are ways of using 'grey water' that is in between tap water and sewage water. Specifically, it can probably be used for cooling water in the water-cooled air conditioning of buildings or factories, for flushing the toilets in buildings and in parks, for green vegetation in parks and environmental water in biotopes. Additionally, one can think of many different uses such as emergency water supply in disasters, or as water used to dissipate the heat of urban heat islands.

What is indispensable for putting into effect this kind of effective utilization of groundwater is the public takeover of groundwater. Seen in a larger perspective, groundwater is something that cycles through the global environment. Rain falls, it flows into streams and rivers, it passes through the ground, it returns to the sea, it evaporates and then becomes rain again… While the rain, the rivers, and the ocean do not belong to private individuals, the fact that only groundwater is subject to private ownership is something that is very strange indeed. Concerning that, we are thinking that groundwater should be taken over by the public and appropriately administered and utilized by the national and local governments, and we are lobbying the local governments towards that end.

The significance of doing research as the Advanced Research Institute for Natural Science and Technology

In this team are assembled a variety of specialists who each have their own area of expertise, not just specialists in civil engineering and geo-engineering like myself, but specialists in environmental engineering and geophysics or geology, and even a bacteriologist. Through the mutual exchanging of information there arises a breadth and a depth to the research, and research of great significance can be done.

In July of this year, headed up by Professor Masuda of this same B Group, a book that brings together our research results entitled *Urban Water Resources and the Future of Groundwater will be published.* It approaches the subject of groundwater utilization from a variety of approaches and will be a compilation of our surveys and research, so I hope that you will get your hands on a copy. The effective use of groundwater and problems of the ground are ones that are very close to our lives. We want to continue thinking about and dealing with these issues, not only with the government but together with all of the ordinary citizens.

Urban Water Resources and the Future of Groundwater will be published

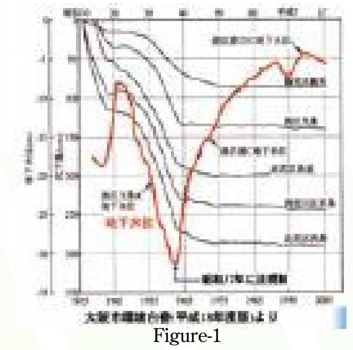

Figure-1

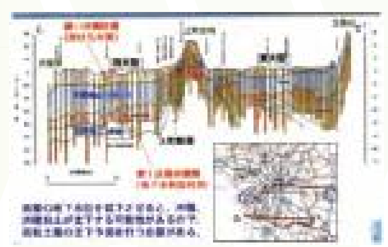

Figure-2

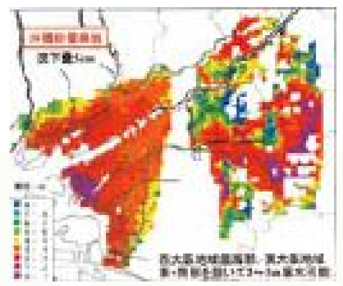

Figure-3

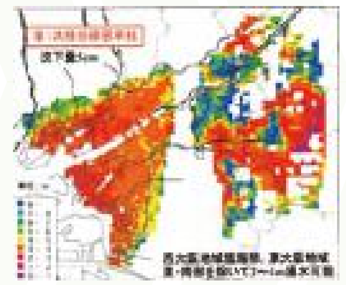

Figure-4

Figure-5

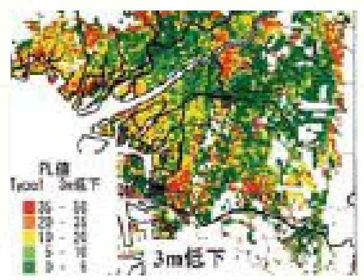

Figure-6

Reports on Activities

Kick Off Symposium

Osaka City University Advanced Research Institute for Natural Science and Technology Symposium Program to Commemorate the Opening of the Institute

▶ **March 10, 2008**

▶ **Invited Speakers:**

- Richard J. Cogdell, Fellow of Royal Society (University of Glasgow, UK)
- Alfred Holzwarth (Max-Planck Institute, Germany)
- Cong-Qiang Liu (State Key Laboratory of Environmental Geochemistry, Institute of Geochemistry, Chinese Academy of Sciences, China)
- Shawn K. Y. Lum (Nanyang Technological University, Singapore)
- Shigenobu YANO (Nara Women's University)
- Makoto NISHIGAKI (Okayama University)
- Nobukazu TANAKA (Electric Power Research Institute)

▶ Outline of the Symposium

Our first symposium, held to commemorate the opening of the Advanced Research Institute for Natural Science and Technology. In order to strategically help develop research for dealing with the urgent urban problems of energy shortages, water resource shortages, and global warming, domestic and foreign researchers active in the appropriate fields were invited, and an energetic exchange of views was carried out while sharing awareness aimed at removing the barriers between disciplines and solving problems.

