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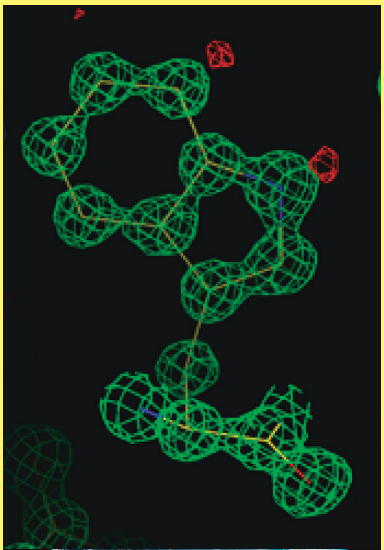

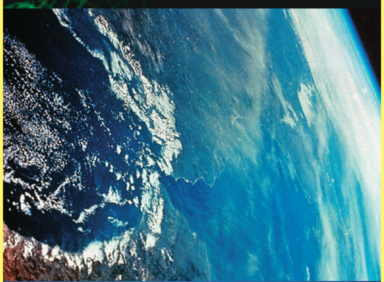

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Foreword

This is the latest issue of "Science and Technology Trends — Quarterly Review".

National Institute of Science and Technology Policy (NISTEP) established Science and Technology Foresight Center (STFC) in January 2001 to deepen analysis with inputting state-of-the-art science and technology trends. The mission of the center is to support national science and technology policy by providing policy makers with timely and comprehensive knowledge of important science and technology in Japan and in the world.

STFC has conducted regular surveys with support of around 2000 experts in the industrial, academic and public sectors who provide us with their information and opinions through STFC's expert network system. STFC has been publishing "Science and Technology Trends" (Japanese version) every month since April 2001. The first part of this monthly report introduces the latest topics in life science, ICT, environment, nanotechnology, materials science etc. that are collected through the expert network. The second part carries insight analysis by STFC researchers, which covers not only technological trends in specific areas but also other issues including government R&D budget and foreign countries' S&T policy. STFC also conducts foresight surveys periodically.

This quarterly review is the English version of insight analysis derived from recent three issues of "Science and Technology Trends" written in Japanese, and will be published every three month in principle. You can also see them on the NISTEP website.

We hope this could be useful to you and appreciate your comments and advices.

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Executive Summary

Life Sciences

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Recent Trends in Animal Experimentation in Japan
— On the Revision and Implementation of the Law for the Humane Treatment and Management of Animals —

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In Japan, the Law for the Humane Treatment and Management of Animals, which was amended in 2005, went into effect on 1st June 2006. This new amendment means that the act now includes consideration of the 3R principles of humane animal experimentation. The 3R principles regarding the welfare of laboratory animals have been established on an international scale. These principles call for, wherever possible, and in a way that will not have a detrimental affect on achieving the scientific objectives behind the use of animals in experimentation, the 'Replacement' of methods which use laboratory animals by those which do not, the 'Reduction' of the numbers of animals used in experimentation, and the 'Refinement' of experimentation, using wherever possible those methods which will cause the least amount of pain to laboratory animals. In the previous law, only 'Refinement' was included as a mandatory item, and 'Replacement' and 'Reduction' have now been added as items for consideration. Thus, the law now covers all of the 3R principles.

In regard to the legal position of animal experimentation and laboratory animals within this same law, in as far as this law has been prescribed from an animal welfare perspective, the subject of the regulatory management stipulated within is considered to be 'laboratory animals (and the improvement of the welfare of such)' and not 'animal experimentation (the act of utilizing laboratory animals).' As a result, this law functions in such a way as to provide fundamental principles of policy, and does not contain any stipulations which could have any direct effect on the contents and scope of animal experimentation, such as evaluations of the necessity of animal experimentation, or the scientific appropriateness of experimental technique used.

Looking towards the enforcement of the amended Law for the Humane Treatment and Management of Animals, government ministries affected by the changes worked towards both revision of current standards and guidelines, and the establishment of new standards and guidelines. In terms of animal experimentation, the Ministry of the Environment revised its 'Standards Relating to the Care and Management of Laboratory Animals and Relief of Pain', and both the Ministry of Education, Culture, Sports, Science and Technology (hereinafter MEXT), and the Ministry of Health, Labour and Welfare (hereinafter MHLW) worked towards drawing up basic guidelines for carrying out animal experimentation (hereinafter Basic Guidelines for Animal Experimentation). The ethics and principles behind the management structure of animal experimentation in Japan are stipulated in law (Law for the Humane Treatment and Management of Animals), and according to relevant ministerial guidance, such as the issuing of proclamations and notifications, each research facility will be required to implement a system whereby it is independently responsible for regulating animal experimentation. In the sense that the Japanese system relies on self-regulation and independent management within experimental facilities, it is very similar to those of both the United States and Canada. On the other hand, in the United Kingdom, France, Germany and Switzerland, animal experimentation is regulated by government legislation and, apart from France, all of these countries also operate systems for review and accreditation of experimental facilities, experimental design, and of persons conducting animal experimentation.

With regard to the number of laboratory animals used in animal experimentation, the only research currently carried out in this area in Japan consists of surveys conducted on a voluntary basis and overseen by concerned bodies; as a result, the real number of animals involved remains unclear. However, according to the results of official investigations published in the United States, Canada and the United Kingdom, the number of animals used in experimentation seems to have either leveled off, or is increasing only very slightly. It is also clear that animal experimentation continues to be an valuable tool in terms of scientific and technological research.

In order to ensure that animal experimentation is carried out properly in Japan, and further to see that the results of such experimentation help fuel an increase in interest in the life sciences, it is crucial that measures be put in place to facilitate the creation of a self-regulation and independent management system for experimental facilities, centered on the Basic Guidelines for Animal Experimentation outlined above. The guidelines drawn up by MEXT and MHLW both require experimental facilities to carry out self-checks and evaluations to regulate the compatibility of said facilities and the relevant guidelines. In this report, I hope to be able to offer some suggestions as to how to best go about creating this management system for animal experimentation, keeping in mind the establishment of an external assessment system (that includes the implementation of the basic guidelines mentioned above), as well as a self-regulating system.

(Original Japanese version: published in May 2006)

Information and Communication Technologies

2 Energy Issues Confronting the Information and Communications Sector
—Need to Reduce the Power Consumed by the Communications Infrastructure—

p.32

People tend to associate energy issues only with the energy used for transport, distribution and manufacturing. However, energy consumption related to information and communications technology (ICT) is now attracting global attention.

In the U.S., a sense of crisis that the amount of electricity used for ICT may come to account for a few tens of percent of national power generation has given rise to a debate on the matter since the late 1990s. In Japan, similar concerns are rising now that the NTT Group, which owns the majority of the Japanese ICT infrastructure, purchases as much as 1% of the total electricity produced in the country, which is double the amount it purchased in 1990. Since the latter half of the 1990s, communications traffic in Japan has grown faster than Moore's Law, at an annual rate of 40%, and is still growing at the same pace. With a further increase in data traffic expected, driven by a full-fledged spread of video distribution and other products resulting from the convergence in broadcast and communications and by wider availability of online public and information services, this rapid growth will highly likely continue for at least the next few years. Some even project that the power consumption of the network infrastructure, which will have to be enhanced to meet such increases in communications traffic, will grow to account for almost 50% of today's total power generation by 2020 if advances in low-power device and circuit technologies slow down.

Although Japan leads the world in low-power device and circuit technologies, especially for consumer products, direct extensions of conventional technologies may not be capable of reducing power consumption of routers that serve as the core of the communications infrastructure. This issue needs to be discussed systematically from different perspectives such as devices, equipment and network architecture, and such discussions will require a cross-sectional approach or area-specific approach among different ministries and agencies. In either approach, the government should formulate a grand design that encompasses everything from devices and systems to power generation.

On the other hand, the growing human desire for information, which brings about an increase in communications traffic, needs to be examined from social scientific perspectives, in light of the essence of communication as the foundations of ICT. For example, families often give a high priority to spending on mobile telephones even when they have to curtail other expenditures, a tendency that is not observed in their spending on other consumer goods. It is also known that humans tend to pursue the desire for information beyond their cognitive capacity (the brain's capacity to recognize and process information). With this in mind, the growth of the ICT sector should also be examined from the viewpoints of cognitive science and detailed economics. This poses a major challenge in the interdisciplinary field spanning engineering and social science.

These energy problems in the ICT sector could prove to be critical in the sustainable development of Japan and the world.

(Original Japanese version: published in June 2006)

Environmental Sciences

3 Restration and Recovery Technologies for Illegal Dumping of Waste Pollution

p.42

As society’s concern for safety and security has increased in recent years, so too has the Japanese people’s expectations that science and technology will help address these issues. As stated in the 3rd Science and Technology Basic Plan, greater contributions to safety and security will be required of science and technology policy in the future. Along with contributing to the economy and the creation of new knowledge, safety and security is the third key criterion in this Plan. The illegal dumping of waste is a problem that must be addressed since it threatens society’s safety and security.

The illegal dumping of waste is not only an impediment to the creation of a sound material-cycle society, it also causes serious environmental problems by polluting the environment with toxic substances included in the dumped waste. The early detection of such problems and implementation of countermeasures is therefore extremely important in minimizing their impact. Pollution from illegal dumping is caused by pollutants with widely differing types and characteristics, the polluted environmental media vary widely among soil, water, sediment, and so on, and the size and volume is very large. This differs from the typical environmental pollution caused by other human and industrial activities. Social factors such as the cost of waste disposal are also intimately related to the incidence of illegal dumping. In order to address the root causes of illegal dumping, the social and economic structures that contribute to it must be sufficiently understood so that effective preventive systems can be introduced. This article summarizes and analyzes the status of illegal dumping and the environmental pollution it causes, surveys the effectiveness of the range of technological countermeasures taken, and addresses those science and technology policy issues that should be directed as preventative technologies against illegal dumping and as pollution recovery technologies.

An example of the use of technology to restore environments damaged by illegal dumping includes the excavation and shipment of contaminated soil and waste from one island to another where they are detoxified by intermediate processing using high-temperature melting, with the molten slag produced then being reused as a resource. In addition, advanced treatment processes such as VOC removal and advanced oxidation can be applied to water seeping from illegal dump sites. In this way, specific technologies should be applied to particular soil and water conditions for maximum effect. Since it may take a long time for illegal dumping to become apparent, and since the scale and impact can be so large, the situation must be understood so that emergency, urgent, or permanent measures can be taken and an effective and appropriate response implemented. Recovery technologies include the use of physicochemical and biological technologies, separation and decomposition technologies, and technologies for in-situ decontamination and decontamination following excavation. The ways in which these technologies are applied should be optimized and the development of specific pollution recovery technology and application methods should be promoted, taking into account the particular characteristics of each type of environmental risk.

In order to more effectively control and monitor illegal dumping, support tools are needed that make use of advanced science and technology. Satellite monitoring systems can be effective in the early detection of illegal dumping and in preventing its spread and impact, thereby minimizing environmental pollution. From the perspective of prevention, survey technology for the quick and systematic detection of problems and simulation systems should also be developed.

(Original Japanese version: published in April 2006)

4 Proposition in order to Promote the Practice of the Environmental Conduct by the Individual

— Promotion of Environmental Education and the Utilization of Environmental Monitoring Data —

p.59

In 1997, Japan agreed to the greenhouse gas reduction goals of the Kyoto Protocol. Japan's goal is to reduce emissions for 2008-2012 to 6 percent below the 1990 level. Looking at 2002 CO_2 emissions by sector, however, although the industrial sector, which accounts for the largest percentage of emissions, showed a 1.7 percent decrease, the household sector showed a 28.8 percent increase rather than a reduction. It is therefore necessary to raise environmental awareness and promote the understanding of all members of the public regarding energy issues and energy conservation measures. Individual efforts to address water and air pollution, waste, and various other environmental issues are also very important.

According to a 2003 survey of attitudes towards energy and environmental issues, a large percentage of young people (in their 20s) said that "I don't know what I can do" (60.2 percent) and/or "Even if I do something, I can't see it having any effect" (61.1 percent) when it comes to environmental conservation activities. From these and other findings, it is apparent that prompt action is needed on the dissemination of environmental education which will have a significant impact on individual efforts.

Environmental education in Japanese primary and secondary schools is not a separate subject from social studies, science and so on, but is carried out as part of other subjects throughout the school curriculum. At both elementary and junior high school level, however, some schools often include the subject in the curriculum while other schools rarely take it up. More support for enhanced environmental education is desirable and, in higher education, comprehensive environmental education is needed for students with a low awareness of environmental issues. Another issue is the fact that environmental education is not a required course for university students training to become teachers, even though they will play an important role in the education of future students.

The goal of environmental education is the promotion of individual environmental conservation activities. This process comprises three stages: (i) understanding of environmental conditions and awareness of environmental issues, (ii) understanding of concrete actions that can be taken by individuals, and (iii) implementation and continuation of individual environmental conservation activities. In order to overcome environmental problems, it is extremely important that people can personally experience the results of their activities at each stage of progress through methods such as visualization. Therefore, the utilization of environmental monitoring data and the development of equipment that transmits data in concrete figures is vital.

Based on the above, the following three points should be noted in order to promote environmental conservation activities by individual members of the public.

(1) Enhanced support for environmental education in primary and secondary schools and further promotion of environmental education in higher education
(2) Raising awareness of environmental problems and promoting understanding of concrete actions that can be taken for environmental conservation
(3) Dissemination and development of support systems and equipment that provide feedback to help facilitate environmental conservation activities

(Original Japanese version: published in May 2006)

Nanotechnology and Materials

5 Patent Application Trends in the Field of Nanotechnology

p.77

Since the Japanese government prioritized nanotechnology in 2001 and because of its wide range of applications, there have been growing expectations that there will be major achievements in this field. The Promotion Strategy for the Prioritized Areas, which was formulated by the Council for Science and Technology Policy in March 2006, stresses the need to implement an intellectual property strategy targeted at specific areas of application in the field of nanotechnology. However, almost no research has been conducted to obtain an overview of patent application trends in this field. Therefore, this article outlines these trends by country, sector and application, with the objective of providing a brief overview of patent application trends.

Keyword searches were used to extract nanotechnology-related patents and technologies that appear to be related to its applications from patent publications released by the patent offices in Japan, the US and Europe, as well as the World Intellectual Property Organization (WIPO). Extracted patents were categorized according to nine designated areas of technology, by sector, by nationality of applicant as well as by other criteria. The principal results of the analysis are as follows.

- The total number of nanotechnology patents registered with the Japan Patent Office accounts for approximately 1% of the total number of patent applications.
- The number of nanotechnology patent applications is increasing yearly for all patent offices.
- Nanotechnology patent applicants are predominantly American, followed by Japanese and German applicants. The top two nationalities (American and Japanese) account for more than 70% of the total number of applicants.
- Approximately 72% of patents registered with the Japan Patent Office are of Japanese origin (meaning that the inventors of these patents are Japanese). Approximately 62% of inventors of patents registered with the United States Patent and Trademark Office are American. Thus, the percentage of patents registered by the country's own citizens varies depending on the patent office.
- Patent applications by sector show that the largest percentage of all applicants, approximately 80%, is from corporations. This is true for all countries. University applicants account for the second largest percentage in such countries as the US, the UK, Canada and the Netherlands. Meanwhile, public research organizations account for the second largest percentage in such countries as Japan, Germany, France and South Korea. Hence, two major trends are observed; the US-type trend and Japanese-type trend.
- A cross-country comparison of the areas of technology in which nanotechnology is applied reveals that different countries have different characteristics. The US comes out on top in all areas of technology in terms of the number of applications. Japan compares favorably with the US in the materials area, but is far behind the US in the medicine and life science areas.

This article was compiled by reorganizing the results of research and analysis conducted by the Nanotechnology Researchers Network Center of Japan, together with the cooperation of the same center. Presently, the Center is categorizing and analyzing US patents by state as part of its ongoing research of nanotechnology patents [1].

[1] Nanotechnology Researchers Network Center of Japan: http://www.nanonet.go.jp/english/

(Original Japanese version: published in June 2006)

Frontier

6

Trends in Research on the Utilization of Microgravity
— Competition and Collaboration between Research in Space and Research on the Ground —

p.89

It is more than 20 years since Japan started experiments utilizing the space environment (space experiments), and a great deal of new fundamental knowledge has been obtained. Noteworthy achievements include single crystal growth of semiconductors, single crystal growth of proteins, space breeding, and medical experiments with astronauts as the test subjects.

Space experiments are being performed worldwide. The construction of the International Space Station (ISS) is expected to speed up as a result of the resumption of full-scale operation of the space shuttle, and there is a good possibility that the Japanese experiment module (JEM), “KIBO,” will be launched in FY2007. The samples of three-dimensional photonic crystals and high-quality protein crystals prepared in the experiments conducted on the ISS since December 2005 were returned to the earth on April 9, 2006 without any problems. The space environment is being utilized for industrial and commercial applications with experiments being performed on products with nonconventional functions and on the development of new pharmaceuticals.

Prior to the full-scale operation of “KIBO,” there are many issues to be sorted out concerning the conditions for the utilization of the microgravity environment. Important factors in the utilization of microgravity environment are: (i) quality, (ii) cost, (iii) shorter turnaround time (or timely provision of samples to researchers), and (iv) support systems. By the time the ISS is in full use, all of these four factors must be improved. The opportunities for utilizing microgravity environments are not limited to "KIBO." In addition to the U.S.A. and Russian modules on the ISS, drop test facilities, parabolic flight by aircraft and small rockets, recoverable satellites, and manned spacecraft also provide microgravity environments. The following actions are recommended for promoting research on the utilization of microgravity in the future with competition and collaboration between experiments on the ground and in space.

(1) Promotion of research on microgravity prior to the full operation of “KIBO”

Although opportunities for experiments to utilize microgravity environment are increasing, they are still of high value. Relevant parties must increase their commitment to the development of experimental instruments and the performance of experiments on the one hand, and, on the other, the government must pave the way for a better environment for research so that more researchers can fully utilize the experimental instruments.

(2) Promotion of industrial and commercial applications of the microgravity environment

Since activities related to the full-scale utilization of the space environment will come on stream with the prospect of the operation of “KIBO,” opportunities for experiments aimed at industrial and commercial applications of the space environment should be utilized more than ever.

(3) Other possible benefits

It is difficult to obtain new knowledge without developing new experimental methods. To go through the step-by-step process from the creation of an idea to the implementation of experiments on the study of microgravity in a university education course would be a valuable experience for students. Such an experience will give them the basic technical competence necessary for a range of future applications. Prior to the routine operation of full-scale space experiments, creative ingenuity in research and development, including activities in the preparatory stages, will lead to the arising of national pride in Japan's science and technology.

(Original Japanese version: published in April 2006)

Science & Technology Policy

7 Report on the Annual AAAS Forum on Science and Technology Policy

p.106

On April 20 and 21, the American Association for the Advancement of Science (AAAS) held its annual Forum on Science and Technology Policy in Washington, DC. With people such as Dr. John H. Marburger, Science Adviser to the President and Director of the Office of Science and Technology Policy (OSTP), and Samuel W. Bodman, Secretary of the US Department of Energy (DOE), participating, the forum was an important opportunity to understand the direction of science and technology policy in the US.

In his address at the forum, Dr. Marburger noted that federal research and development expenditures increased by 45 percent during President Bush’s first term. That was the highest rate of growth since the Apollo program of the 1960s and early 1970s. He also described the American Competitiveness Initiative (ACI), which was announced by the OSTP in February 2006 in conjunction with the budget proposal for fiscal 2007 (October 2006 through September 2007), and emphasized the government’s commitment to research and development. The purpose of the ACI is to increase US global competitiveness through federal investment in research, tax breaks for research and development, and human resources development. It has a budget of about $6 billion.

From the AAAS, Kei Koizumi, Director of the organization’s R&D Budget and Policy Program offered an analysis of fiscal 2007 research and development budgets. According to Mr. Koizumi, factors such as hurricane relief, the war in Iraq, and tax cuts are having a profound effect on budgets. Budgets for the National Science Foundation (NSF), the DOE and the National Institute of Standards and Technology (NIST) increased through the ACI, but expenditures for other agencies related to research and development decreased. It is clear that with population increase and greater longevity, costs for Social Security, the health insurance system for the elderly, and the healthcare system for low-income people will continue to rise. In addition, defense spending is a heavy burden for the federal government. The AAAS analysis asserts that this trend will continue for several years, and some government agencies will have to deal with budget cuts of 10-30 percent.

In part because of the sudden jump in gasoline prices, the session on “Science and Technology Policy for the Energy Challenges of the 21st Century" drew a great deal of interest. One presentation described the social risks that will be brought about by climate change, stated that technology is the key to reducing those risks, and discussed the issue of who is to invest in that technology. Although investment in research and development on hydrogen energy remains active, there were strong opinions that its practical application, particularly as a fuel for automobiles, remains unrealistic because of infrastructure and supply problems. The budget proposal requested a 22 percent increase for the DOE's clean energy research. This included a 75 percent increase for solar power and a 62 percent increase for biomass. The budget for hydrogen and fuel cells increased by 23 percent. There is no budget for geothermal research, indicating that there is little interest in the subject at this time. Several papers related to climate change were presented. Because the relationship between industrial activity and climate change can no longer be ignored, the government has also become active on the issue of CO_2 emissions.

Another theme for discussion was unethical behavior that has occurred in the science and technology fields. Other discussion topics included the need for ethics education for scientists and some subjects that are not relevant to Japan (e.g. the emphasis on military research, immigration issues, etc.).

In addition, one of the presenters brought up the e-Japan Strategy as an example of how the US should work strategically to construct networks.

(Original Japanese version: published in June 2006)

1

Recent Trends in Animal experimentation in Japan
— On the Revision and Implementation of the Law for the Humane Treatment and Management of Animals —

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1 Introduction

Animal experimentation has played a very important role in the life sciences, particularly in health science, which is directly concerned with the survival and health of humankind. It goes without saying that the information gleaned from animal experimentation has contributed a great deal to research into fundamentally important human medicine and veterinary medicine, which of course helps to cure and prevent diseases in both humans and animals, and also contributes to education and training in healthcare technology. In Japan in recent years, how best to ensure the safety and hygiene of food and to take measures against the pollution of the natural environment, have become issues of national concern, and animal experimentation has been used effectively to evaluate such things as food additives and pathogens, and the harmful effects of chemicals and other residual substances found in the natural environment.

Last year, the Law for the Humane Treatment and Management of Animals (hereinafter the Amended Law for the Humane Treatment and Management of Animals)[2] was amended in order to create legislation that gave consideration to the 3R principles*1. These principles represent the fundamental thinking of the international community in terms of the welfare of laboratory animals used in animal experimentation. In preparation for the implementation of this law, on 1st June 2006, government ministries affected by the changes worked towards both revision of current standards and guidelines, and the establishment of new standards and guidelines.

Ensuring that animal experimentation is carried out according to these 3R principles is a global trend. The recent revision of the Law for the Humane Treatment and Management of Animals in Japan has provided an appropriate opportunity for change in this country; basic guidelines for carrying out animal experimentation were formulated by relevant government ministries (hereinafter Basic Guidelines for Animal experimentation), and independent management systems for each experimental facility are gradually being put in place.

In this article, I have attempted to outline a picture of the legal management systems in place for animal experimentation in Japan from a scientific point of view. This I will compare to the legal situation regarding animal experimentation in Western countries, and will make suggestions as to what is required in order to improve the independent management systems for animal experimentation in Japan. Further, in regards to the appellations used for types of animal and so on, these have, unless otherwise specified, been matched to those used within the Law for the Humane Treatment and Management of Animals.