The 2nd Activitiy Report

2010 OCU International Symposium on the Foundation of Environmental Research

▶ **March 8~9, 2010**

▶ **Invited Speakers:**

- Richard J. Cogdell (University of Glasgow, UK)
- Thomas A. Moore (Arizona State University, USA)
- Ana L. Moore (Arizona State University, USA)
- Bruno Robert (CEA, FR)
- Leroy Cronin (University of Glasgow, UK)
- Timothy J. Storr (Simon Fraser University, CA)
- Lawrence R. Sita (University of Maryland, USA)
- L. James Wright (University of Auckland, NZ)
- Osamu ISHITANI (Tokyo Institute of Technology)
- Chikara MIYASAKA (Toin Yokohama University)

▶ Outline of the Symposium

The venue for the Second International Symposium was the Awaji Dream Stage International Conference Hall. In an environment of blue sea and green forests where one could feel close to abundant nature, there were eleven presentations by invited speakers and 27 poster sessions. Under the slogan of "Saving the World from Osaka," energetic discussions were held over two days and a first step was taken towards the dissemination of information.

The 3rd Activitiy Report

Osaka City University Advanced Research Institute for Natural Science and Technology Conference Commemorating the Opening of Hall Number 2

▶ **November 18, 2010**

▶ **Invited Speakers:**

- Special Lecture by Shigenobu YANO
- Visiting Professor, Nara Graduate School of Advanced Science and Technology
- Researcher, Kyoto University Center for Liaison with Industry, Government, and Academia
- Special Researcher, Osaka City University Advanced Research Institute for Natural Science and Technology
- External Evaluator, Osaka City University Advanced Research Institute for Natural Science and Technology
- Visiting Professor, Osaka City University

▶ Keynote Speeches: Ritsuko FUJII (Osaka City University Advanced Research Institute for Natural Science and Technology)
Keisuke KAWAKAMI (Japan Society for the Promotion of Science)

▶ Outline of the Symposium

In November, 2010, in the fourth year since the establishment of the Advanced Research Institute for Natural Science and Technology, it was formally established as a truly active research facility base. On the occasion of its projects beginning in actuality as well as in name, a commemorative conference was held, and in addition to a special lecture by Visiting Professor Yano, there were two keynote lectures and 34 poster sessions. All the participants renewed their determination to make this into a world-leading research organization.

The 4th Activitiy Report

The Third Osaka City University Advanced Research Institute for Natural Science and Technology International Conference: Kakuno Memorial

▶ **March 7~9, 2011**

▶ **Invited Speakers:**

- Richard J. Cogdell (University of Glasgow, UK)
- Thomas A. Moore (Arizona State University, USA)
- Ana L. Moore (Arizona State University, USA)
- Dalio Polli (Politecni di Milano, Italy)
- Kazi Matin Ahmed (University of Dhaka, Bangladesh)
- Guoji Ding (Shanghai University, China)
- Yuriko MATSUMURA (Seikei University)
- Masako KATO (Hokkaido University)
- Toshio ASADA (Osaka Prefectural University)
- Mitsuo TODA (Shizuoka University)
- Satoshi MATSUDA (Shizuoka University)
- Sarah Henry (University of Glasgow, UK)
- Misaki NAKAI (Kansai University)

▶ Outline of the Symposium

Our third international symposium was held titled the 'Kakuno Memorial' in recognition of the great achievements of the late Professor Shohachi Kakuno who exerted great efforts in the establishment of the Advanced Research Institute for Natural Science and Technology. In addition to announcing the achievements up till now of the institute and presenting the results of the latest research, lectures were presented by researchers from Japan and abroad. Also, at the same time, aiming at even more substantial research activities, ideas for new projects were solicited and then announced.

■ Topics

profile

Nobuo KAMIYA

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Solving the mystery of oxygen release in photosynthesis– A stepping stone towards artificial photosynthesis

The research group led by Professor Nobuo Kamiya (specialist in structural chemical biology molecular physics) of the Advanced Research Institute for Natural Science and Technology and Professor Shen Jian-Ren (specialist in biosciences) of Okayama University's Graduate School of Natural Sciences has solved the mystery of the reaction in photosynthesis where light energy is used to break down water and release oxygen. Analyzing the mechanism whereby radiant light energy from the sun is transformed into chemical energy that can be utilized by living things is a dramatic result that contributes to the solving of global environmental problems, energy problems, and food supply problems. The results of this research are published as a research article in the British journal Nature (Nature 473 (7345), 55-60, 2011).