Concerning to the several names of regulations, standards and committees etc. in this article, I bestowed their suitable names because I could not identify their official English names on websites.

2 The background to, and an outline of, the Law for the Humane Treatment and Management of Animals — in terms of animal experimentation and laboratory animals —

2-1 The position in law of animal experimentation and laboratory animals

The Law for the Humane Treatment and Management of Animals not only contains articles relating to the humane treatment of animals, such as the prevention of cruelty to animals and appropriate ways of treating animals, but also outlines regulations for the correct management of animals. The animals covered by this law are considered to be those that come into close contact with humans, and includes domestic animals, animals exhibited in places such as zoos, and farm animals, as well as laboratory animals. Further, one distinction of this law is that the regulations stipulated differ according to the purpose and role of each category of animal, from domestic dogs and cats, to animals in general.

In regard to the legal position of animal experimentation and laboratory animals within this same law, in as far as this law has been prescribed from an animal welfare perspective, the subject of the regulatory management stipulated within is considered to be 'laboratory animals (and the improvement of the welfare of such)' and not 'animal experimentation (the act of utilizing laboratory animals)[*2].' As a result, this law functions in such a way as to provide fundamental principles of policy, and does not contain any stipulations which could have any direct effect on the contents and scope of animal experimentation, such as evaluations of the necessity of animal experimentation, or the scientific appropriateness of experimental technique used.

2-2 Background to the amendment

The provisions of and amendments to this law were all carried out on the initiative of the lawmakers themselves. The law was enacted in September 1973, then referred to as the 'Law concerning the Protection and Control of Animals' (issued by the then Ministry of Internal Affairs and Communications). The name was subsequently amended in December 1999 to its current appellation (this previous law is hereinafter referred to as the Old Law for the Humane Treatment and Management of Animals). Jurisdiction was transferred to the Ministry of the Environment (hereinafter MOE) in 2001, as part of the reorganization of central government ministries. It was amended further in June 2005 (Amended Law for the Humane Treatment and Management of Animals).

As part of the 1999 amendment, new measures were included that were intended to improve the environment in which pet animals were kept, as a response to both the increasing awareness of the need to treat animals humanely, and also the fact that the abandonment of, and cruelty to, domestic pets was starting to come to the attention of society. However, provisions concerning animal experimentation were excluded from any amendments, with the comment "self-regulation and independent management based on the current standards[*3] shall continue to be seen as fundamental." Other issues had also been left unamended, such as the need to strengthen regulations for businesses dealing with animals; for this reason a review of the law was begun for completion in 2005, approximately 5 years after the introduction of the amended version, and additional rules, designed to put in place measures deemed necessary through examination, and supplementary resolutions intended to combat issues considered unresolved, were put in place[4,5].

Each political party carried out investigations necessary for the revision of this law, based on the way that the Law for the Humane Treatment and Management of Animals had been stipulated and subsequently amended through the initiation of members. At the same time, in February 2004 the MOE held the '1st Investigative Committee on the Nature of Animal Welfare Management,' which carried out surveys and investigations into how the law was being carried out. On the basis of the results of such investigations, it was decided in June 2005 that the law should again be put up for amendment through the initiative of the lawmakers.

2-3 The scope of reform

In terms of regulations regarding laboratory animals and animal experimentation, stipulations on both the welfare of laboratory animals and the ethics of animal experimentation were included in Article 41 of the amended law, 'cases in which animals are provided in order to be utilized for a scientific purpose.' In the old law, only 'Refinement' had been included as a mandatory item from among the 3R principles, which set out international thinking on the welfare of laboratory animals. However, the newly amended law includes the other two Rs, 'Replacement' and 'Reduction', as items for consideration. Thus, the law now covers all of the 3R principles.

3 Regulations on animal experimentation in Japan, Canada, the US and Europe

3-1 International regulations on animal experimentation (Table 1)

The laws and regulations regarding the management and administration of animal experimentation in each country are based on the international principles laid down by the Council for International Organizations of Medical Sciences (CIOMS). These international principles call for the reaffirmation and continued promotion of the 3R principles, as well as setting out guidelines for the evaluation of pain levels suffered by laboratory animals*4 and the strengthening of the functions of those bodies which examine and review the contents of animal experimentation.

3-2 Regulations in Japan

(1) Administrative regulations

Animal experimentation and laboratory animals are legally defined within Japan (Table 2). Animals used in laboratory testing should be bred, maintained and provided for those various purposes, and regulations apply to all animals used in tests, from small rodents such as mice and rats, through to cats, dogs, monkeys and birds. In accordance with the advancements in animal biotechnologies*5 seen in recent years, there have been cases in which domestic livestock, such as pigs and cows, have been used in experimentation [10].

The ethics and principles behind the administrative structure for animal

Table 1 : Outline of the main international guidelines on animal experimentation and laboratory animals

Name of guidelines (Year of enactments / date of newest amendment)	Prescribing body	Outline of guidelines
World Medical Association Declaration of Helsinki: Ethical Principles for Medical Research Involving Human Subjects (1964/2004)[6]	18th World Medical Association (WMA) General Assembly	• Advocates the ethics and welfare of all humans and animals in biomedical research
Guidelines for the Regulation of Animal Experimentation (1974)[7]	International Council for Laboratory Animal Science (ICLAS)	• Forms the basis of current laws and regulations on animal experimentation, prescribes an ethical framework • Reinforcement of the concept of the 3Rs • Makes clear the responsibility of the head of each facility involved in animal experimentation to ensure that the experimentation carried out is necessary in order to gain improvements in health and healthcare for both humans and animals, and further that objective decision-making is crucial when carrying out animal experimentation
International Guiding Principles for Biomedical Research Involving Animals (1985)[8]	Council for International Organizations of Medical Sciences (CIOMS)	
Declaration of Bologna: Reduction, Refinement and Replacement Alternatives and Laboratory Animal Procedures (1999)[9]	3rd World Congress on Alternatives and Animal Use in the Life Sciences	• Advocates the promotion and reaffirmation of the significance of the 3R principles • Outlines recommendations regarding the scientific and ethical rationalization of legal regulations (e.g. recommendations on the evaluation of pain levels suffered by laboratory animals; the strengthening of the influence of animal experimentation regulatory committees)

Prepared by the STFC

Table 2 : Definitions of animal experimentation and laboratory animals

	Laws and regulations	Scope of definition	Intended targets
Animal experimentation	Standards Relating to the Care and Management of Laboratory Animals and Relief of Pain (April 2006, MOE, Notification No. 88)	Provision of animals for the purposes of education, experimental research, and the manufacturing of biologics, and for any other scientific purpose	Education, experimental research, manufacturing of biological drug products and any other scientific purpose
Laboratory animals		Animals which are raised or maintained within facilities in order to be used for experimental purposes (including animals being transported to facilities for those purposes)	Mammals, birds and reptiles

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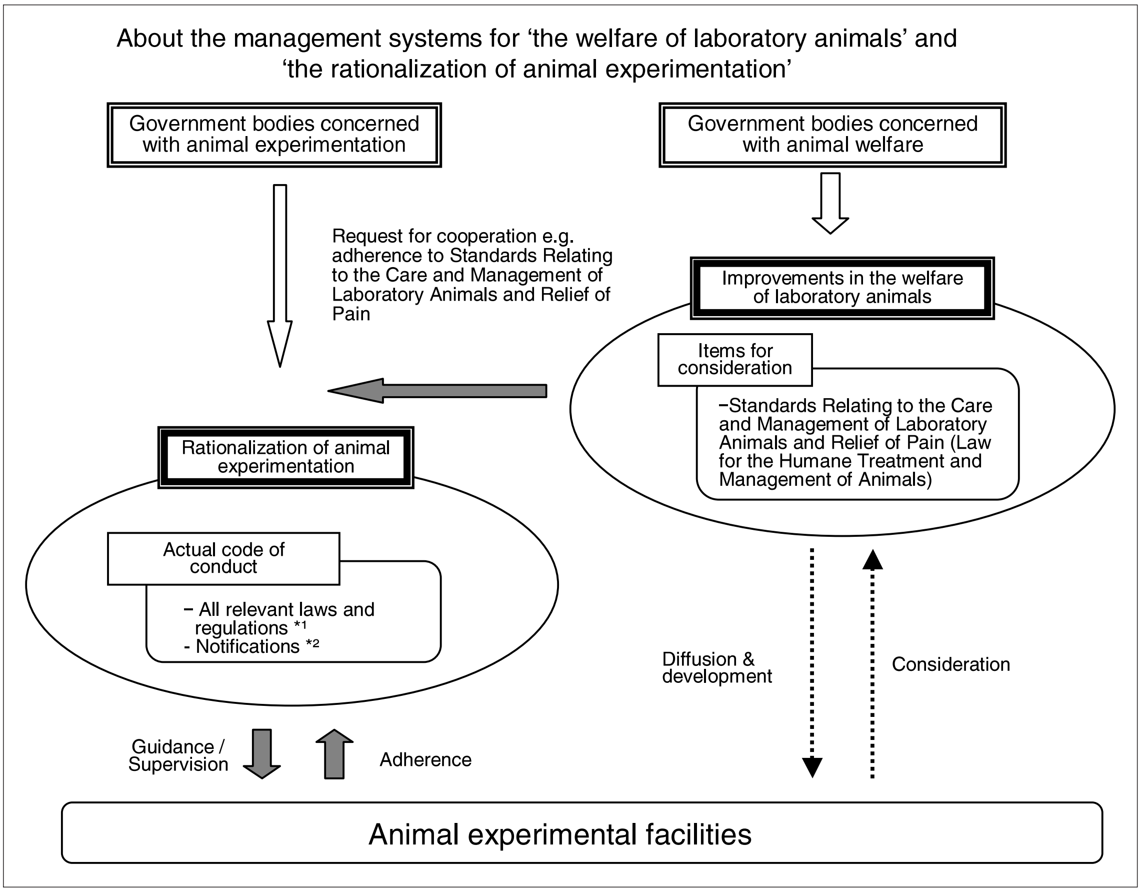

*1 Pharmaceutical Affairs Law, Industrial Safety and Health Law, Law concerning the Evaluation of Chemical Substances and Regulation of their Manufacture, etc.
*2 Notifications sent by MEXT to all heads of national, public and private universities, etc.
Note: Facilities engaged in the production and reproduction of laboratory animals (Agriculture, Forestry and Fisheries government administration) have been omitted from this chart.

Extracted from Reference[11]

Figure 1 : Management system for animal experimentation in Japan

experimentation in Japan, as mentioned in Section 2-1, are stipulated in law (Law for the Humane Treatment and Management of Animals), and according to both the proclamation which specifies those regulations that refer specifically to 'animals' (Standards Relating to the Care and Management of Laboratory Animals and Relief of Pain) and the notification on 'experimentation' (regarding Animal Experiments in Universities etc.), each experimental facility is required to implement a system whereby it is responsible for regulating animal experimentation independently (Figure 1)[11]. Further, in cases where animal experimentation is carried out for any kind of hazard assessment testing, the scope of any relevant conduct will be bound by the laws and regulations set out in the Pharmaceutical Affairs Law, the Industrial Safety and Health Law, and

Table 3 : Main efforts regarding independent management of animal experimentation in Japan

Government Measures	Measures Taken by the Science Council of Japan and Japanese Association of Laboratory Animal Facilities of National Universities	Measures Taken by Associated Academic Bodies & Associations
• Law for the Humane Treatment and Management of Animals (1973 Legislation No. 105; partially amended July, December 1999, partially amended 2005). • Standards Relating to the Care and Management of Laboratory Animals and Relief of Pain (April 2006, MOE, Notification No. 88) • Guidelines on the Disposal of Animals (Prime Minister's Office, Notification No.40, July 1995; partially amended December 2000) • Animal Experiments in Universities etc. (Notification of the Director-General of the Science and International Affairs Bureau, Ministry of Education, Science, Sports and Culture; 1987) (Ministry of Education, Science, Sports and Culture, Information Publication No. 141) • Introduction of Laboratory Animals in Universities etc. (Notification) (Notification of the Director-General of the Research Promotion Bureau, Ministry of Education, Culture, Sports, Science and Technology (MEXT); January 2001) (12th MEXT Promotional Proclamation No. 42)	【Science Council of Japan】 • Planning with Respect to the Guidelines for the Care and Use of Animals (Recommendations) (1980) • Ethical and Practical Problems Encountered During the Treatment of Animals in Education and Research, and Some Suggestions (August 1997), 16th Special Committee on the Relationship between the Development of Life Sciences and Social Understanding • Suggestions on How to Improve Social Understanding of Animal Experimentation (Report No.7, July 2004) 【Japanese Association of Laboratory Animal Facilities of National Universities】 • Guidelines on the Giving and Receiving of Laboratory Animals: Mice and Rats Edition (Final revision, May 2001) • Understanding the Classification of Levels Based on Pain, Distress and Stress Suffered by Laboratory Animals (June 2004) • Basic Concept on the Treatment and Handling of Genetically Modified Animals etc (May 2005)	【Japanese Association for Laboratory Animal Science】 • Guidelines on Animal Experimentation 【Physiological Society of Japan】 • Guiding Principles for the Care and Use of Animals in the Field of Physiological Sciences 【Japanese Pharmacological Society】 • Guiding Principles for the Care and Use of Laboratory Animals, Approved by Japanese Pharmacological Society 【Japan Neuroscience Society】 • Guidelines on Animal experimentation within the Japan Neuroscience Society 【Japanese Society of Toxicology】 • Japanese Society of Toxicological Sciences Guidelines on Animal Experimentation 【Japanese Society for Laboratory Animal Resources】 • Laboratory Animal Welfare Charter • Guidelines on the Transportation of Laboratory Animals • Guidelines on the Euthanasia of Laboratory Animals

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Law concerning the Evaluation of Chemical Substances and Regulation of their Manufacture, etc., as well as the Agricultural Chemicals Regulation Law. Depending on the purpose of the experimentation, experimentation may be subject to several laws; no guidelines have been drawn up on creating an integrated method for managing animal experimentation through combining these pieces of legislation into a single comprehensive law.

According to the scope of conduct based on the government guidelines laid out in the above proclamations and notifications, and other relevant legislation, each testing facility must establish a system of independent management and administration; it must set out internal regulations, establish an animal experimentation committee which will be responsible for the review and approval of experimental design, and carry out training programs for those staff responsible for conducting animal experimentation. These internal regulations must indicate clearly the way in which laboratory animals are to be handled, with a view to their welfare, as well as those scientific methods of use which are acceptable within the facility. The regulations should be drawn up with consideration to the guidelines on animal experimentation that have been published by the Science Council of Japan, the Japanese Association for Laboratory Animal Science (JALAS), the Japanese Society for Laboratory Animal Resources (JSLA), and other academic bodies concerned with animal experimentation (Table 3).

(2) Systems of accreditation through related organizations

In Japan, there is no legal system for the licensing of those persons who carry out animal experimentation. However, JSLA and the Japanese Association for Laboratory Animal Medicine (JALAM), affiliated with the Japanese Society of Veterinary Science (JSVS), has set out guidelines on skills and technical standards required when handling laboratory animals. Both of these bodies accredit those persons proven to have met these standards by passing an examination: the former confers the Laboratory Animal Technician Diploma (approved by JSLA) and the latter the JALAM-approved Laboratory Animal Veterinarian.

3-3 Regulations in Europe, the US and Canada

One feature characteristic of the regulations of animal experimentation in Western countries is that in many cases there are in place legal and regulatory measures, in one form or another, which refer specifically to both the execution of animal experimentation, and to the humane treatment of laboratory animals. The nature of these regulations differs according to country, but one can broadly place them in one of two general categories: the management systems of the United States and Canada, which are centered on the principle that the experimenter themselves will be responsible for individual and autonomous management; and the systems seen in Europe, which tend to place emphasis on management being achieved through regulations overseen by governmental authorities. However, one important similarity is maintained throughout: be it the United States, Canada, or Europe, nationally uniform regulations are in place which are designed to guarantee certain standards for animal experimentation. The responsibility for drawing up these standards differs from country to country. In the United States and Canada, that responsibility lies with organizations concerned with the furthering of scientific research, namely a subsidiary organization of the National Academy of Sciences and a government-controlled NPO respectively, whilst in EU countries, national laws tend to reflect the stipulations of EU Directives.

(1) EU countries

Each member country has established laws relating to animal experimentation according to the following EU Directives: the European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes[12], and the Protection of Animals Used for Experimental and Other Scientific Purposes (EU Directive 86/609/EEC)[13]. With regard to the latter directive, EU member countries are required to institute this as domestic legislation; this in turn stipulates that countries must establish a system whereby the experimental facilities, the experimental design, and the persons responsible for carrying out the testing must be reviewed and approved directly by the national authorities. Therefore, if those experimental designs, intended to be carried out at facilities deemed to be meeting specific standards as set by the national government, and which are recognized as constituting a balance between both scientific and animal welfare perspectives, are not carried out by a person possessing the appropriate license, then that practice will be punishable as an illegal act.

• United Kingdom

Has a centralized system of laws and regulations in force, based on the Animals Act of 1986[14]. The Home Office oversees a system of certification for animal experimental facilities, for experimental design, and for those who carry out such experiments, based on these laws.

• France

Based on the government ordinance on animal experimentation (No. 87-848), the Decret aux Expériences Pratiquées sur les Animaux[15], a system of accreditation for animal experimental facilities and for persons conducting such experimentation, is in place. However, there are no regulations in place regarding experimental design. The reason for this lies in the fact that reasonable and acceptable experimentation can be achieved through the implementation of thorough education and training, such as training programs for each individual involved in experimentation.

• Germany

An administrative system is in place, based on the Animal Welfare Act[16]. Accreditation for animal experimentation is carried out by each state authority, and is carried out for animal experimental facilities, experimental design, and the persons who conduct the experimentation, identical to the UK system. Further, each facility carrying out animal experimentation must appoint an Animal Welfare Officer, who is responsible for procedures relating to the review of experimental design.

(2) Switzerland

Regulations on animal welfare and protection are extant within the constitution, and the Animal Welfare Act of 1978, as well as the Animal Protection Orders of 1981 and 1991, have been set in place on the basis of these. Further, several legally binding guidelines are extant[17]. The responsibility for implementing these regulations is delegated to each municipal authority, and the relevant body carries out accreditation for animal experimental facilities, experimental design, and the persons who carry out the testing.

(3) United States

Animal experimentation is carried out according to the Animal Welfare Regulations, which are themselves based on the stipulations in the Animal Welfare Act[18]. Furthermore, nationally uniform guidelines (Guide for the Care and Use of Laboratory Animals, hereafter ILAR Guidelines)[19] have been issued by the Institute for Laboratory Animal Research (ILAR), which is a subsidiary organization of the National Academy of Sciences. Laboratories are required to carry out experimentation according to these guidelines. In the case of research projects receiving funding from the National Institutes of Health (NIH), experiments are required to adhere strictly to the Public Health Service Policy on Humane Care and Use of Laboratory Animals[20]. Each animal experimental facility manages itself independently, according to the above regulations. However, the Association for Assessment and Accreditation of Laboratory Animal Care (AAALAC), a third party independent body, is responsible for investigating whether or not animal experimentation is being carried out appropriately. There is no program of accreditation for experimental design, nor for animal experimenter, but research institutes are required to set up an Institutional Animal Care and Use Committee (IACUC), which reviews and approves experimental design plans.

(4) Canada

Although there are no laws relating specifically to animal experimentation, nationally uniform guidelines[21], which stipulate specific standards of management, are in place. The Canadian Council on Animal Care (CCAC), a government-controlled NPO, plays a central role in the management system, and is responsible for carrying out inspections of animal experimental facilities, among other duties. In the same way as the US, Canada requires laboratories to establish bodies that are responsible for the review and approval of experimental design plans; in Canada, such bodies are referred to as Animal Care Committees (ACC).

3-4 A comparison of the regulatory systems of Japan, Canada, the US and Europe

Table 4 represents a comparison of the management systems in place for animal experimentation within Japan, with those of the European nations, the United States and Canada.

In the sense that the management system in Japan also centers on the concept of self-regulation and individual management for animal experimentation, it is similar to those found in the United States and Canada. In the US, as well as implementing an independent management system, testing laboratories are required to notify and report to designated bodies, to undergo inspections by the government, and to implement the nationally uniform guidelines stipulated.

Table 4 : Comparison between the management systems in place for animal experimentation within Japan, and those in Europe, the US and Canada

Country	Name of law, date of implementation, date of newest amendment	Regulatory body	Animals affected	Accrediting body for: experimenter / facility / experimental design	Inspections / Investigatory visits	Committees on animal testing	Guidelines & Standards
Japan	Law for the Humane Treatment and Management of Animals 1999/2005 (Law concerning the Protection and Control of Animals was enacted in 1973)	MOE	• Differs according to the measures and regulations in place, from those specific to dogs & cats, to those covering all animals in general • animals under humane treatment: mammals, birds and reptiles which have an especially close relationship with humans	None / None / Internal committees within experimental facilities	None	• Internal committees within experimental facilities	• Legal guidelines on the care and management of laboratory animals • Internal standards for each experimental facility (After June 2006, standards set by relevant government ministries should come into effect)
United States	Animal Welfare Act 1970/1985	Department of Agriculture	All warm-blooded animals (excluding mice, rats and birds)	None / Secretary of the Department of Agriculture / Internal committees within experimental facilities	Department of Agriculture-affiliated investigating officer	• Internal committees within experimental facilities: Institutional Animal Care and Use Committees (IACUC), responsible for experimental design review etc.	• Uniform guidelines set by the Institute for Laboratory Animal Research (ILAR) • Internal standards for each experimental facility
	Public Health Service Policy on Humane Care and Use of Laboratory Animals 2002	National Institutes of Health (NIH)	* laboratory animals used in research receiving funding from the NIH	None / Association for Assessment and Accreditation of Laboratory Animal Care (AAALAC) or the NIH / Internal committees within experimental facilities	Inspections carried out in some specific cases	• Internal committees within experimental facilities: IACUC (Institutional Animal Care and Use Committees), responsible for experimental design review etc.	
Canada	Guide to the Care and Use of Experimental Animals	Canadian Council on Animal Care (CCAC)	Living vertebrates, living cephalopods (octopus, squid)	CCAC / CCAC / Internal committees within experimental facilities	CCAC	• Internal committees within experimental facilities (Animal Care Committees: ACCs)	• Uniform standards stipulated by the CCAC • Internal standards for each experimental facility
UK	Animals (Scientific Procedures) Act 1986	Home Office	Living vertebrates	Secretary of State / Secretary of State / Secretary of State	Home Office investigating officer	• National committee: Animal treatment committee, responsible for national policy decisions • Internal committees within experimental facilities; ERPs: Ethical Review Process, responsible for experimental design review etc.	• Investigatory standards as defined by law
France	Decret aux Expé rience Pratiquées sur les Animaux (No. 87-848) 1987)	Ministry of Agriculture	Living vertebrates	Minister of Agriculture / Minister of Agriculture / None	Facility employees as directed by the Minister of Agriculture	• No committees at present • Currently in the process of setting up a national committee (national committee on laboratory animal ethics)	• Investigatory standards as defined by law
Germany	Animal Welfare Act (Experimental Animals Section V) 1972/1998	State government	Vertebrates	State government / State government / State government	State government	• State committee (no internal committees within experimental facilities)	• Investigatory standards as defined by law
Switzer-land	Federal Act on Animal Protection 1978	National government	Vertebrates	State government / State government / State government	State government	• State committee	• Various legally binding standards

Prepared by the STFC based on References[22,23]

4 Numbers of laboratory animals used in Japan, Canada, the US and Europe

Understanding the numbers of laboratory animals used helps to further an understanding of the current global situation regarding animal experimentation. In this chapter, I have attempted to outline the numbers of laboratory animals used in experimentation in Japan, and in the European nations, the United States and Canada.