The familiar and important reaction of photosynthesis

Photosynthesis, the phenomenon in which the leaves of plants receive sunlight and produce carbohydrates from water sucked up from their roots and carbon dioxide from the air, and at the same time release oxygen back into the air, is well known. I think there are probably people who can remember performing an experiment about the time they were in middle school of putting a piece of black paper cut in the appropriate shape over a leaf and exposing it to sunlight for a while. In the part of the leaf blocked from the sun the green pigment which is chlorophyll has been removed and it has turned white. If one applies iodine to the leaf, the part where there was no black paper is stained purple, and the part covered by the paper stays white and the original shape can be seen floating up. This was precisely the process of starch (carbohydrates) being made in the leaves of plants through photosynthesis, made visible by the reaction of iodine and starch turning a purple color. In this way photosynthesis is something that is familiar to us, and among the many phenomena of life it is something that can be said to be especially important. The carbohydrates produced through photosynthesis, together with proteins and lipids, are called collectively the three major nutrients. These carbohydrates break down into sugars inside our bodies, and the oxygen we obtain from breathing reacts chemically with them and becomes the energy for our activity. If we look for the source of the oxygen in the air, during the long period said to be 3 billion years since the origin of the earth, all of it has been created by photosynthesis. Additionally, the proteins and lipids as well that are indispensable for our life, if we look into the basis of the whole organic world, the source of the energy for producing them comes entirely from photosynthesis.

The base of the green pigment is chlorophyll

Since photosynthesis is thus an extremely important life phenomenon for all of us, research on it has a long history going back more than 200 years. It started first of all with the discovery, during the industrial revolution that began with the invention of the steam engine, that plants could purify the air that had been polluted by humans burning unlimited amounts of coal. From observations with optical microscopes it became understood that not all the cells of plants were entirely green, but that chlorophyll was concentrated in the green body of leaves and that is where photosynthesis occurred. And then, after the electron microscope was invented, it was discovered that inside the chloroplasts there was a structure of sac-like double membranes of lipids (thylacoid membranes) stacked on top of each other, and that the chlorophyll was only in this part. Chlorophyll works by absorbing sunlight and harvesting its energy, and by the mid 20th century its chemical structure was understood. Chlorophyll is made up of a ring-shaped part at its tip (a chlorine ring with magnesium at the center) combined with an elongated chain part (phytol chain). Both the chlorine ring and the phytol chain are hydrophobic, not breaking down easily in water but rather easily soluble in oil, and the chlorophyll is surrounded by a hydrophobic compound of lipids and membrane protein buried in the thylacoid membranes.

Crystallization of a natural catalyst that produces oxygen from water

Photosystem II (PSII) is one of these lipoproteins membrane proteins and it works as an enzyme, in other words as a biological catalyst, to break down water in photosynthesis and make oxygen molecules. Along with oxygen molecules, PSII also produces hydrogen ions and electrons, and they are used in the synthesis of biological material necessary for changing carbon dioxide into carbohydrates (carbon dioxide assimilation). Because PSII acts in this crucial way as an enzyme that is crucial in photosynthesis, there is a long history of research attempting to reveal its molecular structure and understand the reaction mechanism by which it produces oxygen. X-ray crystallography is a method of gathering molecules into crystals and revealing the molecular structure from the X-ray diffraction image, and it has been possible to use it to look at proteins with a large molecular weight for about forty years now. However, in the beginning, all of the proteins whose crystal structure was successfully analyzed were water soluble ones that easily dissolved in water, and it wasn't until only about 20 years ago that hydrophobic membrane proteins such as PSII could be structurally analyzed. Whether in compounds with a small molecular weight or compounds with a large molecular weight, what is important when trying to crystallize the molecules is to obtain pure specimens that do not contain impurities. In the case of PSII which is not water soluble and is buried in the thylacoid membrane, first it must be made water soluble by treating it with a surface activating agents, and then all the impurities must be removed. However, the surface activating agents are essentially like the detergents that are used to make grease spots on clothes dissolve, and if ones that are too strong are used they will break down the structure of the PSII itself (protein degeneration). Also, while the PSII is originally stable within the hydrophobic thylacoid membrane, in its soluble state due to the surfactants, it is unstable, and with time degenerated material becomes mixed in with the pure material. This degenerated material resembles PSII, and so it cannot be easily removed, and this is the most troublesome part of trying to crystallize membrane proteins.

X-ray crystallography crystallographic analysis of PSII

This is only one of the reasons why the crystallization of membrane proteins is so difficult, and our research team has consumed a very long time in trying to obtain good crystals. It has already been 20 years since we first started our research trying to crystallize PSII and reveal its structure. Actually, in the first few years we obtained a green colored precipitate and so we took it to the Synchrotron Radiation Experimental Facility (the Photon Factory) in Ibaraki Prefecture and tried X-ray diffraction experiments. However, the results were abysmal and we could not verify any specks spots (diffraction points spots) that would show indicate that it was a crystal. In other words, although it was green and it contained chlorophyll, it was not a crystal of pure PSII. From then on a long and bitter struggle ensued, but recently we have finally succeeded in obtaining crystals of very high quality and we took them to the Large Synchrotron Radiation Facility (SPring-8) in Hyogo Prefecture and had them complete a crystal structure analysis. Figure 1 shows a model rendition of the entire structure of PSII, in which two monomers with a molecular weight of 350,000 are gathered into a dual-monomer dimer. The monomer of PSII is a compound in which 19 varieties of proteins (called subunits) are gathered together. In each subunit amino acids are arranged in straight lines (called polypeptide chains) and they are sterically folded up, but the molecular structure of the atoms of which they are composed becomes too complex when shown and it is impossible to illustrate well its entire appearance. In Figure 1, the parts of the polypeptide chains that that has a structure of spiral twists (called helixes) are shown as sticks like a baton, and the other parts are folded and connected by strings. From the figure, one can see that there is an area in the PSII where long helixes stand in rows, and below that there is an area where comparatively short helixes are clustered. The area where the batons are standing up in rows are a group of hydrophobic helixes, and in PSII this part is buried in the thylacoid membrane. The second part is the water soluble part outside of the thylacoid membrane, and in the spots circled in red in the figure are the Mn_4CaO_5 clusters which play the most important part in PSII's production of oxygen. (Please refer to Figure 2).

Figure-1 Photosystem II (PSII)

The electron transfer reaction of PSII

In Figure 1, between the multiple helixes standing up that pierce through the thylacoid membrane, here and there are narrow openings. Actually, in these crevices a lot of hydrophobic chlorophyll is buried which absorbs sunlight and works as an antenna to transmit that energy to the reaction center (called P680). P680 is where two units of special chlorophyll are gathered, and from the energy they receive from the surrounding chlorophyll there is momentarily an opposition created between electrons wrapped in a negative charge and 'holes' (this is called a charge-separated state as charge separation). These electrons move from the P680 to outside the PSII and are ultimately used in the synthesis of biological material necessary for carbon dioxide assimilation. On the other hand, the holes that are left behind exert an extremely strong pull on electrons, and this force pulls out electrons from the nearby Mn_4CaO_5 cluster and additionally from the water molecules that are compounded with coordinated to the cluster. Altogether this process leads to one electron being pulled away from a water molecule, but to produce one molecule of oxygen from two molecules of water a total of 4 electrons must be pulled away. Which is to say that in PSII the process outlined above continues to occur through 4 repetitions.

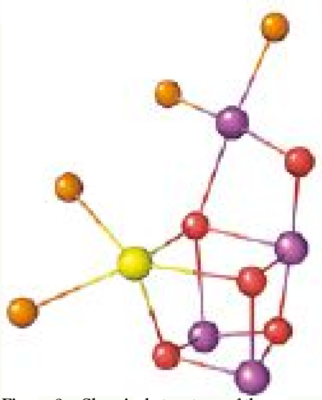

Figure-2 Chemical structure of the Mn_4CaO_5 cluster

Chemical structure of the Mn4CaO5 cluster

Figure 2 shows the detailed chemical structure of the Mn_4CaO_5 cluster that operates in this complicated reaction. It has a shape like a warped distorted chair, and this has been revealed to the world for the first time through this crystal structure analysis. The resolution is 1.9 A (angstroms). Resolution as used here means the shortest distance that can clearly separate two points, and 1 angstrom equals 1/10,000th of a micron, so in the present structural analysis the two atoms that are combined in the center of the molecule can clearly be distinguished. In the illustration, the 4 atoms of manganese (Mn) are shown colored purple, calcium (Ca) is yellow, the 5 atoms of oxygen that connect them are red, and the 4 atoms of oxygen from the water that is combined with the cluster are shown as orange. What we particular notice is that the special oxygen is the cause of the chair's warped distorted shape, which is in the middle right side of the calcium in long distances from the surrounding metals, and the two units of water that are near it–2 of these 3 atoms of oxygen (which combination it will be is unclear) we can expect to combine into an oxygen molecule. If we accept this expectation as our working hypothesis, we can envision the reaction mechanism of PSII that releases oxygen. If When we assume that refer the molecular structure has been undeniably clarified by the current structural analysis and we have a vision of the reaction mechanism, we can design an artificial catalyst to break down water and produce oxygen, and we can predict expect that in the future synthesis research will develop on a global scale.