I have also attempted to make comparisons regarding projected changes in the number and type of laboratory animals used in experimentation in Japan and Western countries. However, as previously mentioned, the fact that the systems of management that regulate animal experimentation used are different, differences

Table 5 : Numbers of laboratory animals used in Europe, the United States and Canada

		United States		Canada		United Kingdom	
Year of Survey		2000[26]	2004[26]	1999[27]	2002[28]	2000[27]	2004[24]
Type of animal	Mice	Not subject to Animal Welfare Act		648,550	759,790	1,606,962	1,910,110
	Rats			268,583	332,065	534,973	456,981
	Dogs	69,516	64,932	7,444	9,518	7,635	5,570
	Cats	25,560	23,640	2,576	3,561	1,813	498
	Monkeys	57,518	54,998	1,131	2,109	1,494	2,792
	Other*	1,133,818	958,388	818,322	996,092	561,849	402,678
Total		1,286,412	1,101,958	1,746,606	2,103,135	2,714,726	2,778,629

* Includes rabbits, guinea pigs, hamsters, domestic livestock, birds, amphibians, reptiles and fish
* Classification of animal types used is identical to the references materials used

Prepared by the STFC based on References[24-28]

are also seen in the methods used to calculate numbers of laboratory animals.

4-1 Numbers of laboratory animals used in Japan

In Japan, there is no law requiring laboratories to make reports regarding the numbers of laboratory animals used in experimentation. However, JALAS conducts research into the number of animals used for such experimentation, and JSLA carries out investigations into the total number of laboratory animals sold within Japan. However, both of these bodies rely on voluntary questionnaires as the basis of their research, and therefore cannot be considered to accurately reflect the actual number of laboratory animals involved in experimentation.

4-2 Numbers of laboratory animals used in the Europe, the US and Canada

Out of those countries which, as a result of legal requirements, both carry out and publish the results of research into the numbers of laboratory animals used in experimentation for the purposes of education, research and safety trials, I have investigated the United States, Canada and the United Kingdom (Table 5).

In terms of general trends, the number of laboratory animals used in each country seems to have either leveled off, or is increasing in only very slightly. In the United Kingdom and Canada, the number of genetically modified mice used is rising, and this is likely to account for the increase in overall figures[24].

In terms of the type of animal used, mice and rats account for over 50% of the total in both the United Kingdom and Canada, and in terms of total usage represent about 85% in the United Kingdom, and about 52% in Canada, according to the latest data. In the United States, experimentation on mice and rats is not subject to Animal Welfare Act, and therefore the numbers of these animals used in experimentation are not known. However, the National Association for Biomedical Research (NABR) has estimated that experimentation on mice and rats accounts for 85%-90% of the total number of laboratory animals used in the United State[25].

5 National and international trends in animal experimentation in recent years

5-1 National trends

(1) Stipulations and amendments in guidelines and standards in animal experimentation, and regarding laboratory animals

In response to the clear specifications regarding the 3R principles set out in the Amended Law for the Humane Treatment and Management of Animals, guidelines and standards for concerned government agencies regarding animal experimentation and laboratory animals were formulated and amended. At the Ministry of the Environment, basic standards were altered in order to ensure that methods which minimize the suffering of laboratory animals are used, both in terms of the care and housing

Table 6 : Standards relating to animal experimentation to be notified or communicated in accordance with the implementation of the Amended Law for the Humane Treatment and Management of Animals

Name of legislation, date of implementation	Department responsible	Facilities / institutions affected	Animals affected	Contents
Standards relating to the care and management of laboratory animals and relief pain[2] (April 2006, MOE, Notification No. 88)	Subcommittee on Laboratory Animals, Animal Protection Committee, Central Environment Council, MOE	Persons and bodies connected with laboratory animals as follows: • Managers (those persons responsible for laboratory animals and experimental facilities) • Persons responsible for laboratory animals • Persons who carry out experimentation • Persons who raise and care for laboratory animals • Facilities which produce animals for the purposes of laboratory experimentation	• Animals being taken care of, or managed in, facilities for the purposes of being used in experimentation • Animals being transported to facilities • Mammals, birds, reptiles * Excludes animals kept for stockbreeding purposes	• Revised 'Standards Relating to the Care and Management of Laboratory Animals' (Notification No. 6, Prime Minister's Office, March 1980) • Common standards: health of animals, maintenance of safety standards, maintenance of living conditions and environment, prevention of harm, hazards etc., rationalization of record keeping, appropriation of knowledge about 'Zoonoses', treatment and handling of animals during transportation, treatment and handling of animals when facilities are closed down etc. • Individual standards: points for consideration in terms of the actual execution of animal experimentation; points for consideration in terms of the production and provision of laboratory animals
Basic guidelines on animal experimentation in research institutes[29] (Notification, June 2006)	Special Committee on Examination of Guidelines on Animal Experimentation, Life Sciences Committee, Subdivision on R&D Planning and Evaluation, Council for Science and Technology, MEXT	Research facilities under the authority of MEXT: • Universities • Universities using joint facilities • Specialized vocational high school • Facilities under MEXT control • Independent administrative institutes under MEXT control • Corporations under MEXT control which were established according to Article No.34 of the Civil Law	• Animals being taken care of, or managed in, facilities for the purposes of being used in experimentation • Mammals, birds, reptiles	• Clear indication of the accountable entity: the director of each facility The following should be carried out by each separate facility or institution: • Drawing up of internal regulations • Establishment of an animal research committee • Implementation of training and education programs • Self checks and evaluation * According to MEXT guidelines, facilities should, as well as implementing a system of self-checking and evaluation, also work to examine the results of any such evaluations • Information disclosure
Basic guidelines on the implementation of animal experimentation in facilities under the control of MHLW[30] (Notification, June 2006)	Science and Technology Committee, Health Sciences Council, MHLW	The following facilities which carry out animal experimentation (including laboratories affiliated to facilities which carry out animal experimentation) • Facilities & institutions under the control of MHLW • Independent administrative institutes, public interest corporations (under the control of MHLW) • Privately-owned corporations (under the control of MHLW that were established according to Article No. 34 of the Civil Law, Law No.89, 1896) • Any other corporations under the control of MHLW	• Mammals, birds and reptiles being taken care of, or managed in, facilities for the purposes of being used in experimentation	
Under consideration *	Science Council of Japan	Under consideration	Under consideration	Guidelines on animal experimentation that are relevant in terms of the internal regulations drawn up for each experimental facility

* The guidelines were published in June 2006 ('Guidelines on the appropriate implementation on animal experimentation').

Prepared by the STFC based on References[2,29,30]

of such animals, and their use in scientific experimentation. Furthermore, the Ministry of Education, Culture, Sports, Science and Technology (hereinafter MEXT), and the Ministry of Health, Labour and Welfare (hereinafter MHLW) formulated basic guidelines, to which supervisory organizations will be subject, that were designed to ensure the implementation of a system of animal experimentation that maintains a balance between both science and issues of animal welfare (Table 6)[2,29,30]. These guidelines and standards set out the fundamental thinking regarding animal experimentation and the management of laboratory animals in Japan, and are not legally enforceable.

The Basic Guidelines for Animal experimentation, as formulated by MEXT and MHLW, set out those fundamental concepts to be followed when any and all experimentation is carried out. When experimentation is carried out, the necessity arises to stipulate internal regulations for the maintenance and management of experimental facilities, and concrete rules on experimental methodology within relevant institutions. According to the guidelines set out by both ministries, such internal regulations will be formulated for each institution, with consideration to the guidelines set out by the Science Council of Japan.

(2) Research organizations involved in alternatives to animal experimentation

'Alternatives to animal experimentation' refers to the process of substituting methods

Table 7 : Main research subject for developing alternatives to animal experimentation

Acute toxicity test (reduction in number of animals used, cytotoxic effect test)
Conjunctival irritation test (cytotoxic effect test, protein metamorphic test etc.)
Primary skin irritation test (cytotoxic effect test, 3-dimensional cultured skin model)
Skin permeability test (isolated skin method)
Phototoxicity test (cytotoxic effect test, covalent binding test, histidine oxidization method)
Skin sensitization testing (protein binding test, cultured human skin cell method, cultured Langerhans cell test, skin permeability test, local lymph node assay)
Mutagenicity test
Carcinogenicity test (short-term test*, cell mutagenicity test, peroxisome proliferation test)
Reproductive toxicity test (embryo cultured test, limb bud cell culture test)

The items in bold type are proving particularly active in the development of in vitro alternative methods
* Evaluation test for promoter levels using p53 (tumor suppressor gene) knock-out mice and partially-hepatectomized mice

Extracted from Reference[31]

of experimentation that use laboratory animals for experimentation that do not. It also covers the reduction of the numbers of laboratory animals used, as well as a relief of pain of laboratory animals used in experimentation. The relevant experimental methods are considered to be essential procedures in the carrying out of animal experimentation based on the 3R principles, and diverse research projects are in place (Table 7). Through the development and subsequent validation*6 of new experimental methods based on such research, investigations are being conducted on a global scale to ascertain whether or not such methods could be used in government testing (e.g. the screening of chemical substances).

In Japan, the Japanese Society for Alternatives to Animal Experiments (JSAAE) has for several years played a pivotal role in the development of research into methods that provide alternatives to animal experimentation, and in November 2005, the Japanese Center for the Validation of Alternative Methods (JaCVAM) was established within the Biological Safety Research Center, part of the National Institute of Health Sciences, as a focal point for such research. Accordingly, hopes are high for the continued development of such research into alternatives to animal experimentation.

(3) Formulation of a system for the systematic collection, preservation and provision of laboratory animals: the National BioResource Project

This project was begun in July 2002, as part of the ‘Research Revolution 2002 (RR2002)’ project overseen by MEXT. Under this project, a structure is being implemented that will allow the systematic collection, preservation and provision of those bioresources (laboratory animals and plants, various cells, the genetic stock of various living organisms etc.) that Japan should be proactively looking to have amassed to international levels by the target year of 2010. As of 1st May 2006, there were 24 types of bioresources in total[32].

Laboratory animals are also being systematically collected and kept under this project. It is believed that if the systematic breeding, maintenance and usage of laboratory animals become possible, then this will lead both to further rationalization of animal experimentation, as well as improvements in the welfare of laboratory animals.

(4) Establishment of new regulations regarding the areas used to keep genetically modified animals

Research and development on genetically modified animals in Japan is carried out in strict accordance with the following laws and regulations: the domestic law for the implementation of the Cartagena Protocol on Biosafety*7, implemented in February 2004 and known as the Law Concerning the Conservation and Sustainable Use of Biological Diversity through Regulations on the Use of Living Modified Organisms (Law No. 97 of 2003; hereinafter referred to as the Cartagena Law), the Ministerial Ordinance Stipulating those Measures to be Taken to Prevent Diffusion during the Type 2 Use of Living Modified Organisms on Research and Development (January 2004, MEXT and MOE Ordinance No. 1; hereafter Type 2 R&D Ordinance)*8, and the Notice on Ordinances on Research and Development (Amended February 2006, MEXT)[33,34].

In the Type 2 R&D Ordinance, those measures required to prevent diffusion during animal experimentation are specified, and new regulations are laid out regarding provisions for 'Special breeding section' (enclosed areas, e.g. by fencing), which are not to be closed off. The ability to provide such section is however dependent on the fulfillment of certain conditions specified in the ordinance, such as being able to prove that the recombinant nucleic acids within the genetically modified animals have already been identified, and that any such identified nucleic acids are not related to the pathogenicity. In those cases where conditions are met and such section can be created, then, after ensuring complete installation of two-fold escape control facilities, and a system to identify individual animals, keeping laboratory animals outdoors in an environment closer to that of their natural habitat becomes possible, even if that section remains confined to a certain extent.

Before the implementation of the Cartagena Law, genetically modified animals were kept under containment, regardless of size, and there were issue of animal welfare, such as the fact that it was not possible to provide larger animals with areas to exercise. Although the scope of application of the regulations concerning these 'Special breeding section' is limited, the fact that such regulations have been established does point to a greater awareness of animal welfare.

5-2 Trends in the Europe, the US and Canada

Regarding the hazard assessment of chemical substances, alternatives to animal experimentation are being actively adopted, and efforts are being made to reduce the number of animal experimentation. At the same time, in the United Kingdom, laws have been established to protect those persons holding licenses allowing them to carry out animal experimentation, as well as animal experimental facilities, from acts of violence and protest; as such, the movement to protect and maintain animal experimentation has grown in strength.

(1) Establishment of regulations to limit animal experimentation

An EU Directive banning safety assessment experiments for cosmetics which use laboratory animals as subjects, and guidelines on alternatives to animal experimentation are being investigated by each country (Table 8).

Table 8 : Significant legislation on animal experimentation implemented overseas in recent years

Date of legislation	Legislating body	Scope of legislation
December 2001[35]	Organisation for Economic Co-operation and Development (OECD)	Agreement to abolish acute toxicity test procedures aimed at calculating LD50 (Guideline for the testing of chemicals No.401), and adoption of alternative methods (Guidelines for the testing chemicals No.420, 423, 425 which allow for a reduction in the number of animals used) (Abolishment to be executed by December 2002)
July 2002[36]	Germany	Basic law of Federal Republic of Germany (constitution) : proclamation and implementation of amendments to Article 20(a) Introduction of animal welfare legislation
March 2003[37]	EU Council	Proclamation of 7th Amendment to EU Directive 76/768/EEC on cosmetic products Complete abolition of all safety tests using animals by 2009 (or by 2013 for certain specific testing)
May 2004[38]	World Organisation for Animal Health (OIE)	Adoption of guidelines on the basic principles of animal welfare. '5 freedoms' for the welfare of domestic livestock (freedom from hunger, thirst and malnutrition, freedom from physical and thermal discomfort, freedom from pain, injury and disease, freedom to express normal patterns of behavior, freedom from fear and distress), and the clarification of the 3R principles in terms of animal experimentation
July 2005[39]	United Kingdom	Enactment of legislation designed to control animal rights fundamentalists Intended to protect animal experimental facilities and those persons involved in animal experimentation

Prepared by the STFC based on References[35-39]

Table 9 : OECD test guidelines on the safety evaluation of chemicals

【Acute toxicity test】 TG420 Acute oral toxicity – fixed-dose method (Updated guideline, adopted 20th December 2001) TG423 Acute oral toxicity – acute toxic class method (Updated guideline, adopted 20th December 2001) TG425 Acute oral toxicity – up and down procedure (Updated guideline, adopted 20th December 2001)
【Acute inhalation toxicity test】 TG433 Acute inhalation toxicity – fixed-dose procedure (Draft revised guideline June 2004) TG436 Acute inhalation toxicity – acute toxic class method (Draft new guideline December 2004)
【Acute dermal toxicity test】 TG434 Acute dermal toxicity – fixed-dose procedure (Draft new guideline May 2004)
【Skin sensitization test】 TG429 Skin sentisation – local lymph node assay (Updated guideline, adopted 24th April 2004)
【Skin corrosivity test】 TG430 In vitro skin corrosion - transcutaneous electrical resistance (TER) method (Original guideline, adopted 13th April 2004) TG431 In vitro skin corrosion - Human skin model test (Original guideline, adopted 13th April 2004) TG435 Membrane barrier test methods for skin corrosion (Draft new guideline May 2004)

TG : Test Guidelines

Prepared by the STFC based on References [31, 35]

In order to facilitate the sharing between member countries of the safety test data deemed necessary when handling high production volume chemicals, the Organisation for Economic Co-operation and Development (OECD) is pushing for the drawing up of test guidelines which will standardize the methods of assessment testing used in each member country. Based on the Draft Guidance Document: Recognition, Assessment and Use of Clinical Signs as Humane Endpoints for Experimental Animals Used in Safety Evaluation Studies (October 1998), testing methods which require a 50% lethal dose (LD50) as a barometer for evaluating acute toxicity will be abolished, and methods which use fewer laboratory animals, and which are based on the 3R principles, are to be used instead (Table 9).

(2) Development of alternatives to animal experimentation and expansion of centers for alternative methods

Alternatives to animal experimentation began to be investigated in Western countries at a fairly early point in time, and in the mid 1990s a specialized institute was founded to carry out work relating to research into, and assessment of, such alternatives to animal experimentation. Particularly well known are, in the EU, the European Center for the Validation of Alternative Methods (ECVAM)[40] and, in the United State, the Interagency Coordinating Committee on the Validation of Alternative Methods (ICCVAM)[41]. These institutes are in close contact, and carry out joint validation projects. More recently, the National Center for the Replacement, Refinement and Reduction of Animals in Research (NC3Rs)[42] was established in 2004 in the United Kingdom, and active efforts are being made on a governmental level to further research into alternatives to animal experimentation.

6 Measures required in order to establish a self-regulation and independent management system for animal experimentation within Japan

The 3R principles have been accepted internationally as expedient by those responsible for the carrying out of animal experimentation, and much effort is being put into furthering research into alternatives to animal experimentation. At the same time, animal experimentation continues to be widely used as an important means of observation and analysis in life sciences. Animal experimentation provides opportunities to analyze and resolve complex biological processes, such as the higher functions of the central nervous system, intercellular crosstalk, and also remains an effective technique for furthering the development of medical technologies. Animal experimentation can also be used successfully in research conducted with a view to establishing treatment and preventative methods for emerging and reemerging infectious diseases so prominent in the news recently, as well as in the evaluation of harmful effects of environmental pollutants. The role of animal experimentation in cases such as these continues to diversify, and can be expected to continue to do so in the near future.

With the establishment of the Basic Guidelines for Animal experimentation, stipulated after the amendments to the Law for the Humane Treatment and Management of Animals last year, and the creation of standards for the fair management and treatment of laboratory animals, a system of management for animal experimentation and laboratory animals is in the process of being established within Japan. As mentioned in Chapter 3, the management system for animal experimentation in Japan is based around a system of self-regulation and independent management, carried out by each institution and facility performing animal experimentation. The practical regulations for these systems are shouldered by governmental directives, through proclamations and notifications from the relevant governmental bodies, and the code of conduct determined by associated laws and regulations. The standards and guidelines mentioned above should help to further the establishment of a self-regulation and independent management system, and can be considered a milestone in terms of the construction of an original system of management for animal experimentation within Japan.

In order to facilitate the creation of an independent management system for animal experimentation carried out within Japan, certain measures will need to be put in place that can guarantee the Basic Guidelines for Animal experimentation mentioned above. With this in mind, in this chapter I will provide an overview of those measures required in order to ensure the creation of an independent management system for animal experimentation in Japan from now on.

Creation of an evaluating body to oversee facilities carrying out animal experimentation

In the United States and Canada, animal experiment committees are established within those institutes carrying out such experimentation, and are responsible for the review and evaluation of the legitimacy of all animal experimentation. At the same time, third party bodies also independently evaluate the systems of management in place at those facilities where animal experimentation is being carried out (AAALAC in the United States, CCAC in Canada). Although the process of review for each individual program of animal experimentation in Japan resembles those of the United States and Canada, Japan as yet has no organization responsible for the evaluation of animal experimental facilities.

When a piece of scientific research which involves animal experimentation is submitted for inclusion in an international scientific journal, as well during the scientific review process, the ethical treatment of the laboratory animals used becomes subject to investigation. Should questions arise over the ethics of the submitted report, then it will not be accepted for publication. The fact that, up until now, results from research using laboratory animals carried out in Japan have been published in numerous such international scientific journals, implies that the independent system of management currently in place in Japan is comparable to international standards. However, it remains a fact that there may well exist gaps in the management standards of different experimental facilities. In order to eliminate such potential problems, each experimental facility should be required to adhere to the Basic Guidelines for Animal experimentation stipulated by the relevant governmental bodies. It also goes without saying that experimenters in such facilities must be prepared to make the necessary efforts to ensure that their independent management systems function effectively, and it would seem expedient to establish a system to evaluate experimental facilities. This evaluation system is crucial if Japan is to achieve greater levels of objectivity and transparency within the independent management systems in those facilities.

An evaluation system complete with the functions mentioned above could take on many forms, but here I would like to suggest the creation of a special body with the specific task of carrying out evaluations of experimental facilities involved in animal experimentation. The role of such a body would be to evaluate the internal regulations in place within each experimental facility, and the conditions under which experimentation is taking place, as well as to provide guidance and instruction as and when necessary. The body would not be responsible for reviewing the content of experimental design plan regarding animal experimentation. Placing the evaluation of proposed animal experimental designs outside the jurisdiction of such a body should be considered from the perspective of protecting intellectual property rights related to research utilizing animal experimentation, and the privacy of assessment testing on toxicity and so forth.

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Glossary

*1 3R

Stands for ‘Replacement,’ ‘Reduction’ and ‘Refinement.’ These three fundamental principles were first advocated in the United Kingdom in 1959 by Russell and Burch as a more humane approach to animal experimentation[1]. The concept behind the philosophy represented by these principles is to implement the 3Rs within the Law for the Humane Treatment and Management of Animals, wherever possible, and in a way that will not have a detrimental affect on achieving the scientific objectives behind the use of animals in experimentation. ‘Replacement’ refers to the use, wherever possible, of alternative means of experimentation which do not use animals; ‘Reduction’ refers to decreasing, wherever possible, the numbers of animals used in experimentation; and ‘Refinement’ refers to using, wherever possible, methods of experimentation that relieve pain of the animals. In recent years, a fourth R has been occasionally added, meaning either ‘Responsibility’ or ‘Review.’

*2 The welfare of laboratory animals (animal protection) and methods used in animal experimentation

The welfare of laboratory animals (animal protection) and the methods used in animal experimentation are fundamentally considered to be two separate issues. The welfare of laboratory animals is seen to consist mainly of ‘the abstract concept of observing the 3R philosophy,’ as well as ‘practical conduct’; practical conduct can be described as the appropriate implementation of such matters as the care and housing of laboratory animals, the relief of pain during experimentation and the disposal of laboratory animals after the completion of experimentation (including euthanasia). However, the scientific appropriateness of animal experimentation within scientific research, and the guarantee of reproducibility, are required as conditions that must be met for animal experimentation to be considered appropriate. As such, perspectives on the scope of conduct and the rationalization of said conduct differ[3].

*3 Current standards
Refers to the 'Standards Relating to the Care and Management of Laboratory Animals' (March 1980, Proclamation No. 6, Prime Minister's Office; hereinafter Laboratory Animal Care and Management Standards). These were amended and proclaimed in April 2006 (See Chapter 5).

*4 Categories of research experiments based on levels of pain, distress and stress suffered by laboratory animals
A classification system for animal experimentation based on levels of pain, distress and stress suffered by laboratory animals. It was drawn up to act as the basis for making judgments on Refinement issues. Various systems of classification exist, and there is no globally uniform system. Most of the systems used in Japan are based on the classification system developed by the Scientists Center for Animal Welfare (SCAW) in the United States, and the Japanese Association of Laboratory Animal Facilities of National Universities issued a practical guide to standards, called 'Understanding the Classification of Levels Based on Pain, Distress and Stress Suffered by Laboratory Animals' in June 2004.

*5 Animal biotechnologies
This refers to technologies that are used in the manufacturing of pharmaceuticals, and the production of organs intended for xenotransplantation, which utilize genetically modified domestic livestock that have been created through genetic engineering and reproduction technologies. This is a new area that directly connects domestic livestock and medical sciences, and as such is currently attracting a great deal of attention.

*6 Validation
This refers to one of the necessary steps involved in the development of new safety evaluation testing. It demonstrates both the validity and reproducibility of test results, and is a process which is required in order to confirm that the relevant test is indeed reliable enough to be used in specific toxicity testing.

*7 Cartagena Protocol on Biosafety
This was adopted in January 2000 after the Convention on Biological Diversity made in 1992 at the UN Conference on Environment and Development (also known as the Earth Summit), and is designed to prevent potential ramifications (in terms of the effect on human health) on biological diversity through the use of Living Modified Organisms (LMO). Subject to this convention are such things as genetically modified farm produce and microorganisms; drugs and medicines used for people are not included in the scope of the convention. So far, 132 nations have ratified the convention (as of 1st March 2006).

*8 Regulations on the usage of Living Modified Organisms in the Cartagena Law
According to the Cartagena Law, prior to the use of LMOs, measures need to be put in place according to a system of LMO usage which defines two types of use: Type 1 (use without measures to prevent dispersal into the environment, such as cultivation and importation) and Type 2 (use with measures to prevent dispersal into the environment, required in experimental facilities and factories etc.). Type 2 usage must be accompanied by preventative measures against dispersal, and those preventative measures in place differ for usage within research and development (under the authority of MEXT and MOE) and industrial usage (under the joint authority of the Ministry of Finance, MHLW, the Ministry of Agriculture, Forestry and Fisheries, the Ministry of Economy, Trade and Industry, and the MOE).

Abbreviations

- *AAALAC* American Association for the Accreditation of Laboratory Animal Care (USA)
- *ACC* Animal Care Committee (Canada)
- *CCAC* Canadian Council on Animal Care
- *CIOMS* Council for International Organizations of Medical Sciences

- *ECVAM* European Center for the Validation of Alternative Methods
- *FAWC* Farm Animal Welfare Council
- *IACUC* Institutional Animal Care and Use Committees (USA)
- *ICCVAM* Interagency Coordinating Committee on the Validation of Alternative Methods (USA)
- *ICLAS* International Council for Laboratory Animal Science
- *ILAR* Institute for Laboratory Animal Research, Component of the National Research Council, National Academy of Science (USA)
- *JaCVAM* Japanese Center for the Validation of alternative Methods
- *JALAS* Japanese Association for Laboratory Animal Science
- *JSAAE* Japanese Society for Alternative to Animal Experiments
- *JSLA* Japanese Society for Laboratory Animal Resource
- *JSVS* Japanese Society of Veterinary Science
- *NABR* National Association for Biomedical Research (USA)
- *NC3Rs* National Center for the Replacemnet, Refinement and Reduction of Animals in Research (UK)
- *NIH* National Institutes of Health (USA)

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* All URL addresses correct as of 1st May 2006

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2

Energy Issues Confronting the Information and Communications Sector
—Need to Reduce the Power Consumed by the Communications Infrastructure—

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1 Introduction

"Sustainable development" as proposed by the Brundtland Commission in 1987, the holding of the Rio Conference in 1992, and the coming into force of the Kyoto Protocol in 2005 all contributed to steady progress in addressing environmental issues, fostering the awareness of the need to reduce environmental loads as a key to the development of any market economy. While the 20th century was an era of economic growth and increased energy consumption, the 21st century inevitably emphasizes effective use of limited resources and minimization of environmental loads to ensure sustainable development of societies and economies.

In the physical world (the 'hard' innovation -driven world), which consists of hardware, such as products, and the technologies to produce, transport and distribute this hardware, the above awareness is rapidly being enhanced and spread. Concepts such as recycling-oriented life cycle assessment (LCA) and minimal manufacturing (which aims to manufacture products with minimal resource inputs, using minimal energy), are primary examples of hard innovation toward sustainable development.

Although the 21st century is undergoing a rapid transition from the industrialized society typical of the 20th century to an advanced information society, there has been insufficient discussion on how to improve efficiency and minimize the consumption of energy associated with advanced information processing and communications. In particular, now that the service industry accounts for over 70% of the U.S., Japanese and other developed economies, a transition from hard innovation to 'soft' innovation and service innovation has become a significant issue. As information distribution technologies and services driving such innovations advance, concerns have risen over the increasing amounts of energy consumed by information processing and communications.

People tend to associate energy issues only with the energy used for transport, distribution and manufacturing. However, energy consumption related to information and communications technology (ICT) is now attracting global attention. To what extent does energy consumption of ICT (energy consumption of ICT equipment and infrastructure) contribute to total energy consumption and how it is expected to increase in years to come should be carefully evaluated. Controlling and restricting energy consumption is crucial to any discussion on sustainable economic development and industrial competitiveness.

Japan is changing its IT strategy from the e-Japan Priority Policy Program, the goal of which is to construct an extensive broadband information infrastructure, to u-Japan Policy, which seeks to further promote the service and content industries. This would require a comprehensive discussion on energy consumption in a future ubiquitous network society to ensure that energy issues do not inhibit the planned development. There is also a need to consider social scientific perspectives of ICT, in light of the essence of communication as the foundations of ICT.

This article analyzes the current state of the ICT sector and energy consumption from the above perspectives and seeks to inform decision-making regarding the direction future research should take.

2 Energy consumption in the ICT sector

The amount of energy consumed by the most common ICT equipment has reduced steadily over the passage of time. For example, the mobile telephone evolved from a bulky shoulder bag-size model before 1990 to a hand-held type in the 1990s. However, the product still weighed over 300 grams and its battery standby time was only a day at the most until the late 1990s. Since then, mobile handsets have dramatically reduced in size and power consumption with the advance of digitization, enabling a battery standby time of over 500 hours (about 20 days) today.

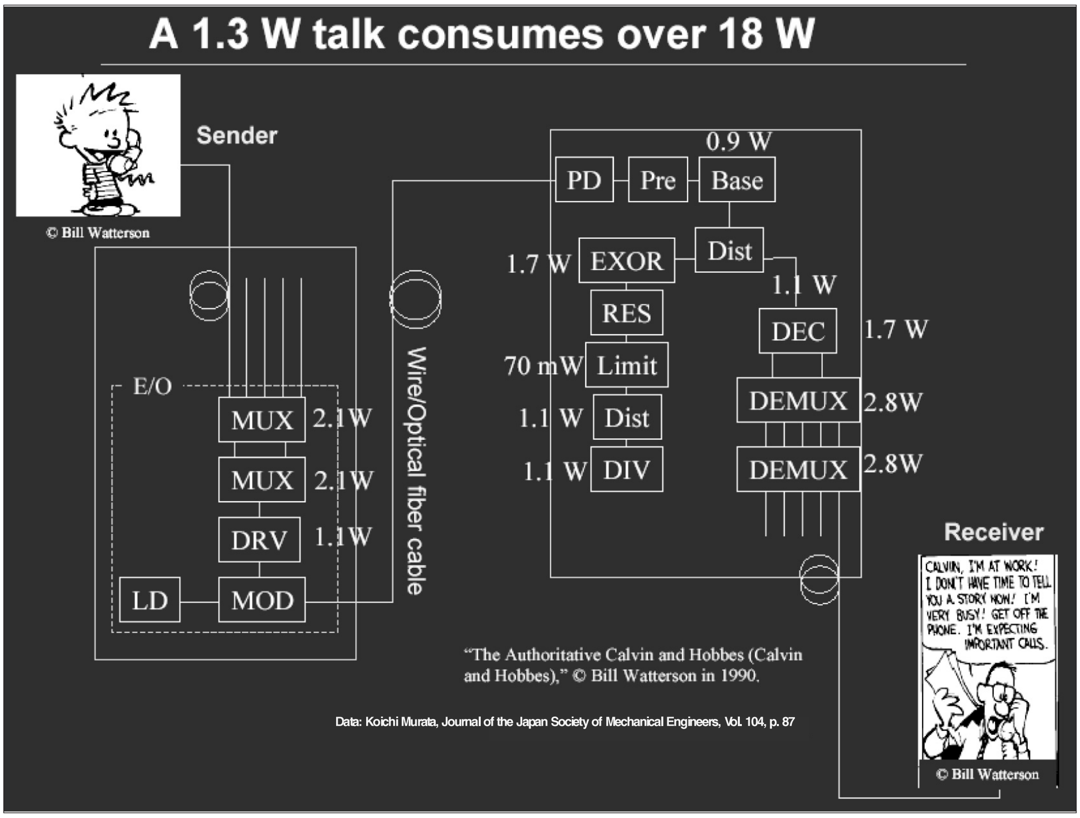
However, even current technology requires a phone call between two parties to be connected via many information processing and communications devices. The energy used per call cannot be calculated simply by summing the energy consumed by these devices individually, because they are shared among many callers. Tsukamoto solved this problem by drawing a chart that incorporated estimates made by Murata and others as shown in Figure 1, and estimated that 18 W of power is used for a single phone call. It should be emphasized more strongly that ICT consumes a sizable amount of energy.

3 Perspectives and recent debate on ICT and energy

3-1 Debate in the U.S.

In the U.S., researchers estimated in the late 1990s the extent to which power consumption would grow as personal computers and other electronic equipment made their way into offices and as the Internet proliferated, and drew attention to potential problems.

Mark P. Mills estimated that the energy used



Prepared by the STFC based on Reference[4]

Figure 1 : Electricity consumed by the communications infrastructure

Table 1 : Best estimate of annual electricity used by U.S. office equipment in 1999, TWh/year (Kawamoto, et al. Laurence Berkley Laboratory, 1999)

Equipment Type	Residential	Commercial	Industrial	Total
Portable Computer	0.14	0.13	0.02	0.29
Desktop Computer	2.67	10.21	1.46	14.34
Server	0	1.60	0.23	1.83
Minicomputer	0	8.86	2.95	11.81
Mainframe	0	5.62	0.63	6.25
Terminal	0	1.83	0.61	2.44
Display	3.13	9.82	1.40	14.35
Laser Printer	0.10	5.36	0.77	6.23
Inkjet/Dot Printer	1.10	1.56	0.22	2.88
Copier	1.10	5.71	0.82	7.63
Fax	0.44	2.26	0.32	3.02
Total	8.7	53	9.4	71

Prepared by the STFC based on Reference[2]

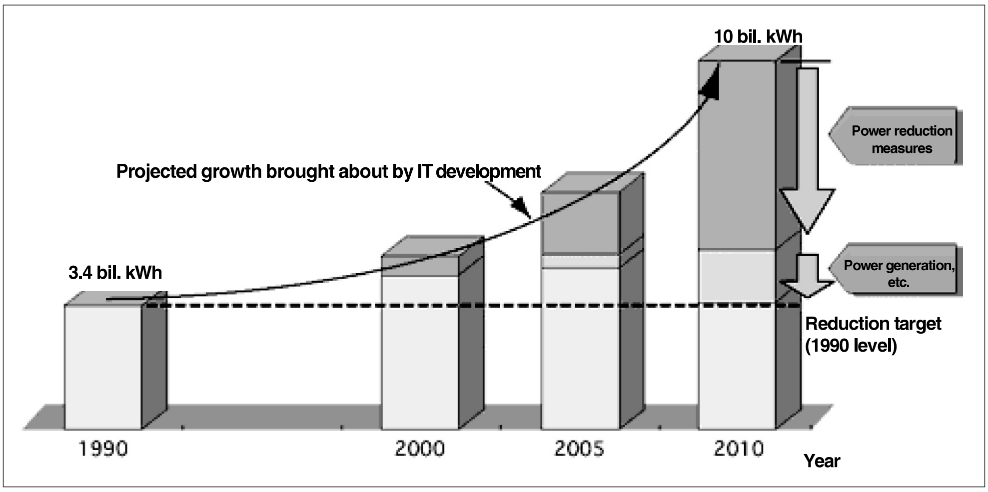
by Internet-related equipment accounted for 8% of the total American energy consumption in 1999[1], initiating debate on ICT and energy issues in the U.S. Around the same time, Kawamoto and others in the End-Use Energy Forecasting Group of the Environmental Energy Technologies Division (EETD), Lawrence Berkeley National Laboratory, U.S. Department of Energy (DOE), reported the results of a detailed analysis of electricity used by 11 types of office equipment in FY 1999[2]. It was found that office equipment consumed 71 TWh of electricity in 1999, and when combined with 3 TWh, the annual amount used by network equipment (not including communications equipment), the total reached 74 TWh per year, which accounted for approximately 2% of national power consumption. Although much different from the estimate by Mills, the proportion of 2% was considered a more reliable reference value for 1999 because the analysis performed by Kawamoto's team was more exhaustive.

Since the 1999 estimation attempts, communications traffic has been increasing at an annual rate of 40%, and the major power consumer among ICT equipment has changed from office and home PCs to routers, the function of which is to route massive amounts of data. This suggests the need for an estimation that takes the ICT infrastructure into account. The electricity used by office equipment and home PCs has not grown so much due to the fact that their performance has improved, thanks to advances in technology to reduce power consumption in stand-by mode (low-load conditions). Such technology to interrupt the power supply to circuit blocks under low load, although effective for office equipment and home PCs, is difficult to apply to equipment used in the ICT infrastructure, whose chips and circuits operate constantly under high-load conditions. Therefore, a consensus is being built in both government and industry that a debate is needed to consider the fundamental reengineering of ICT devices and circuits as well as network architecture.

3-2 Debate in Japan

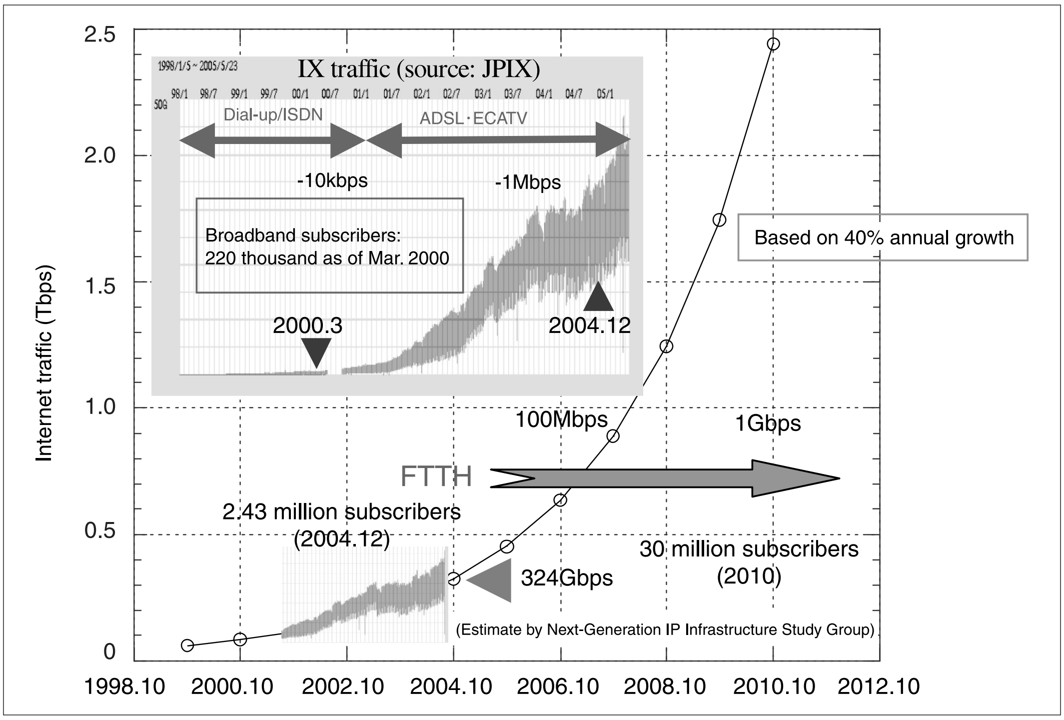
In Japan, faced with growing electricity usage driven by increased communications traffic, the NTT Group has examined ICT-related electricity consumption. Because of its business structure, the NTT Group's electricity consumption has a strong correlation with the electricity consumption of its communications network infrastructure and with the demand for communications from its clients.

The graph in Figure 2, which is reprinted from NTT West's Web site[3], shows how advances in information technology will most likely triple the company's electricity consumption (from 3.4 billion kWh to 10 billion kWh) between 1990 and 2010 if no action is taken. Although this



Prepared by the STFC based on Reference[3]

Figure 2 : NTT Group's power consumption: projected growth and reduction target



Prepared by the STFC based on Reference[4]

Figure 3 : Projected growth of Internet traffic

increase is not entirely attributable to ICT, there is no doubt that the growth of ICT will make a significant contribution to it.

NTT Facilities reported that the NTT Group purchased 6.6 billion kWh of electricity in FY 2002. This accounts for 0.8% of the total power generated in Japan, and the company estimates this rate increased to 1.0% by 2006. The NTT Group is trying to reduce its power requirements by strengthening power conservation measures such as supplying direct current to broadband communications equipment (e.g., servers, routers) in an attempt to curtail transmission loss and AC/DC conversion loss. The group also aims to become self-reliant in power supply through power generation and other measures, but being self-reliant will not directly lead to reduced power consumption.

3-3 Issues to be addressed in the future

Internet traffic has increased exponentially as Figure 3 shows. The major factor behind this is a change in the nature of data being transferred over the network from text information, which predominated until the late 1990s, to music and still/moving images, which generate larger traffic

Table 2 : History of mobile telephone development and data traffic growth

Feb. 1999	NTT DoCoMo starts the “i-mode” service • Transmission of text information from mobile terminals (up to 1 KB) • Text content browsing (up to a few KB)
Nov. 2000	J-Phone (now Vodafone) starts the “Sha-mail” picture transmission service • Transmission of still images from mobile terminals (a few 10s of KB) • Introduction of handsets with color LCD screens • Image content browsing
Oct. 2001	NTT DoCoMo starts the FOMA service (3G in 2 GHz band) • Faster data transfer: 9.6 Kbps → 384 Kbps (while not moving) • Start of the video phone (moving image) service (a few 10s-100s of KB)
Nov. 2003	au starts a flat-rate packet communications service (toward a MB era)
Jun. 2004	NTT DoCoMo starts a flat-rate packet communications service • Unlimited data exchange at a flat rate (toward a MB era)

flows.

As Table 2 shows, e-mail messages mainly consisted of text (a few kilobytes per message) until five to six years ago. They then progressed to include still images (a few tens of kilobytes to 1 megabyte) three to four years ago and then, in the past year or two, have come to include moving images (a few megabytes). Today's Internet traffic is mainly comprised of the exchange of music and video files. At one point, such traffic accounted for as much as 90% of the backbone traffic between Tokyo and Osaka. These facts highlight the proliferation of software to enable so-called P2P (peer-to-peer, i.e., direct communications between computers with no intermediate server) file sharing as a significant factor in the growth of traffic.

The wide availability of mobile telephones has had a strong impact on increases in communications traffic and the expansion of the communications infrastructure. While communications over the Internet involve distribution of relatively large-volume (megabyte-size) content files, mobile phone communications consist of not only distribution of large still and moving image files but also frequent transmissions of small bits of data. Like sensed data in a ubiquitous network, these small bits of data must be transferred in real time and therefore require constant operation of the receiving network and frequent routing. Since there can be a trade-off relationship between a ubiquitous network's benefits and energy consumption, these issues should be discussed with the overall balance in mind.

Communications traffic in Japan has grown faster than Moore’s Law, at an annual rate of 40%, since the latter half of the 1990s and is still growing at the same pace. With a further increase in data traffic expected, driven by a full-fledged spread of video distribution and other products resulting from the convergence in broadcast and communications and by wider availability of online public and information services, this rapid growth will no doubt continue for at least the next few years.

4 Energy consumption of ICT infrastructure equipment

As the ICT infrastructure grows and communications traffic continues to rise, the increase in the number of installed servers, for sending and receiving information, and routers, for routing data, becomes increasingly significant. The Energy Conservation Technology Strategy Report, released by the Ministry of Economy, Trade and Industry in June 2002, estimated annual electricity consumption of servers in Japan to be 8.4 billion kWh and that of routers to be 3.6 billion kWh. These estimates for growth are becoming a reality today (Table 3).

By performing an in-depth analysis of the router structure and taking lower-power LSI chips and other relevant factors into account, Hasama projected electricity consumption for routers together with growth in data traffic, as shown in Table 4[4]. His projection suggests, assuming communications traffic continues to grow by 40% annually as it did in the past several years, that the electricity used annually by routers will increase 8 times to 15.8 billion

Table 3 : Number of installed servers and their power consumption

	Item	Avg. power requirements (W)	Installed units in FY 2000	Operating units (as of FY 2000)	Annual operating hours (h/yr)	Annual power consumption (MWh/yr)	Crude oil equivalent (kl/yr)
Server	Mainframe (large)	60,000	456	5,018	8,760	2,637,461	245,213
	Mainframe (small to medium)	7,500	1,034	8,491	8,760	557,859	51,866
	Midrange computer (high-end)	5,000	9,753	21,591	8,760	945,686	87,923
	Midrange computer (middle)	1,000	25,154	139,823	8,760	1,224,849	113,878
	Midrange computer (low-end)	400	123,660	383,542	8,760	1,343,931	124,949
	PC server	300	326,496	649,326	8,760	1,706,429	158,652
	Subtotal		486,553	1,207,791		8,416,215	782,480
Router	High-end ATM switch	2,000	6,800	14,260	4,380	124,918	11,614
	High-end router	1,200		225,000	4,380	1,182,600	109,950
	Midrange router	200		2,625,000	4,380	2,299,500	213,791
	Low-end router	30		15,000	4,380	1,971	183
	Subtotal			2,879,260		3,608,989	335,538
Total				4,087,051		12,025,203	1,118,019

Servers' power consumption: 8.4 billion kWh/yr; Router's power consumption: 3.6 billion kWh/yr

Prepared by the STFC based on Reference[4]

Table 4 : Projected power consumption of routers

	2001	2004	2010	2015	2020
Traffic growth rate (40%)	1	2.7	21	111	597
Projected traffic (Tbps)	0.12	0.324	2.4	13	71
Routers' power consumption (100s of millions kWh/yr)	7.5	20	158	833	4478
Ratio to national power generation (assumed 920 billion kWh/yr) (%)	0.08	0.22	1.7	9.0	48.7
LSI operating voltage (V)	5.0	3.3	2.5	1.0	0.8
Ratio of reduced power consumption of electronic equipment	1.0	0.44	0.25	0.04	0.03
Routers' power consumption with lower voltage LSIs (100s of millions kWh/yr)	7.5	8.8	40	33	134
Ratio to national power generation (assumed 920 billion kWh/yr) (%)	0.08	0.1	0.4	0.4	1.5

Prepared by the STFC based on Reference[4]

kWh by 2010 and nearly 600 times to 447.8 billion kWh by 2020. This 2020 figure would account for an astonishing 50% of Japan's annual power generation, should the generation capacity remain around 920 billion kWh. Hasama's projection implies that if electricity consumption of routers grows without taking advantage of low-power LSI technology, Japan will face an energy crisis. However, the figure of 48.7% is based on the worst-case scenario and will not become a reality if new LSI chips with lower power consumption continue to emerge at the current pace.

People tend to be optimistic about the future of LSI power reductions because they have seen many electronic appliances successfully reduce their power requirements. However, routers marketed in the future are unlikely to benefit from power reductions enabled by technologies to shut off the power to certain circuit blocks during low-load conditions and by smaller transistors, or so-called LSI scaling, which has traditionally played a key role in reducing power requirements. It should be noted that scaling technology faces challenges such as that in miniature MOS transistors at 90nm or below in line width, gate leakage current offsets the power reduction effect generated by scaling and that lowering the transistor's threshold voltage is difficult because of process variation. These issues need an R&D approach that even reviews fundamental device structure. On the other hand, technology to interrupt the power supply to circuit blocks under low load, an area where Japanese manufacturers have excelled, may not be effective for routers, because routers are constantly operating under heavy load. In recognition that reduction of electricity consumption is difficult to achieve on routers operating as the core of the communications infrastructure, energy issues in the ICT sector need to be discussed systematically from different perspectives such as devices, equipment and network architecture.