Towards artificial photosynthesis

In the Advanced Research Institute for Natural Science and Technology's A Research Group, development of artificial antennas for the efficient collection of solar radiation is being pursued, and research on the synthesis of metallo-organic complexes that will absorb sunlight and produce a stable charge-separated state, and research on artificial catalysts that can produce oxygen from water are all being carried out, so one may believe that it will not take much time before an artificial oxygen-producing catalyst is synthesized modeled on the structure of the Mn_4CaO_5 cluster which has now been revealed. Looking ahead towards the realization of artificial photosynthesis, the remaining issues are artificial catalysts that can cause hydrogen to be produced at the same time that oxygen is; the development of artificial catalysts for synthesizing methanol from carbon dioxide; and to create a system that combines these together with the antennas, the charge-separation complex, and the oxygen-producing catalyst generation mentioned above. In ultimately creating a system and making it highly efficient, one can expect that there will be major hurdles to overcome like the development of artificial catalysts for synthesizing hydrogen and methanol, the know-how for integrating each of these modules into a system is already being accumulated in the world of industry, and if we can collaborate fruitfully with industry, I believe there is abundant potential for realizing the artificial photosynthesis that is our goal.

OCARINA Communication 1
The OCU Advance Research Institute for Natural Science and Technology

Osaka City University's Advanced Research Institute for Natural Science and Technology

At present, among the problems that we human beings must urgently solve are the lack of energy, the lack of water resources, and global warming. At the same time that these are problems created by modern cities, they exert tremendous influence over the cities themselves and can precisely be said to be symbolic of contemporary urban problems. For those of us who live in Osaka, these are of course pressing problems, and as one of the government's designated major cities, to lead the world in proposing and advocating policies and guidelines that appropriately deal with these problems is an extremely essential and important task.

Towards that end, at Osaka City University we have strategically fused together the wisdom of the separate research disciplines of this university and established OCARINA, the OCU Advanced Research Institute for Natural Science and Technology as the research organization to pursue the organic development of the core themes. In the project we are currently pursuing, "Strategic New Development for Rebirth of the Urban Environment," we are dealing with the following three research topics:

Strategic Topic A: Pioneering and industrial application of the next generation of energy;

Strategic Topic B: Constructing sound utilization methods for groundwater resources to preserve the metropolitan environment and prevent ground subsidence;

Strategic Topic C: Spatio-temporal changes of the environment and ecology of the metropolitan area.

These topics are inclusive, including a range of scales from microscopic spaces to macroscopic forecasts. In order to appropriately respond to the various problems to environmental problems in the urban region and at the global scale, it is indispensable to have mutual communication that transcends the boundaries of disciplines. We also believe we have a responsibility to convey the results we obtain to all the citizens of Osaka and to the wider world.

It has been just one year since the Advanced Research Institute for Natural Science and Technology began operating formally as an organ. At the end of last year we were able to able to establish a base in Hall Number 2. Moreover, construction work has now substantially begun on the new Natural Sciences Building Complex, scheduled for completion in the summer of 2012, which will become our second base. From our desire to urgently solve global scale issues, we first brought together the people and the knowledge, but physical improvements to our facilities are also advancing, and we intend to make this into a world-leading research institution.

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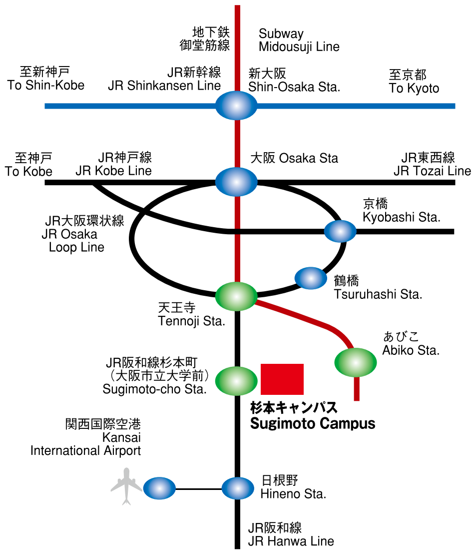

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