Japan leads the world in hardware technologies such as materials, devices and low-power circuits. The country is also ahead of many others in optical device technology, which can be a substitute for electronic technology. Japan should systematize and strengthen these technologies in the future, with ICT and energy issues in mind. There is a particular advantage in using optical technology: Although inefficient for small-scale implementations because of a significant loss of energy during photon-electron conversion, optical technology improves energy efficiency in large-scale implementations, where gain exceeds loss and efficiency increases as capacity is enhanced. In the U.S., IBM and other organizations are considering the use of optical backplanes for next-generation supercomputers. In Japan, the introduction of optical technology is under discussion among the researchers participating in a next-generation supercomputer project led by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) for connection between nodes, and is being considered by Hitachi for router backplanes[5]. The Ministry of Internal Affairs and Communications (MIC), the National Institute of Information and Communications Technology, the Ministry of Economy, Trade and Industry (METI), and the National Institute of Advanced Industrial Science and Technology (AIST) are also conducting studies toward the use of optical backplanes for electronic routers.

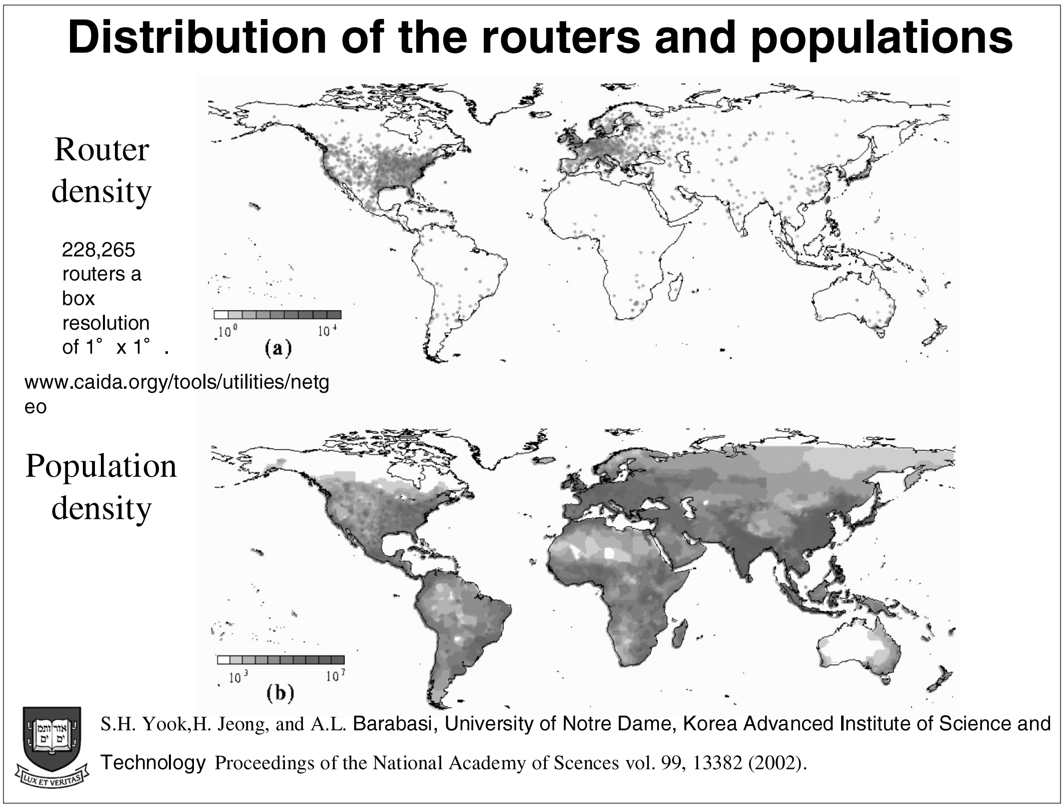
As mentioned above, issues surrounding ICT and energy encompass different government functions from MEXT, which is in charge of device and other basic technology research, to MIC and METI, which are responsible for applied technologies, suggesting the need for a systematic solution. The government should formulate a grand design that includes everything from devices and communications equipment to networks and power generation, although a debate is necessary to decide whether to take a cross-sectional approach or area-specific approach.

Now that the electricity purchased by the NTT Group is double the amount it was in 1990 and that next-generation core routers for communications are expected to require megawatt-range power, Japan is in urgent need to accurately ascertain its current status and plan actions to be taken in this area. On March 30, 2006, AIST hosted the “Symposium on Information and Energy,” attended by experts from telecommunications operators, communications equipment manufacturers and universities as well as policymakers, and active discussions were held. As this event demonstrates, growing attention is focused on the issue of ICT and energy.

5 Concerns about increases in energy consumption associated with the expansion of global ICT infrastructure

The data collected by S.H. Yook[4] indicates that if the number of installed routers, which now exist mainly in developed countries, increases according to population distribution, a global energy crisis will occur (Figure 4). Especially in China, India and other countries that are experiencing rapid economic growth and have enormous populations, infrastructures for telephone, the Internet and TV (video distribution) are often built concurrently, and once these infrastructures are completed, communications traffic can increase explosively. Even though the pace of growth may level off eventually, the potential for tremendous increases in traffic in these regions poses a serious concern.

The problem is not limited to the number of installed units but extends to the growth in



Prepared by the STFC based on Reference[4]

Figure 4 : Global distribution of installed routers and populations

the speed and size of high-end routers residing on backbone networks. The top-of-the-line routers of Cisco Systems, a U.S.-based vendor, are designed to use as much as 2 MWh of electricity. Given that the Earth Simulator, Japan's fastest supercomputer, operates at 6-8 MWh, power consumption levels of these routers are high enough to redefine the traditional notion of routers. The Earth Simulator and many other supercomputers around the world consist of a few tens to hundreds of units placed in rows in a room as large as a gymnasium and require an air conditioning system that uses as much power as the supercomputer itself to cool the exhaust heat from numerous units. Unlike supercomputers, whose ownership per country is very limited, top-end routers will have to be installed in substantial numbers across the world as long as the current communications network architecture is retained.

6 Research issues in ICT's social scientific aspects

Previous sections focused on identifying problems by reviewing R&D in hardware and the current state of growth in communications traffic. However, social scientific perspectives are also important in examining the ICT sector.

Although Figure 3 and Table 4 predict by extrapolation of current conditions that communications traffic will soar by an astounding 40% annually, some may doubt if communications traffic will continue to grow at the current pace even in regions with a sufficient information infrastructure. There are limitations to humans' information processing capacity as long as they exchange information using the five senses as the interface.

Nevertheless, humans have a desire for information, an inherent desire to seek as much information as possible, even where the amount of information exceeds their capacity to process it. In a questionnaire survey conducted around 1990, a time when mobile telephones were not yet widely available, most of the respondents answered, when asked whether they would use mobile telephones if any became available, that they would not need such telephones. Many also answered that they would not use functions to transmit text messages and pictures even if they were enabled. However, the reality today is that the majority of the Japanese, the young and the old alike, are familiar with these functions and even use more advanced services such as music and video distribution on a routine basis. Moreover, exchanging e-mail via PCs and mobile telephones has become the mainstream mode of communication. Sending e-mail via a PC or mobile telephone, even to communicate with a person sitting next you, is nothing unusual any more, especially among younger generations. From a purely resource-saving viewpoint, it would be preferable to restrict such actions that require the data, directed to the person in the next seat, to travel a few tens, or sometimes a few tens of thousands, of kilometers over a huge communications infrastructure. However, this issue is not simply about sending information, when viewed from the perspective of the significance of communication.

A debate on sustainable development often concentrates on restrictions, such as saving petroleum resources, but in the ICT sector, such a debate should start by determining from which standpoint the debate should be held. A common view is that the limitations of disposable income, combined with increased costs as a result of increased energy consumption, will naturally restrict the volume of information that people will be able to obtain. However, curtailing communications costs can be more difficult because the process of satisfying the desire for information may be more complex.

For example, the Family Income and Expenditure Survey conducted by the Statistics Bureau of the Management and Coordination Agency (now the Ministry of Internal Affairs and Communications) shows that while consumption expenditure per household has declined since 1995 (from ¥329,062 in 1995 to ¥266,508 in 2005), the ratio of spending on transportation and communication to total expenditure has expanded (from 10.0% in 1995 to 13.0% in 2005). The statistics on monthly income and expenditure by income quintile group, for which households are divided into five groups by annual income level, also suggest that spending on transportation and communication accounts for 10.8% to 14.0% of the total expenditure regardless of the family's annual income. This makes transportation and communication distinguishable in nature from normal goods (goods for which demand increases as the incomes of consumers increase, e.g., clothing, education and entertainment) and inferior goods (goods for which demand falls as the incomes of consumers increase, e.g., food). For instance, families often give a high priority to spending on mobile telephones even when they have to curtail other expenditures, a tendency that is not observed in their spending on other consumer goods.

Humans tend to pursue the desire for information beyond their cognitive capacity. With this in mind, increases in information processing and communications traffic should be examined from the viewpoint of cognitive science. This poses a major challenge in the interdisciplinary field spanning engineering and social science.

7 Conclusion

Quantitative discussions on energy issues in connection with ICT have started in many parts of the world. In the U.S., the Department of Energy (DOE) and the Institute of Electrical and Electronics Engineers, Inc. (IEEE, a U.S.-based electrical and electronics professional association), as well as IBM and Intel in the private sector, are seriously addressing this topic. On the other hand, activities in Japan are still in their early stages as MIC and the NTT Group have just initiated their own efforts. The development of the information infrastructure under the e-Japan Priority Policy Program has brought the rapid proliferation of ADSL, FTTH (optical fiber) and other broadband circuits, while the burgeoning of content businesses to distribute music and video has led to a surge in data traffic (information distribution) at a stunning annual rate of 40%, exceeding Moore's Law. This has resulted in a sharp increase in energy consumption. It is a little known fact that the electricity purchased by the NTT Group is already almost double the amount in 1990, accounting for as much as 1% of the total power generated in Japan.

Since substantial progress has been made in reducing the power consumption of ICT equipment for use in homes and offices, people tend to be optimistic about the resolution of energy problems. However, reducing energy consumption of the ICT infrastructure may not be as easy as this. The equipment used for the communications infrastructure must constantly operate under heavy loads and has reached a phase where conventional energy-saving technologies can no longer bring about the same effects as they did in earlier models. These issues raise the need to start R&D that will review the fundamental device structure, and these technologies should be systematically examined from different perspectives, including devices, equipment and network architecture.

At the same time, debates are needed on the social scientific aspects of ICT. The desire for information and increases in communications traffic should be discussed from a cognitive scientific viewpoint, and the notion of consumption should be reviewed from more detailed economic perspectives, in light of the essence of communication as the foundations of ICT. These pose major challenges in the interdisciplinary field spanning engineering and social science.

These energy problems in the ICT sector could prove to be critical in sustainable development of Japan and the world.

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3

Restration and Recovery Technologies for Illegal Dumping of Waste Pollution

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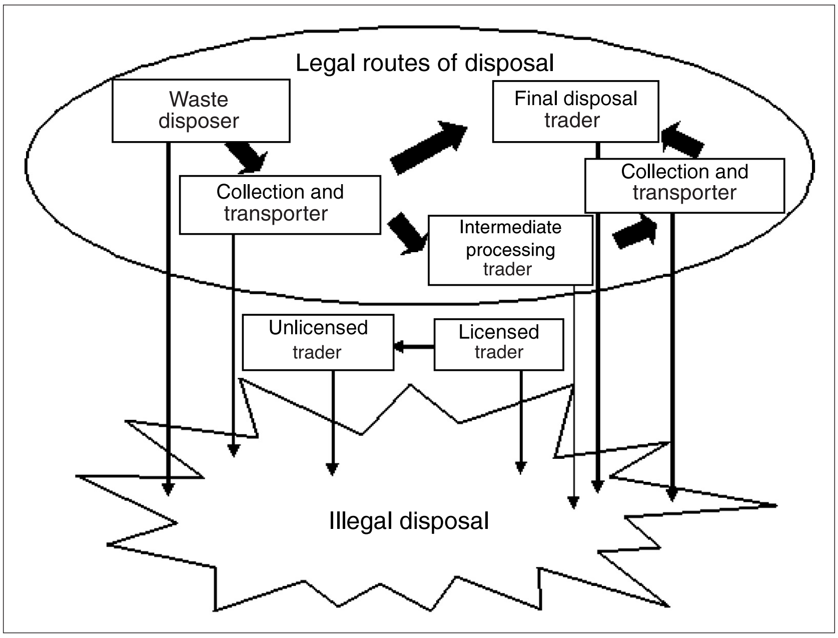
1 Introduction

As society's concern for safety and security has increased in recent years, so too has the Japanese citizen expectations that science and technology will help address these issues. Greater contributions to safety and security will be required of science and technology policy in the future[1].

The illegal dumping of waste is a problem that must be addressed since it threatens society's safety and security. As illustrated in Figure 1[2], the illegal dumping of waste that should be reused, recycled for use as resources, or properly processed or disposed of is an ongoing problem. Illegal dumping of waste is not only an impediment to the creation of a sound material-cycle society, but it also causes serious environmental problems by polluting the environment with toxic substances included in the dumped waste. Pollution from illegal dumping has characteristics that differ from the typical environmental pollution caused by other human and industrial activities. In addition, the restoration and recovery of sites where illegal dumping have occurred poses a variety of problems, including not only technical issues but also enormous economic costs and impact on surrounding environments.

Social and technological factors contribute both to illegal dumping and the countermeasures



Based on Reference[2], with some modifications

Figure 1 : Flow chart of illegal waste disposal

that can be taken against it. From a different perspective, there are both preventative measures that can be taken before the act of illegal dumping and responsive measures that can be taken afterwards. Social factors such as the cost of waste disposal are intimately related to the incidence of illegal dumping. In order to address the root causes of illegal dumping, the social and economic structures that contribute to it must be sufficiently understood so that effective preventive systems can be introduced. This article focuses on the technical aspects involved both before and after illegal dumping, looking at the problem from a science and technology perspective. In addition, by summarizing and analyzing the status of illegal dumping, environmental pollution and the technological countermeasures taken, this article addresses those science and technology policy issues that should be directed as preventative technologies for illegal dumping and as pollution recovery technologies.

2 Status of illegal dumping and characteristics of environmental pollution

2-1 Nationwide situation in Japan[2-3]

Figure 2 illustrates trends in the illegal dumping of industrial waste over the past 12 years. Cases of illegal dumping increased annually from FY 1993 through FY 1998, reaching well over 1,000 cases in FY 1998. The number of cases of illegal dumping remained high (above 1,000 annually) through FY 2001 but began declining in FY 2002. The volume of waste dumped, however, did not show a corresponding decline. This is because of the large differences in volume among cases of illegal dumping, with just a few large-scale cases accounting for the bulk of an entire year's volume. For example, of the 745,000 tonnes noted in Figure 2 for FY 2003, a single case in Gifu City (Tsubakibora area) accounted for 567,000 tonnes, or about 76 percent of the entire annual total.

Figure 3 summarizes the number of cases and volumes in FY 2004 according to the types of industrial waste dumped. In terms of the number of cases, rubble, wood scrap, and mixed construction waste were the most common types, accounting for around 64 percent of the total. Including additional types of construction-related waste, construction waste accounted for about 71 percent of the total. In terms of volume, however, construction-related waste plastic chips, alone, accounted for 56 percent, with all forms of construction waste accounting for 86 percent of the total. Looking at the statistics for past fiscal years, in terms of the number of cases, little change is seen in the relative composition of the various types of waste. In terms of volume,

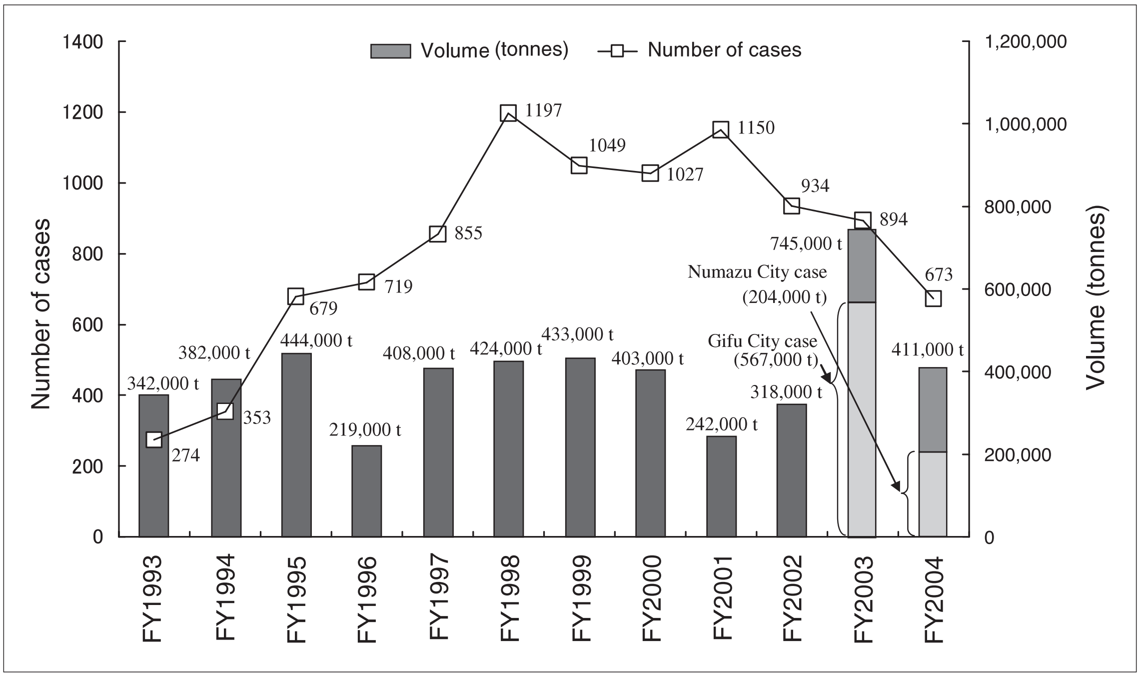


Figure 2 : Cases of illegal dumping of industrial waste and the volumes dumped[3]

however, composition can be seen to vary from year to year with rubble, wood scrap, and mixed construction waste each accounting for about 20 percent of the total, overall, while specific types of waste were particularly common in fiscal 2003 and 2004 because of a single large-scale case of illegal dumping.

As for those who engaged in illegal dumping, waste-generating enterprises were the most common, accounting for about 48 percent of all cases, in terms of numbers. In terms of volume, waste-generating enterprises and unlicensed enterprises accounted for the majority of cases. Forests and agricultural land accounted for about half the illegal dumping sites (by land use category), indicating a preference for areas that are not easily observed. Looking at the prefectures where most dumping occurred, Ibaraki and Chiba Prefectures figured prominently, suggesting a pattern of waste from the greater Tokyo area being transported to surrounding areas. The number of cases of dumping found in municipalities in outlying regions such as Aomori and Nagasaki Prefectures is also notable.

Table 1 shows the status of efforts undertaken to eliminate the problems resulting from recent cases of illegal dumping. In terms of the number of cases, 30-35 percent have yet to be addressed. In terms of volume, due to a large-scale incident (FY 2003), there is a significant difference between the volume that has been partly addressed and the volume yet to be addressed. Because countermeasures require a long time to implement, complete elimination has only been possible in less than 10 percent of all cases.

2-2 Characteristics of large-scale incidents and the countermeasures taken against them

The following characteristics are typical of environmental pollution resulting from illegal dumping[4].

- The types of waste buried vary widely, and

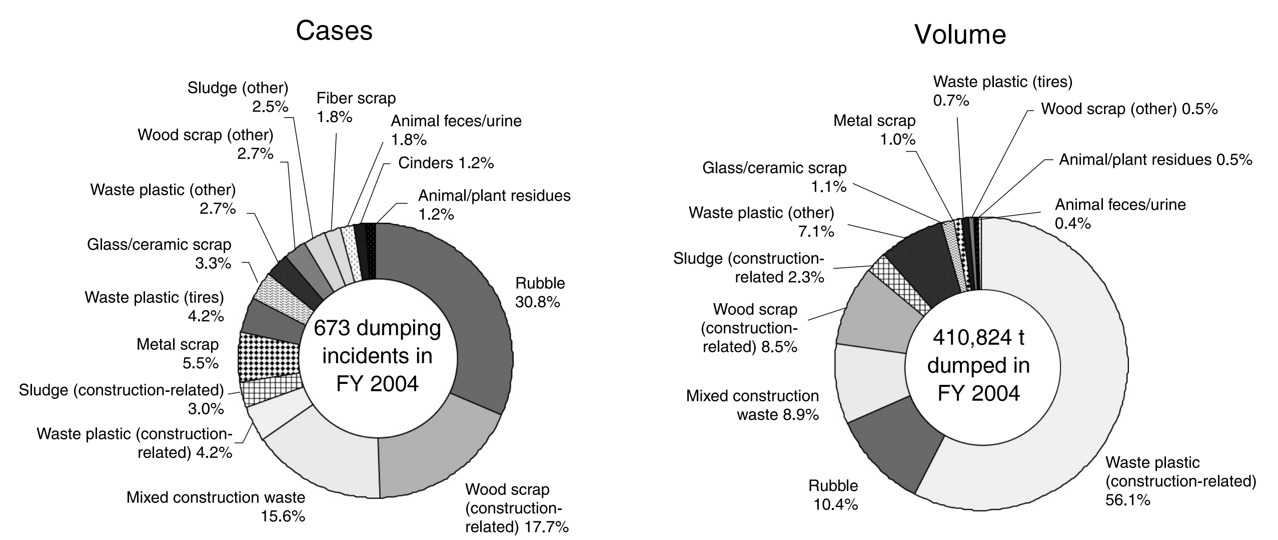


Figure 3 : Illegally-dumped waste (number of cases and volume)[3]

Table 1 : Status of elimination of problems resulting from illegal dumping(responses carried out within each fiscal year)[3]

Status	FY 2004		FY 2003	
	No. of cases	Volume (t)	No. of cases	Volume (t)
Completed	387 (57.5)*1	37,081 (9.0)	463 (51.8)	62,990 (8.5)
Partially addressed	71 (10.5)	279,370 (68.0)	75 (8.4)	65,225 (8.8)
Not addressed	215 (31.9)	94,373 (23.0)	298 (33.3)	613,125 (82.3)
Others*2	0	0	58 (6.5)	3,639 (0.5)
Total	673 (100)	410,824 (100)	894 (100)	744,978 (100)

*1 Numbers in brackets are percentages of the overall total
*2 No response from surveyed municipality

Table 2 : Large-scale illegal dumping cases

Date of discovery, location	Extent	Dumped waste	Pollution status and major pollutants
1990, Teshima, Kagawa Prefecture	Estimated area of 69,000 m^2, volume of about 560,000 m^3, and wet weight of about 600,000 tonnes	Mainly shredder dust, along with paper-making sludge, slag, dehydrated cake, cinders, etc.	Lead, PCB, 1, 2-dichloroethane, cis-1,2-dichloroethylene, 1, 2- trichloroethane, trichloroethylene, tetrachloroethylene, 1, 3-dichloropropene, and benzene
2002, border between Aomori and Iwate Prefectures	15 ha and 150,000 m^3 on Iwate Prefecture side, 12 ha and 670,000 m^3 on Aomori Prefecture side, 820,000 m^3 total	Wide variety of components, mainly bark compost, matter for RDF, cinders, incineration ash, sludge, etc., thoroughly mixed with dirt and buried	Dichloromethane, 1, 2-dichloroethane, cis-1,2-dichloroethylene, trichloroethylene, tetrachloroethylene, and benzene, dioxins, carbon tetrachloride, nitrate nitrogen, and nitrite nitrogen
2004, Tsubakibora, Gifu Prefecture	Estimated 130 m x 200 m x at least 20 m deep, volume of about 753,000 m^3, of which 605,000 m^3 is mixed waste and 148,000 m^3 is concrete rubble	Mainly construction waste, 37% dirt and sand, 30% ceramic/rock/concrete rubble, 21% wood scrap, 7% plastics, etc.	Lead, hexavalent chromium, methane 47 vol. %, hydrogen sulfide 15,000 ppm Water-quality testing of the dump site found high COD and nitrogen concentrations

Prepared based on References[5-8]

include many different pollutants.

- When countermeasures are taken, it is necessary to apply them in stages, i.e., emergency, urgent, and permanent measures.
- The terrain of polluted sites is often complex, making accurate surveying and recovery measures difficult.
- There is little information available on such pollution.
- It is generally difficult to identify the polluters.

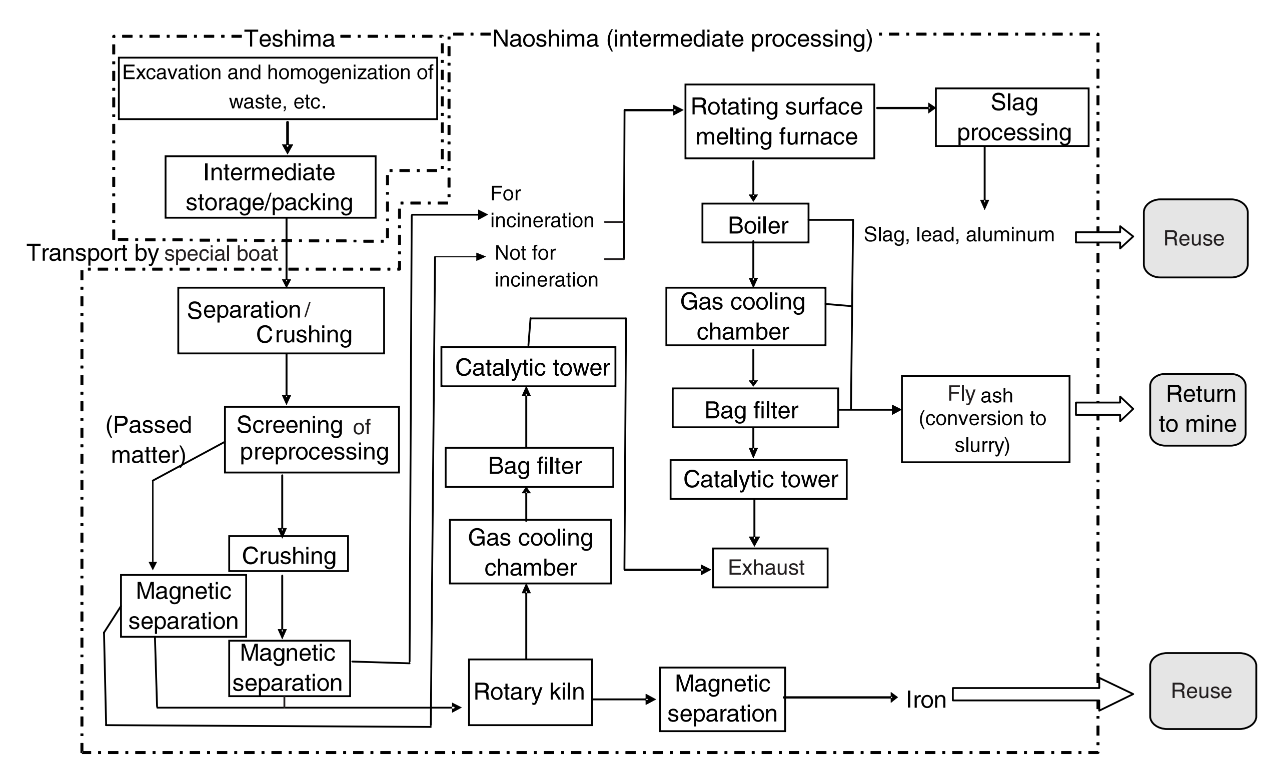
In addition, the occurrence and degree of environmental impact differs depending on the types of pollutants involved and the scale and location of the illegal dumping carried out. Table 2 shows the characteristics of some cases of large-scale illegal dumping around Japan[5-8].

Currently, measures are being taken to solve the problems on Teshima Island and on the Aomori-Iwate prefectural border, in particular, but recovery will take a long time, as shown in Table 1.

(1) Teshima Island, Kagawa Prefecture

Teshima, in Kagawa Prefecture, is a small island west of Shodoshima in the Seto Inland Sea. There, businesses such as an intermediate waste disposal operation, using sludge to raise earthworms in order to manufacture soil amendments, applied to change businesses in 1977 and, around 1983, began transporting and burying large quantities of shredder dust, waste oil, sludge, and so on, as well as openly burning some of it. This resulted in on-going complaints and appeals to the prefectural government from local residents about the damage being done to the environment. In 1990, the Hyogo Prefectural Police raided the site on suspicion of violations of the Waste Management and Public Cleansing Law. This stopped any further illegal waste dumping but left serious, widespread environmental pollution. Currently, all waste disposal on Teshima is now carried out based on the three basic principles of consideration for the environment and for safety, achievement of recycling, and disclosure of information. The more than 600,000 tonnes of waste (mixed with contaminated soil) that were dumped on Teshima are now being transported 5 km by a specialized ship, the Taiyo, to the island of Naoshima for intermediate processing. At a rate of 60,000 tonnes per year, this undertaking will take 10 years to complete[9].

Figure 4 illustrates how these wastes are being processed on the two islands[10]. The primary intermediate process is melting. On Teshima, an impermeable wall has been built along the coastline to prevent leachate carrying toxic substances from the waste layer reaching the sea. Furthermore, temporary environmental protection measures have been taken, including the relocation of scattered waste sites to prevent the spread of contamination and to facilitate the construction of new facilities, and laying gas-permeable waterproof sheets to prevent the scattering of waste and the inflow of rainwater. Seepage water and wastewater are processed at an advanced wastewater treatment facility. The



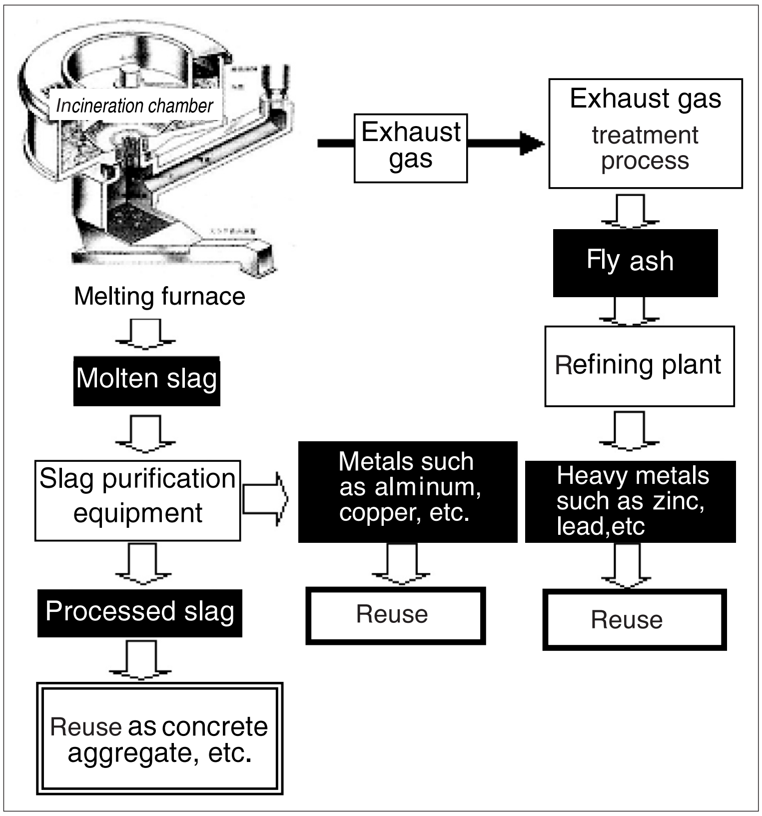
Prepared based on Reference[10]

Figure 4 : Flow chart of waste processing on Teshima and Naoshima

characteristics of the waste change markedly when it is excavated. In order to safely operate the melting furnace during intermediate processing and in order to produce a stable, inert resource from the melting process, the waste that is processed must first be homogenized. The moisture content, composition of its main components, and the flammable volume of the waste are all particularly important. High moisture content can cause handling problems at the processing facilities, as well as increasing fuel use during melting. In order to efficiently carry out melting at about 1,300°C, the CaO/SiO_2 ratio, which has a major effect on melting flow temperature, must be correctly adjusted. In addition, the heat value of the substances being melted must also be controlled. In order to homogenize the waste being processed in this way, lime is mixed in as a melting agent and the resulting exothermic reaction is used to regulate moisture content. After this curing process is completed, the waste is transported to Naoshima on trucks developed especially for disposal work.

At the intermediate processing facility, this waste is then melted along with general waste. The melting furnace has two towers, each capable of processing 100 tonnes per day. It is expected to take 10 years to process all of the waste from Teshima. Melting generally produces molten slag and fly ash. Ordinarily, molten slag can be effectively used as-is for concrete aggregate and so on. However, Teshima's waste contains much shredder dust along with copper wire, aluminum, and stainless steel from auto parts, which form metal particles in the slag. Therefore, separating and refining this metal not only raises the quality of the slag, it enables effective use of the separated metal. Special crushing and selection, along with separation by specific gravity, are used for this recovery process.

Figure 5 illustrates the process involved in melting and byproduct generation[11]. After quality control is carried out on the slag, it is used in Kagawa Prefecture as a material for public works and so on. The fly ash contains a lot of metal, such as zinc and lead, so it is transported to a copper smelting plant already operating on Naoshima and used as a raw material for heavy metal extraction. There is a separate rotary kiln for iron lumps, rocks, and other materials unsuited for melting. The exhaust gas produced is processed in the same way as the melting furnace system.



Based on Reference[11], with some modifications

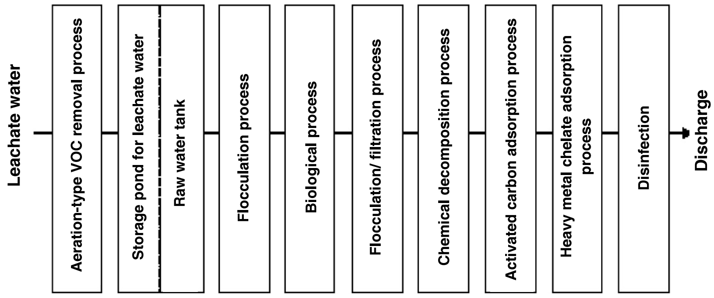
Figure 5 : Flow chart of reusing process of intermidiation byproducts

(2) The border between Aomori and Iwate Prefectures

Illegal dumping along the border between Aomori and Iwate Prefectures began in the early 1990s when an industrial waste disposal company in Hachinohe City, Aomori Prefecture, started illegally dumping the industrial waste it received from a similar company in Saitama Prefecture. On-site investigation and guidance by a public health center began in 1994, and detailed surveys of contamination began in 2000. The waste-generating enterprises connected with the site are primarily in the Tokyo area, but range from Hokkaido to Kyushu.

Recovery measures for the site are being taken by both prefectures. Aomori Prefecture has set up an impermeable wall to prevent the leaching of toxic substances into the rainwater or groundwater. In addition, it has implemented water purification using an advanced wastewater treatment system that can handle mixed contaminants. Toxic landfill waste is removed to an industrial waste processing facility (high-temperature melting using a gasification melting furnace) in Aomori City.

Figure 6 illustrates the advanced wastewater treatment process, described above. Because the water seeping from the contaminated site contains volatile organic compounds (VOCs) such as dichloromethane and benzene, the raw water is first treated with VOC processing equipment. It is then aerated to produce a gas phase from which the VOCs are removed by activated carbon adsorption. Subsequently, biochemical oxygen demand (BOD)*1 components are removed through the use of a biological treatment process, and fine particulate matter is removed using a flocculation/filtration process. Next, an ozone/ultraviolet advanced oxidation process (using chemical decomposition equipment) removes dioxins and other persistent substances and chromatic components. Activated carbon processing equipment removes the few remaining organic components, and chelate adsorption equipment selectively removes heavy metals. This mixed processing system has not been in operation long, but because there has apparently been little seepage from the most contaminated areas, the raw water has been less contaminated than expected, and the quality of the processed water has therefore been very good. When the cleanup process starts excavating areas



	BOD	COD	SS	Dichloro-methene	Dioxins	Boron
Raw water (VOC raw water tank)	59	57	22	<0.02	3.3	1.0
Treated water (discharge facility sampling tank)	<0.5	5.3	<1	<0.02	0.0001	0.82
Setting of processed water quality	60 or less	90 or less	10 or less	0.2 or less	1 or less	10 or less

Units for water quality are mg/l, except for dioxins (pg - TEQ/l)

Prepared from Aomori Prefecture technical documents

Figure 6 : Flow chart of the advanced wastewater treatment facilities for illegally dumped waste on the Aomori side of the prefectural border (above), and examples of water quality values (below)

containing many contaminants, the seepage of more heavily contaminated water may result.

On the Iwate Prefecture side of the border, measures are being taken to remove all the waste. Post-excavation selection is performed, and the waste is transported to industrial waste processing facilities, centered on a major cement plant located in the prefecture. The waste is incinerated, burned, or melted. Reportedly, 23,600 tonnes, 20.7 percent of the total, had been removed as of December 10, 2005. The total volume removed during FY 2005 was 30,108 tonnes.

(3) Tsubakibora, Gifu City

In Tsubakibora, Gifu City, an industrial waste disposal business located in that city began dumping construction waste in a valley next to its disposal facility. Detailed environmental surveys revealed hexavalent chromium levels exceeding allowable environmental standards for soil and lead levels exceeding soil component standards in the waste layer, but the overall risk from toxic substances was judged to be low. In addition, following urgent measures, the matter has reached a stage where concrete actions and possible issues have been narrowed down for each of three permanent measures, i.e., leaving the waste in-place, removing part of it, or removing all of it.

2-3 Legal systems related to illegal dumping

A 1997 revision of the Waste Management and Public Cleansing Law strengthened the responsibility of waste-generating enterprises to assist in the recovery of environments damaged by illegal dumping and imposed serious penalties for improper disposal. However, cases that already existed before the law was implemented have caused long-term problems. They have contributed to public mistrust of industrial waste management, becoming major impediments to the formation of a sound material cycle society. Therefore, the Law on Special Measures Concerning the Removal of Environmental Problems Caused by Specified Industrial Wastes was passed and implemented in June 2003. It mandates the necessary funds, for the period from FY 2003 through FY 2012, to enable prefectures and so on to systematically and steadily implement their own measures to remove and prevent problems in living environments related to illegal dumping that occurred before the revision of the Waste Management and Public Cleansing Law. Under this law, the Minister of the Environment is to set forth basic policies for the systematic and steady removal and prevention of environmental problems, and prefectures and cities with public health centers are to develop specific action plans based on these basic policies. Subsidies from the national government are available for the removal and prevention of specified environmental problems, and prefectures and municipalities can issue bonds in order to meet their expenses. An overview of the removal and prevention of problems is provided in Figure 7.

3 Pollution remediation technology and characteristics

3-1 Commonly used methods for remediation

Remediation from pollution due to illegal dumping requires the setting of appropriate priorities at the time the contamination or environmental damage is discovered. These priorities can be classified according to the urgency of the measures needed[4]:

(i) Emergency measures: Measures that can be taken immediately when quick testing and surveys have judged that the risk to human health, etc. is very high. They include the evacuation of residents, prohibition of the drinking of groundwater, removal of the contamination source, etc.

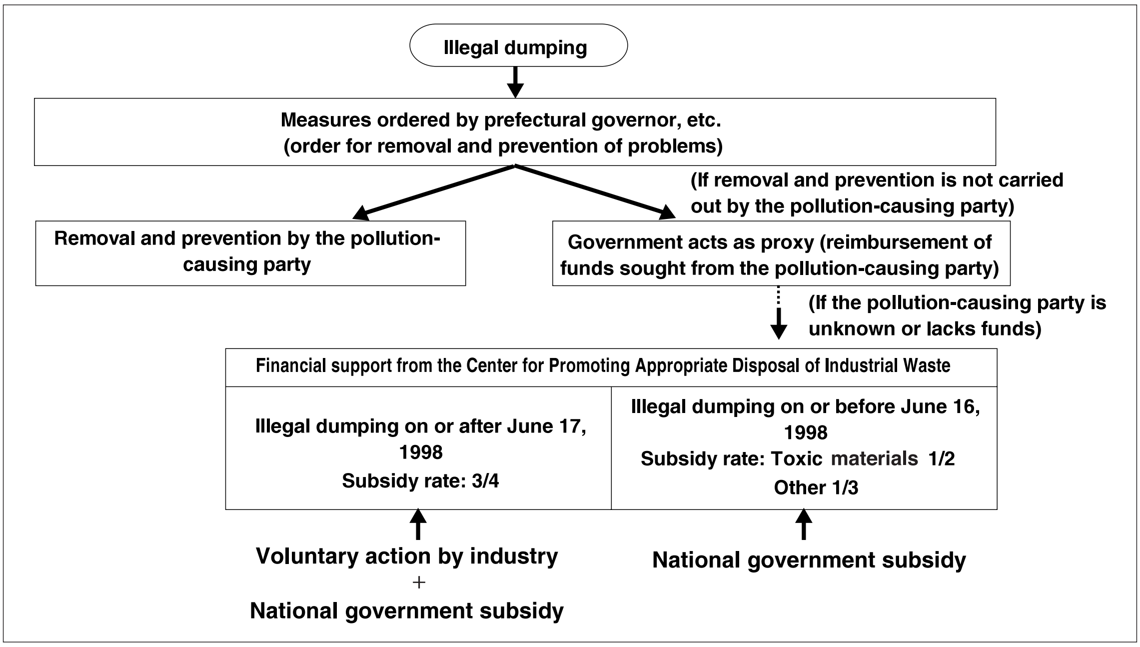
(ii) Urgent measures: Based on detailed site surveys, these include measures such as covering or walling-off contaminated areas to minimize damage by preventing the spread of pollutants to surrounding areas.

(iii) Permanent measures: Based on drilling surveys and test application of recovery technologies, these include measures such as applying appropriate technologies to ensure permanent safety.

The contaminants found at illegal dumping sites and surrounding areas can include the waste itself, the soil, and the water. Technical means to permanently ensure their decontamination can be roughly divided into decontamination and containment (isolation and management). Decontamination may be carried out on-site by removing contaminants from the site or off-site by excavating the site and moving the contaminants elsewhere for further processing. Removal can mean either isolation, moving to other sites using mechanisms for decomposition, or the destruction of the contaminated substances.

3-2 Technologies that target solids

There are no specific, clearly designated technological systems called “remediation technologies for pollution resulting from illegal dumping.” Typically, those technologies already used for other forms of soil and groundwater pollution remediation are modified for use against specific targets, as required. Table 3 shows



Source: Ministry of the Environment

Figure 7 : Flow chart for the removal and prevention of problems related to illegal dumping of industrial waste

remediation technologies for some common soil and groundwater contaminants such as VOCs, heavy metals, dioxins, PCBs, and other refractory organic contaminants.

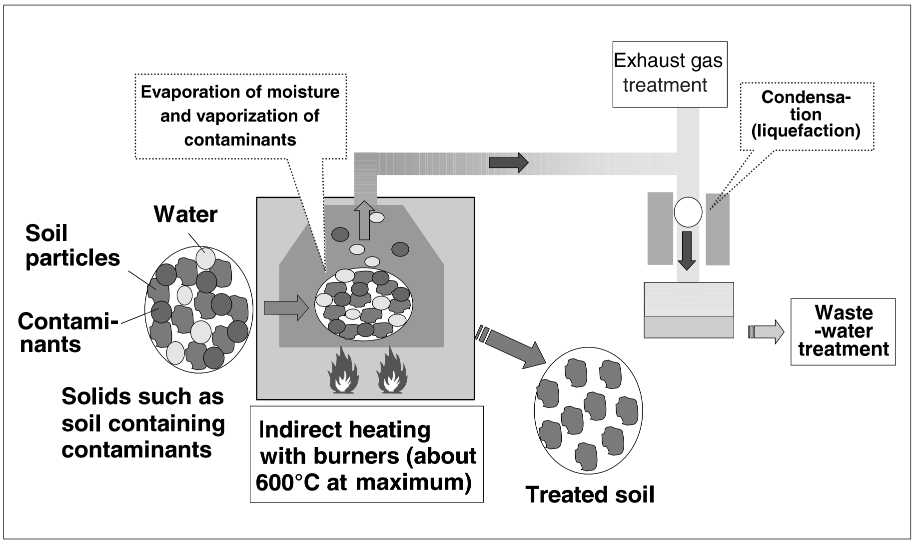
(1) Physicochemical and thermochemical processing

Figure 8 shows an example of separation technology using indirect heating that applies external heat to a target substance. Moisture expelled by heating, contaminants and particulate matter then enter the wastewater through the cooling and condensation of exhaust gas, so the exhaust gas and wastewater must be processed as well. Generally, separation technology requires separate facilities for the processing of contaminants after their separation and recovery.

Refractory organic contaminants are difficult to decompose. High-temperature or combined high-temperature/high-pressure processing technologies such as incineration, melt-solidification, and hydrothermal oxidation are therefore used. Processing is often carried out after excavation. Incineration involves burning at a temperature of about 800-900°C, while melt-solidification involves burning at a high temperature of around 1,300-1,400°C inside a melting furnace, turning solids into molten slag. Melt-solidification requires large energy inputs because it uses electricity or fuels such as kerosene but, since it involves high-temperature manipulation, it can completely decompose refractory organic substances. The major types of melt-solidification treatment used are surface melting, coke beds, rotary kilns, and electric. Slag generated by the melting of inorganic components such as silica dioxide and aluminum oxide contains heavy metals within its mesh-like structure, so there is little likelihood of their elution. This makes the slag suitable for effective use as aggregate in buildings and so on. Another technology in the melt-solidification category is

Table 3 : Treatment technologies for VOCs, heavy metals, and other toxic materials in soil and groundwater

Target	Classification by processing location	Principle of technology		Examples of treatment technology		Examples of target substances
Solids (soil), liquids (groundwater)	In-situ decontamination	Separation	Contaminants are separated by converting them from a solid or liquid to a gas through volatilization, etc.	Physicochemical technology	• Pumped water, pumped water aeration • Soil gas aspiration (simultaneous aspiration of soil gases and groundwater) • Air sparging (includes bioremediation)	Organochlorine solvents such as trichloroethylene and tetrachloroethylene and VOCs such as benzene
					• Soil flushing • Solidification, deliquefaction	Heavy metals
		Decomposition	Decomposition through chemical (dechlorination) or thermochemical processes	Physicochemical technology	• Oxidation-reduction (use of permeable reactive barrier using iron powder)	Organochlorine VOCs
				Biological technology	• Bioremediation • Biostimulation • Bioaugmentation	Organochlorine solvents and VOCs such as benzene
Solids	Excavation and removal decontamination	Separation		Physicochemical and thermochemical technology	• Lime processing • Heating (indirect heating desorption, etc.)	Organochlorine solvents and other VOCs and cyanide compounds
		Decomposition		Physicochemical and thermochemical technology	• Heating • Incineration • Melt-solidification • Alkaline catalytic chemical decomposition	Dioxins (melt-solidification) Petroleum VOCs (oils), heavy metals, PCBs
				Biological technology	• Bioremediation	Organochlorine solvents, petroleum VOCs



Based on technical documents from Konoike Construction Co., with some modifications

Figure 8 : Example of a contaminant desorption system using indirect heating

an electric resistance melting technique that uses heat from electrodes for melting (the geomelt method). This technique is used for contaminants with high dioxin densities and contaminated soil found at industrial waste incineration sites[12].

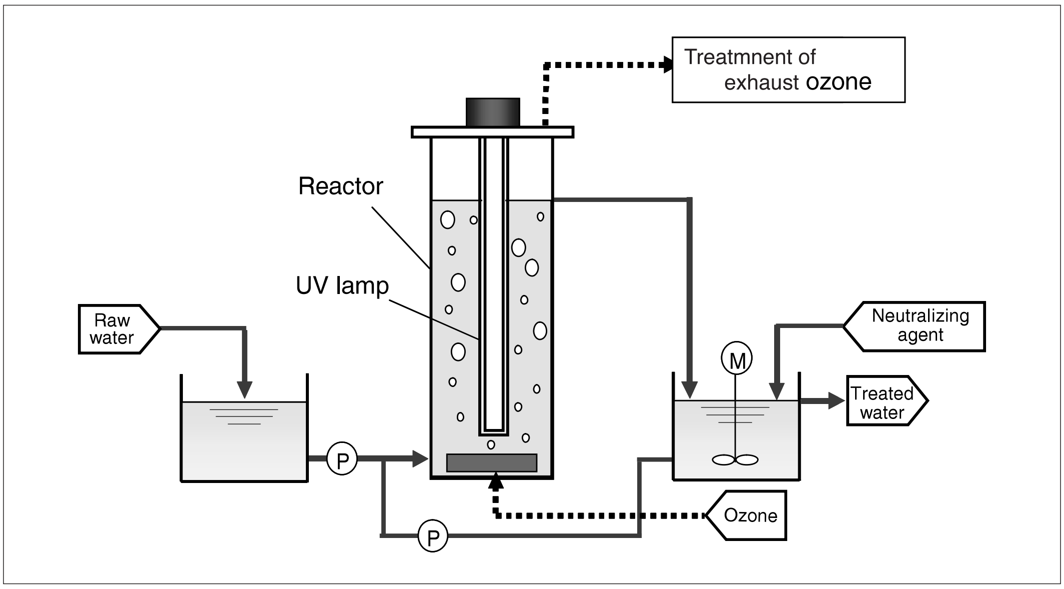
(2) Biological processing

Microorganisms have the ability to decompose various organic compounds. Bioremediation is being developed as a recovery technology that uses biological functions in open environments contaminated by illegal dumping. Bioremediation includes biostimulation, which introduces methane and other organic matter which microorganisms need in order to grow, nutrients such as nitrogen and phosphorus, and air into contaminated soil in order to increase the activity of indigenous microorganisms and to promote decontamination, and bioaugmentation, which introduces cultured microorganisms with a high degree of decontamination activity related to specific target contaminants in order to promote active decontamination. In addition, a passive method such as natural attenuation simply involves waiting for indigenous microorganisms to naturally reduce contaminant densities after physicochemical processes and so on have been used to decontaminate high-density contamination as much as possible. Bioremediation is mostly used to decontaminate soil and groundwater contaminated with petroleum components, especially benzene, and with organochlorine solvents that have low boiling points (trichloroethylene, tetrachloroethylene, etc.). Bioremediation is generally less expensive than other physicochemical processing technologies, but it requires relatively long periods of time to work, is difficult to apply to high-density contamination sites, and is affected by temperature and coexisting substances. In addition, the impact of microorganisms on surrounding environments must be fully assessed. Concern must be given to environmental safety when introducing new microorganisms from the outside.

3-3 Technologies that target water

Decontamination of water at illegal dumping sites usually involves processing of the water that seeps from the dumped waste and the surrounding area. This seepage water is a common characteristic of illegal dumping and typically contains a mixture of many different contaminants. Processing technology for this polluted water should therefore be either a single operation that includes multiple functions or a combination of many single-function operations. This requires advanced wastewater treatment technology.

An advanced treatment technology that has been increasingly adopted for use on persistent substances in recent years is advanced oxidation processing. This process uses physical means or ozone, hydrogen peroxide, ultraviolet rays, or



Prepared based on Reference[13]

Figure 9 : Example of advanced water treatment equipment using an ozone/ultraviolet advanced oxidation process

other substances with strong oxidizing power to cause the oxidative decomposition of persistent substances in water. Figure 9 shows an example of advanced treatment equipment that combines ozone and ultraviolet irradiation[13].

In addition to the above, activated carbon adsorption has long been used as an advanced treatment technology that is very effective at removing hydrophobic organic compounds. In addition, membrane separation processes capable of screening at the μm-nm level - in other words, at the molecular level - are being developed along with new materials such as macromolecules. Furthermore, chelate adsorption using chelate resins with specific binding capacities is widely used for the removal of heavy metals.

4 Trends towards increased safety and security in recovery and resource recycling

4-1 Lowering the environmental risks of recovery

The goals of technological recovery regarding pollution from illegal dumping are removal of the contamination, reduction of environmental risks caused by the contamination, and restoration of the contaminated area.

This involves the following key issues.

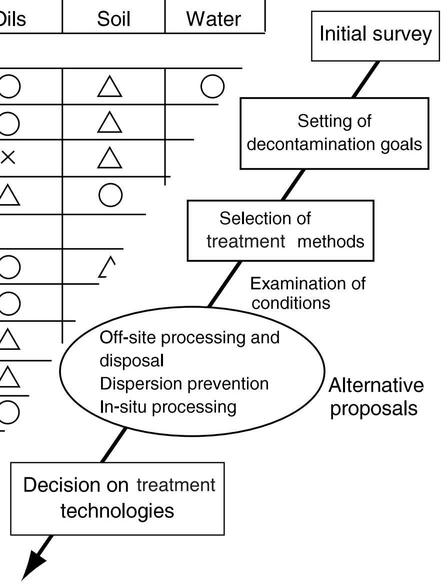
- Establishment of rational methods for the selection of recovery technologies
- Appropriately representing lowered environmental risk due to recovery

Recently, it has become possible to optimize procedures for the selection of recovery technologies because, as depicted in Figure 10, information on the technologies applicable to different contaminants and media has now been collected and arranged into clear standards to assist the selection process[14]. Until now, selection has usually taken place based on the kind of qualitative standards shown in Figure 10 or based on past experience but, in the future, it will be important to make this process as quantitative as possible. Research and development on this subject is being carried out, for example, through joint research by a Hokkaido University research group and private sector businesses[4].

After illegal dumping is discovered, it is necessary to assess the condition of the environment at the site and in the surrounding area. It is vitally important to know the risks posed to human health and to the affected ecosystems. At the same time, it is necessary to assess, as quickly as possible, the state of contamination both on the surface and in the three-dimensional space comprising the affected site. Currently, such monitoring is carried out using the existing survey and measurement

Technology	Contaminant			Target medium	
	VOCs	Heavy metals	Oils	Soil	Water
Dispersion prevention technology					
Impermeable wall	○	○	○	△	○
Barrier reservoir	○	○	○	△	
Reactive barrier	○	△	×	△	
Solidification/deliquefaction	△	○	△	○	
In-situ processing technology					
Pumped water processing	○	○	○	△	
Soil flushing	○	○	○		
Solidification/deliquefaction	△	×	△		
Soil gas aspiration	○	×	△		
In-situ melt-solidification	○	○	○		
Electrical separation	×	○			
Air sparging	○	×			
Bioremediation	○	×			

○ = very appropriate △ = somewhat appropriate × = not appropriate



Based on Reference [14], with some modifications

Figure 10 : Evaluation of applicability and selection of recovery technologies

methods available for soil, groundwater, and air pollution assessment. However, this approach relies either on drilling, which is expensive and cannot always be carried out in some areas, or on the external diagnostic method of high-density electronic surveying, which has accuracy problems. There is, as yet, no simple and quick analysis method that can reliably detect, identify, and measure a variety of contaminants. Furthermore, there are no methods or procedures available for assessing the entire scope and range of pollution based on the limited data available.

4-2 Safety of the technology used

According to the safety-related data available for various industrial fields, the waste disposal sector has a high accident rate. Such accidents are common at facilities using methods involving relatively new technologies. The example described below relates to a case when gasification melting furnaces were first introduced.

About four months after the melting furnace equipment at the Teshima intermediate processing facility began operating, a small explosion occurred[15]. The cause was an accumulation of flammable gases, mainly hydrogen gas derived from the materials being processed, in the space above the conveyor belts where it was set alight (static electricity is suspected) causing a fire and an explosion. The hydrogen gas was generated by the excessive moisture in the waste excavated from the Teshima site reacting with the metals present and the lime mixed in to improve melting. Therefore, a specified period for the dissipation of hydrogen gas had to be set. However, it was found that even after a considerable amount of time, the amount of hydrogen generated increased inside the melting-furnace facilities when the temperature rose. Furthermore, despite the negative pressure maintained inside the facilities, the low-density hydrogen still apparently accumulated around the top of the conveyer. In order to prevent further problems of this sort, sufficient gas dissipation at the intermediate processing facility before processing, sufficient ventilation, temperature control, and so on have had to be strictly enforced.

It is vital that a multifaceted structure be put in place that can prevent abnormalities occurring in basic safety policies or processes, thereby reducing the risk of such accidents and minimizing the effects of any accidents that do happen.

In the case of Teshima, as mentioned above, the results of all environmental monitoring and environmental protection data from the operation

Table 4 : Examples of measures to prevent illegal dumping

Measure	Details of implementation	Government
Adoption of an on-site observation system with mobile data terminals	PDAs (personal digital assistant) with GPS (global positioning system) and digital cameras are used to collect real-time image and text data from a wide area using a network system enabling strengthened observation and enforcement regarding illegal dumping.	Tochigi Prefecture, Chiba Prefecture, Shizuoka Prefecture
Test consignment of tracking system for proof of appropriate disposal processes	Testing is underway of an image verification system that involves GPS units installed on waste disposal vehicles and tracks them to ensure that they follow appropriate routes and dispose of waste properly.	Kagawa Prefecture
Test tracking through insertion of GPS terminals into industrial waste	Testing is underway of a system that inserts water- and shock-resistant GPS terminals into industrial waste and tracks transport vehicles over the internet.	Tochigi Prefecture
Placement of surveillance cameras to monitor illegal dumping	Suspicious vehicles and the like attempting to illegally dump waste are automatically detected and photographed by continuously operating surveillance cameras, which then transmit the images to government computers where they are recorded.	Sendai City
Mandatory stickers for registered collection and transport vehicles	Registered waste collection and transport vehicles are required by law to display stickers allowing easy identification of licensed versus unlicensed vehicles.	Chiba Prefecture
Reward system for information on illegal dumping	Monetary rewards are provided to those who provide information leading to the detection of illegal dumping.	Kiryu City, Gunma Prefecture, etc.
Rating and bonding system for industrial waste disposal firms	Based on applications from industrial waste disposal firms, rating inspections are carried out and the results are made public. A bonding system for industrial waste disposal firms is in place in case removal and prevention of problems becomes necessary.	Iwate Prefecture

Prepared by the STFC

of the facilities have been made available to the public via the internet and various other methods[9]. Recently, other environmental protection facilities have also been actively implementing similar information disclosure measures.

4-3 Prevention of illegal dumping

A root cause of much illegal dumping is that the waste-generating enterprises involved do not always pay the appropriate fees, so that waste disposal companies are unable to make enough profit. First, it is important to ensure business viability, so waste disposal companies must improve their trustworthiness as excellent businesses. Policies and procedures are needed that enable waste-generating enterprises to select reputable and reliable waste disposal companies. A number of new government policies and experimental initiatives are underway, centered on the local governments that directly monitor illegal dumping. Table 4 shows several examples.

In addition, the Ministry of the Environment and the National Institute for Environmental Studies have developed satellite monitoring systems for the early detection of illegal dumping in order to prevent its spread and minimize its impact, and are studying the usefulness of this system in practice[16-17].

4-4 Resource recycling

As can be seen in the use of the molten slag and fly ash from Teshima (Figures 4 and 5), the effective recycling of resources obtained through pollution recovery, processing and environmental decontamination is very important.

When restoring polluted sites to their original condition, where and how best to implement resource recycling are key issues. Local conditions around the site should also be considered. In the case of Teshima, the placement of the intermediate processing facilities on the site of an existing copper refinery helped make more effective use of the fly ash produced.

5 Key issues that should be promoted as standards for Japanese environmental protection and shared infrastructure development

Overall, Japanese science and technology, as applied to environmental protection, is among the best in the world. For example, according to the Delphi survey led by the National Institute of Science and Technology Policy in FY 2004[18], themes in the environmental field where Japanese technology is seen as leading the world include "Technology for the efficient recovery of rare metals from fly ash as a domestic source of supply." In addition, Japan is seen as leading in "Technology for economically and practically desalinating seawater and purifying polluted water using reverse osmosis membranes or other methods" and in the "Methodology for tracing and identifying recycled materials (plastics and metals)."

In the future, science and technology will be expected to make even greater contributions to environmental protection. In order to combine environmental protection with a safe and secure society, the following important issues should be addressed in terms of shared infrastructure development.

(i) Research and development of analytical methods and simulation technology for damage forecasting, impact assessment, and vulnerability detection
(ii) Research and development of measurement and sensing technology for the early detection of abnormalities
(iii) Construction of information provision systems and information networks that are resistant to disaster and highly reliable
(iv) Comprehensive risk management

6 Current and future prevention and progression prevention of illegal dumping and responses after the fact

Illegal dumping is not something that happens over a short period of time. Indeed, based on past cases, it can take a very long time for the first signs to become apparent and for the dumping to be exposed. Environmental damage caused by illegal dumping can differ in both scope and scale from that caused by other human activities. Furthermore, while some instances of illegal dumping can be dealt with using existing methodologies, other cases require different approaches that take specific circumstances into account. These issues can be considered by dividing them into the prevention of illegal dumping, progression prevention, and responses implemented after the fact.

6-1 From the perspective of the prevention and progression prevention of illegal dumping

Based on past experience, there are various social and economic factors that contribute to illegal dumping. In addition, there are regions and terrain where illegal dumping is especially easy to carry out. Therefore, support tools are required that can effectively monitor and control illegal dumping. For example, experiments with the installation of GPS on relevant transport vehicles and with early monitoring systems involving satellites and GIS are already underway.

When illegal dumping occurs, satellite monitoring systems can play a role in detecting it early enough to prevent its spread, thereby minimizing environmental pollution. Existing systems already have sufficient ability to detect relatively large-scale illegal dumping. However, the necessary increases in resolution needed for the detection of smaller-scale localized dumping, and the fact that these systems are easily influenced by cloud cover, are still major problems. Furthermore, it is difficult to obtain frequent observations from existing commercial satellite orbits and costs are an even greater concern than technical issues. In order for local governments to effectively utilize satellite observation, raising the cost-performance per bit of information through multipurpose use would be desirable. Joint use for forest management and disaster preparedness is one possibility. Emphasizing collaborative and cooperative use across different fields should therefore accompany technical progress.

6-2 From the perspective of responses implemented after the fact

(1) Development of quick and systematic survey tools for environmental impact

When, unfortunately, illegal dumping does occur, it is vital to quickly and clearly assess the degree of contamination and judge its environmental impact so that responses can be properly prioritized. For example, it is essential to develop tools that can quickly and accurately determine the type and characteristics of the waste deposited and any soil and toxic substances mixed with it. Furthermore, these tools should be easy for local governments and so on to use in their investigations. Increased accuracy and faster detection and response times are also needed in the development of non-destructive analysis equipment that can be used in contaminated areas and, to achieve this, collaboration among different research institutions and manufacturers is essential. More venues are therefore needed for technical exchange as well.

(2) Development of optimal pollution recovery technology and application methods, in response to the characteristics of environmental risk

The type of environmental risk posed by illegal dumping depends on the contaminants in the contaminated area and the characteristics of the environmental media located there. Along with the development of appropriate recovery technology, it is useful to be able to simulate events over the short and long term in order to predict potential risks and select the appropriate combinations of recovery technologies in response. In order to reduce costs, methodologies should be developed that can optimize the use of specific technologies, either alone or in combination, in response to specific pollution situations.

In addition, when dealing with wastes and soil combined together in complex mixtures, the goal should be to develop processing technologies that can effectively minimize secondary environmental impacts and optimize the conversion of wastes into usable resources. In order to promote effective technical responses to problems that do occur, such as the case of Teshima, Kagawa Prefecture, as discussed elsewhere in this report, it is useful to promote the sharing of information on pollution recovery. The application of technology to illegal dumping differs from case to case but, in light of the fact that there are many similar instances of soil and groundwater pollution, a database of recovery technologies should be compiled and made available for use by all involved parties and governments when a problem occurs. Governments, research institutes, and businesses should therefore collaborate in order to research and analyze new cases of environmental accidents and recovery procedures based on past experience, forming an appropriate technical infrastructure.

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Glossary

*1 BOD

The amount of oxygen required by aerobic bacteria to carry out oxidative decomposition in water. It is an index of water quality. Generally, it is the amount consumed over five days at 20°C, expressed in terms of mg/l or ppm. While chemical oxygen demand (COD) is used in oceans and lakes, BOD is used as an index of river pollution.

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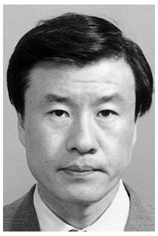

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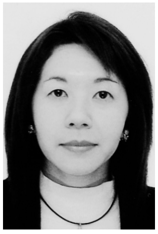

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Proposition in order to Promote the Practice of the Environmental Conduct by the Individual — Promotion of Environmental Education and the Utilization of Environmental Monitoring Data —

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1 Introduction

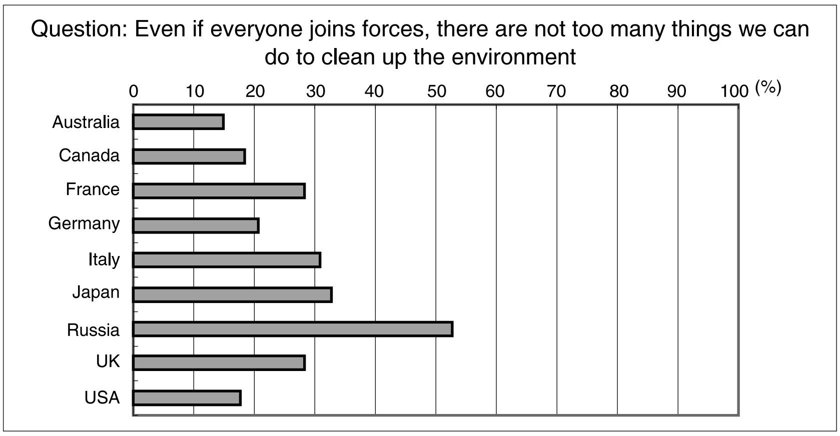
In 1997, Japan agreed to the greenhouse gas reduction goals of the Kyoto Protocol. Japan's goal is to reduce emissions for 2008-2012 to 6 percent below the 1990 level. From 1990-2002, CO2 emissions by different sectors changed as follows[1]. While the industrial sector showed a 1.7 percent reduction, the industrial process sector a 14.0 percent reduction, and the energy conversion sector a 0.3 percent reduction, the waste sector showed a 43.2 percent increase, the household sector a 28.8 percent increase, the transport sector a 20.4 percent increase, and business and other sectors showed a 36.7 percent increase. Although the industrial sector still accounts for the largest portion of this total, raising environmental awareness and promoting the understanding of all members of the public is important in order to meet the Kyoto Protocol goal. In order to address various environmental problems such as air pollution other than global warming, water pollution, waste and so on, it is extremely important that individual members of the public break away from the idea that these are "somebody else's problem" and instead see themselves as personally involved and take action accordingly. A survey of the public's attitudes towards energy and environmental issues, however, found that young people (in their 20s) in particular had a low level of environmental awareness. The dissemination of environmental education that informs individuals that their efforts are highly significant is therefore an issue requiring prompt action.

A major objective of environmental education is the promotion of individual environmental conservation activities addressing various environmental problems such as global warming, air pollution, water pollution, waste, and so on. This process comprises three stages, (i) understanding of environmental conditions and awareness of environmental issues, (ii) understanding of concrete actions that can be taken by individuals, (iii) implementation and continuation of individual environmental conservation activities. This report discusses the measures needed to promote environmental conservation activities by means of environmental education.

2 The need to enhance environmental education

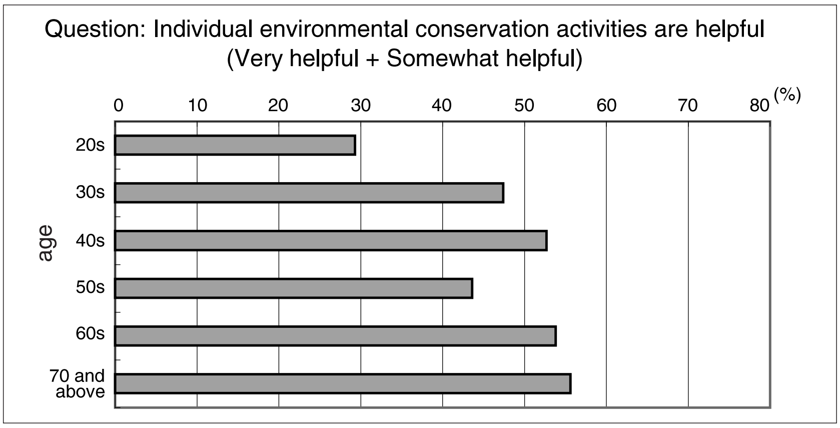
2-1 Results of environmental awareness surveys

Figure 1 shows the results of an international comparison of environmental awareness reported in the Quality of the Environment in Japan (2004 edition)[2]. As shown in Figure 1, more Japanese people hold the opinion that "individual efforts cannot do much to clean up the environment" than do people from the other countries surveyed. Figures 2 through 4 show the results of the Ministry of the Environment's FY 2003 Survey



Prepared by the STFC based on Reference[2]

Figure 1 : Attitudes regarding the effectiveness of individual environmental conservation activities (international comparison)

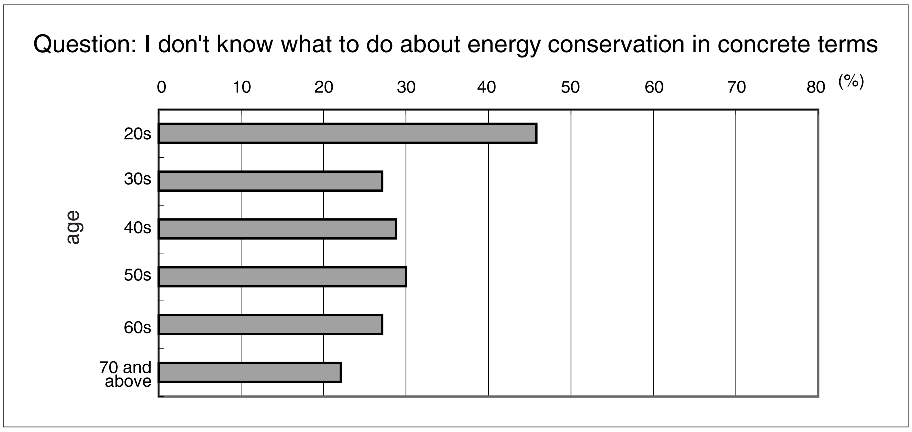


	All	Gender		Age					
		Male	Female	20s	30s	40s	50s	60s	70 and above
Number of samples (N)	1171	545	602	109	169	201	280	258	135
Very helpful	2.0	2.6	1.7	1.8	1.8	2.5	0.7	1.9	5.2
Somewhat helpful	46.1	45.0	46.7	27.5	45.6	50.2	42.9	51.9	50.4
Not really helpful	28.8	33.0	25.1	34.9	32.5	27.9	32.9	26.0	17.0
Not helpful	1.8	1.8	1.7	3.7	1.2	1.5	0.7	2.3	2.2
Don't know	18.9	16.0	21.8	30.3	18.9	17.9	20.4	13.6	19.3
No response	2.4	1.7	3.2	1.8	0.0	0.0	2.5	4.3	5.9

Prepared by the STFC based on Reference[3]

Figure 2 : Attitudes regarding the effectiveness of individual environmental conservation activities (Japan: by age group)

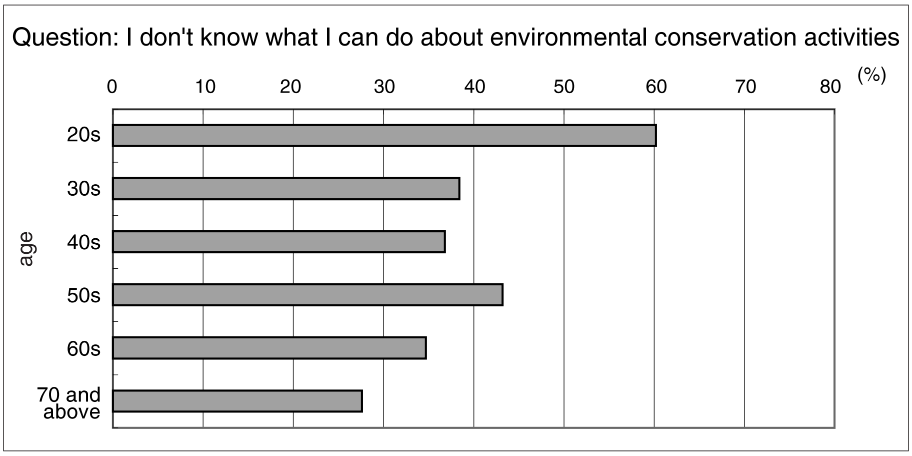
of Environment-conscious Lifestyle[3]. Figure 2 shows a breakdown of the survey results by age, regarding the effectiveness of environmental conservation activities carried out by individuals. The younger age group (20s) contained very few who believed that individual environmental conservation activities are helpful. Figure 3 shows the results of an attitude survey carried out on energy conservation by age group. Over 90 percent of respondents across a broad range of age groups, believed that energy conservation is good for protecting the environment and saving resources, and saw energy conservation as essential. In response to a question regarding actions they were actually taking, however, the answers "I don't know what to do in concrete terms" and "It is troublesome and takes time and effort" were especially common among young people in their 20s. Figure 4 shows the results of a survey on attitudes towards environmental conservation activities. Across a broad range of age groups, over 90 percent of those responding



	All	Gender		Age					
		Male	Female	20s	30s	40s	50s	60s	70 and above
Number of samples (N)	1267	586	652	118	177	212	287	288	163
I think it is good for protecting the environment and saving resources	91.6	91.1	92.7	94.9	97.2	98.6	96.2	86.4	77.3
I don't know what to do in concrete terms	29.2	26.7	30.9	45.8	27.1	28.8	30.0	27.1	22.1
It is troublesome and takes time and effort	25.5	25.0	25.7	33.1	30.5	26.0	27.5	18.4	22.7

Prepared by the STFC based on Reference[3]

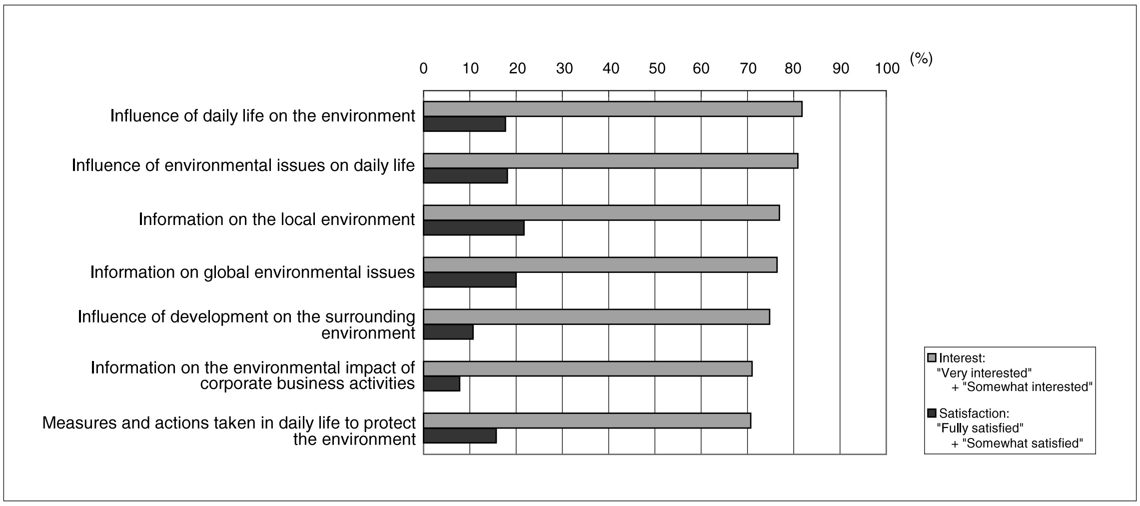
Figure 3 : Attitudes regarding energy conservation (by age group)



	All	Gender		Age					
		Male	Female	20s	30s	40s	50s	60s	70 and above
Number of samples (N)	1267	586	652	118	177	212	287	288	163
I should do what I can to protect the environment	94.5	93.8	95.2	94.9	99.4	97.7	97.9	91.3	85.2
I don't know what I can do	38.7	37.5	40.1	60.2	38.4	36.8	43.2	34.7	27.6
Even if I do something, I can't see it having any effect	37.2	33.5	40.6	61.1	48.0	43.3	37.2	27.1	19.0
It is too hard to do something regularly and continue it for a long time	42.1	42.0	43.0	64.4	52.0	47.1	41.4	34.4	27.0

Prepared by the STFC based on Reference[3]

Figure 4 : Attitudes regarding environmental conservation activities (by age group)



Prepared by the STFC based on Reference[4] (N=1,267)

Figure 5 : Interest in and satisfaction with environmental information

believed that "I should do what I can to protect the environment". In response to a question regarding actions taken, however, the response "I don't know what I can do", "Even if I do something, I can't see it having any effect", and "It's too hard to do something regularly and continue it for a long time" were particularly common among the younger age group (20s).

Figure 5 depicts the results of an attitude survey regarding interest in and satisfaction with environmental information[4]. The level of interest was above 75 percent for several categories, including "Influence of daily life on the environment", "Influence of environmental issues on daily life", "Information on the local environment", and "Information on global environmental issues". In contrast, the degree of satisfaction with the information obtained was low.

2-2 Measures on environmental education

The development of environmental education intended to raise people's awareness of environmental issues so they would implement and sustain environmental conservation activities, internationally, began with the UN Conference on the Human Environment in Stockholm in 1972. This was the first international conference on environmental problems. With the importance of environmental issues clearly set forth in the Declaration on the Human Environment agreed upon at the conference, international efforts on environmental education became more widespread, led by UNESCO and the United Nations Environment Programme (UNEP). In 1975, the International Workshop on Environmental Education was held in Belgrade with the participation of 60 countries and 96 experts on environmental education. The Belgrade Charter set forth the importance of environmental education to "develop a world population that is aware of, and concerned about, the environment and its associated problems, and which has the knowledge, skills, attitudes, motivations and commitment to work individually and collectively toward solutions for current problems and the prevention of new ones", as well as a proper form and framework for carrying this out[5].

To that end, the goals set forth at the 1977 Intergovernmental Conference on Environmental Education held in Tbilisi subsequently became the foundations for environmental education. These goals are shown in Table 1.

As seen in the table, environmental education differs from many other forms of education in that it requires not just learning, but also participation and action. In other words, the fruits of environmental education appear as the actions taken by the people living in a society. They must appear as having some sort of tangible effect[7].

In Japan, environmental education measures spread rapidly after 1985. Since the Environment Agency's roundtable on environmental education clarified basic thinking on environmental education in March 1988, the national government has actively promoted measures

Table 1 : Goals for environmental education (Tbilisi Declaration)

Awareness	To help social groups and individuals acquire an awareness of and sensitivity to the total environment and its associated problems.
Knowledge	To help social groups and individuals gain a variety of experience in and acquire a basic understanding of the total environment and its associated problems.
Attitudes	To help social groups and individuals acquire a set of values and feelings of concern for the environment and the motivation to actively participate in environmental improvement and protection.
Skills	To help social groups and individuals acquire the necessary skills for identifying and solving environmental problems.
Participation	To provide social groups and individuals with an opportunity to be actively involved at all levels in working towards the resolution of environmental problems.

Extracted from Reference[6]

for environmental education and environmental learning. Underlying the growing interest in environmental education and environmental learning at that time was the fact that although strict environmental regulations targeting specific pollution sources were effectively curbing industrial pollution, no improvement was seen in urban and household pollution, to which daily life and ordinary business activities are major contributors. Instead of getting better, the situation here was, in some cases actually getting worse.

The 1993 Basic Environment Law specified the "promotion of education and learning related to the conservation of the environment" as being an important policy for environmental protection. Environmental education and environmental learning were thereby accorded great importance under Japanese law.

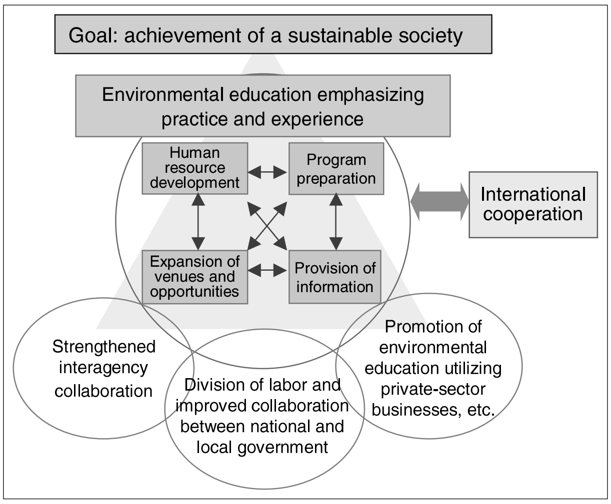
Improving the public's understanding of energy use, which is closely connected with global warming, also became an important issue. The 26th Ministerial Meeting on the Promotion of Comprehensive Energy Measures, held in April 1997, discussed topics such as the importance of further measures by individuals on energy issues including lifestyle changes, and the enhancement of education on resource and energy issues[5]. The Japan Association of Energy and Environment Education[8] was established in September 2005 and began working to raise the level of energy and environmental education, to increase public interest in energy issues, and to promote public understanding of these issues.

It is vitally important that environmental education for all ages and in all fields, including schools, homes, communities and workplaces, does more than just supply people with knowledge. It must enable people to grapple with environmental issues that they have not previously noticed or have never thought of as being personally relevant. It must enable people to see issues as very relevant to themselves and to give them the ability to address those issues by means of sustained action. Measures taken against environmental issues by means of environmental education will therefore become increasingly important.

3 Japan's environmental education and examples of environmental education in advanced environmental countries

3-1 The state of Japanese environmental education

In order to move towards a sustainable society, environmental education must be actively promoted in various venues for all age groups, from children through to adults. Because it is important to connect environmental education with concrete actions for environmental conservation, methods that emphasize practice and experience are preferable. Figure 6 provides a conceptual diagram of policies to promote environmental education in Japan[9]. The following points are especially important when developing environmental education that emphasizes practice and experience: (i) human resource development, (ii) program preparation, (iii) provision of information, and (iv) expansion of venues and opportunities. As we will describe below, these points are all important for environmental education at the primary and secondary levels, as well as in higher education and social education. Strengthened collaboration among national government agencies, division of labor and improved collaboration between national and local government, and the promotion of environmental education utilizing private-sector businesses, etc. are also important means of promoting environmental education. Frameworks for international cooperation are also effective and Japan's international cooperation on environmental education currently includes collaboration with UNESCO's Asia Pacific Programme of Educational Innovation for Development (APEID) to enhance and spread environmental education in the Asia-Pacific region by inviting specialists to Japan for seminars and by providing support for the development and dissemination of teaching materials by the Asia/Pacific Cultural Centre for UNESCO[10].



Extracted from Reference[9]

Figure 6 : Conceptual diagram of policies to promote environmental education in Japan

(1) Environmental education in primary and Secondary schools

(i) Systems

Environmental education began to be incorporated into Japan's primary and secondary school curricula for social studies, science, health and physical education, and so on when pollution issues first gained prominence around 1965. The content was subsequently enhanced and the 1989 revision of national curriculum guidelines for elementary, junior high, and high schools emphasized the importance of not just understanding the environment, but of fostering the skills needed to solve environmental problems. In other words, the aims of environmental education were to foster the abilities and attitudes needed to respond proactively to social change, and to encourage experiential learning and problem-solving ability. The 1998 revision of the national curriculum guidelines (1999 for high schools) further enhanced the environmental content of social studies, science, and other classes. The newly established "integrated study" was used to improve and enhance learning about environmental issues through experiential and problem solving-based learning in order to deepen cross-subject, comprehensive learning[11]. Table 2 shows the main content related to environmental education under the 1998 revision of the national curriculum guidelines. During the 2004 school year, 75.3 percent of elementary schools and 52.8 percent of junior high schools studied environmental issues during the "integrated study"[12].

(ii) Attitudes of elementary and junior high school students

Figure 7 shows ideas found in the elementary and junior high school version of the Ministry of the Environment's 2003 Survey of Environment-conscious Lifestyle[13]. The results show that the ideas that "Lifestyles that are wasteful and generate much garbage should be changed" and "I think that environmental problems affect me too" are widespread. The desire to take action in terms of "I want to be actively involved in environmental conservation", however, needs to be encouraged.

As shown in Figures 2-4 above, attitude survey results for young people in their 20s indicated a low desire for involvement in environmental issues. However, if environmental education is further upgraded through various subjects and the "integrated study", based on the 1998 national curriculum guidelines, then the willingness of young people to become more actively involved in environmental issues is expected to increase.

(iii) Faculty attitudes

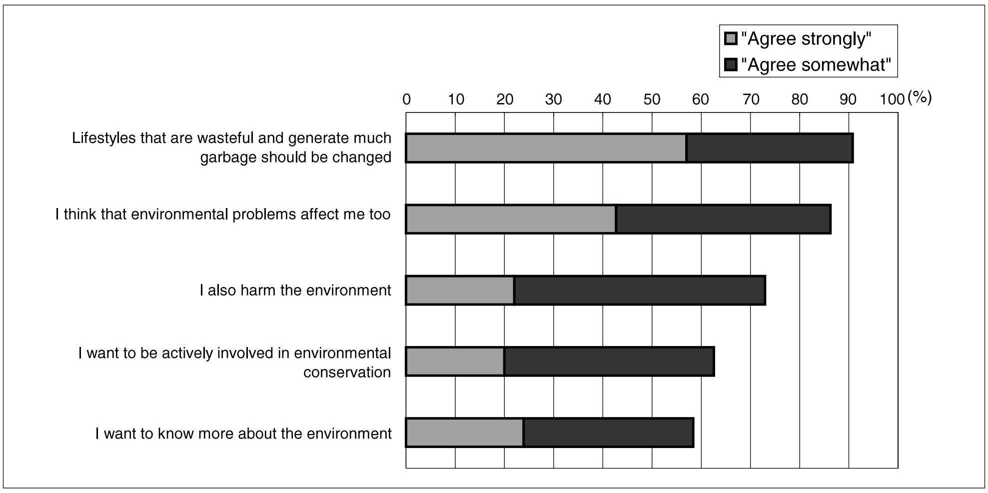
Figures 8 and 9 show the results of the National Institute for Environmental Studies'

Table 2 : Main content of environmental education in national curriculum guidelines (1998 revised guidelines)

	Elementary schools	Jr. high schools	High schools
Social studies, civics	(3rd and 4th grades) • The relationships between obtaining drinking water, electricity and gas, waste disposal, their own lives and industries (5th grade) • The importance of protecting the public's health and living environment from pollution • How forest resources work to preserve the nation's land and recharge watersheds	(Geography field) • **Issues related to the environment and energy** (Civics field) • Pollution prevention and other environmental conservation • **Learning about global environmental, energy, and resource issues**	(Modern society) • Pollution prevention and environmental conservation • **Learning about global environmental issues, etc.** (Politics/economics) • Pollution prevention and environmental conservation
Science	(6th grade) • **A mindset that appreciates natural environments and an attitude of trying to build a better environment**	(Physics / Chemistry) • **The necessity of developing science and technology that works in harmony with the environment** • The various energy sources that human beings use, including hydro, thermal, and nuclear power; the importance of efficient energy use (Biology / Geoscience) • **Study natural environments;** understand that natural environments exist in balance with the natural world. Awareness of the importance of conserving natural environments	(General science A) • **The characteristics, limits, and use of fossil fuels and nuclear, hydro, and solar power, etc.** (General science B) • **Take up water and air pollution, global warming, biodiversity, etc.; deal with the relationships between organisms and the environment and the importance of global environmental conservation**
Life studies	(1st and 2nd grades) • To develop an interest in relationships with local plants, animals, and nature, and to appreciate nature		
Home economics, vocational-technical and home economics	(5th and 6th grades) • Devising a personal home lifestyle that takes the environment into consideration	(Home economics field) • Think about the impact of one's own life on the environment and devise a consumption lifestyle that takes the environment into consideration	(Basic home economics, general home economics, life technology) • **Re-examination of everyday awareness and lifestyles, aiming for a lifestyle with low environmental impact**
Physical education, health and physical education	(3rd and 4th grades) • **The necessity of preparing the living environment in order to be healthy**	(Health field) • The necessity of waste disposal that fully considers environmental conservation • Take up the relationship between pollution and health in accordance with local conditions	(Health) • Human lifestyles and industrial activities can pollute natural environments and impact on health; various countermeasures • Standards are set to make school and community environments healthy, and environmental health activities are carried out
Morals	(5th and 6th grades) • Appreciating natural environments	• Love of nature	
Period for integrated study	• **Experiential, problem solving-based learning**	• **Experiential, problem solving-based learning**	• **Experiential, problem solving-based learning**

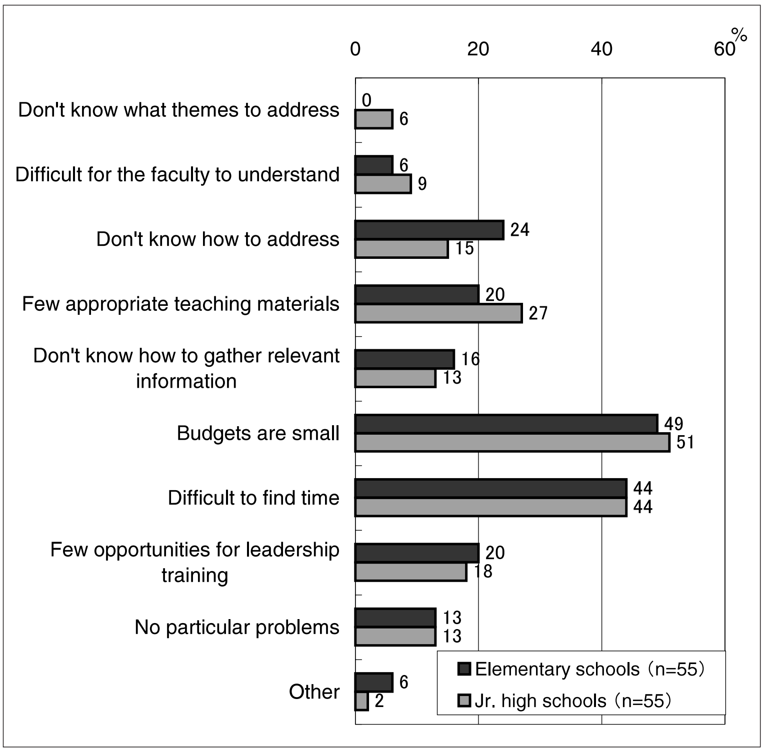
Items in bold type are newly added to the national curriculum guidelines

Extracted from Reference[11]



Prepared by the STFC based on Reference[13] (N=2,221)

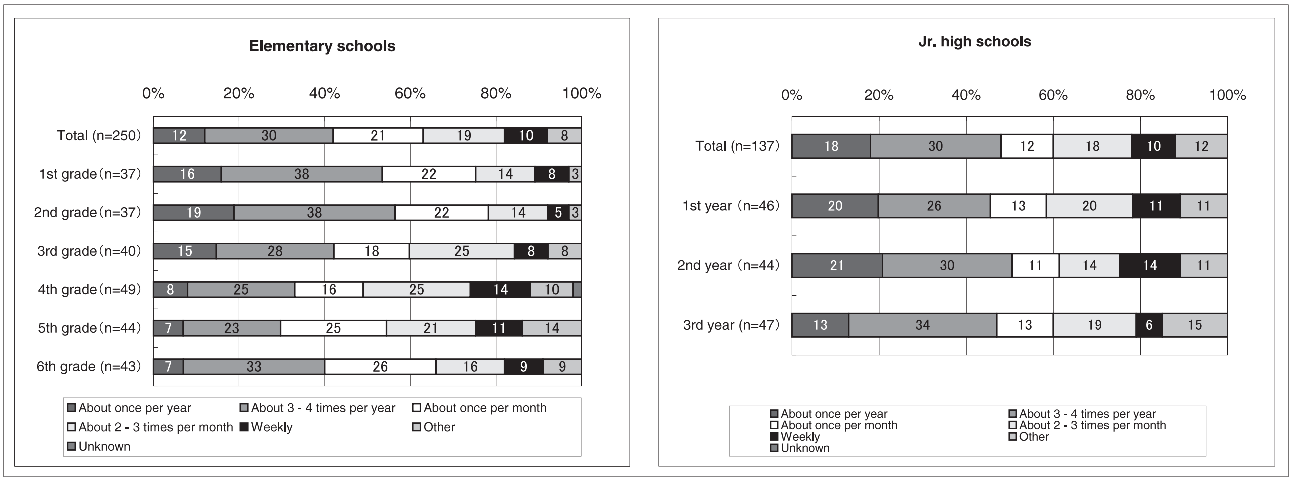
Figure 7 : Elementary and junior high school students' ideas about environmental issues



Extracted from Reference[12]

Figure 8 : Problem areas when addressing environmental education and environmental learning

survey of elementary and junior high school faculties, the Survey Regarding Environmental Education and Environmental Learning. Figure 8 depicts the main problem areas encountered when addressing environmental education and environmental learning. For both elementary and junior high schools, the most common problem mentioned was that "Budgets are small", followed by "Difficult to find time". Furthermore, "Don't know how to address" and "Few opportunities for leadership training" both scored about 20 percent, indicating a need to improve the ability of the faculty to take a lead in environmental education. This calls to mind (i) human resource development, (ii) program preparation, (iii) provision of information and so on, as described in Figure 6 above. The results shown in Figure 9 detail the frequency with which environmental education is currently addressed. At both the elementary and junior high school levels, there is a mix of schools that often take up the subject and other schools that rarely take it up. This indicates that there is yet another issue that needs to be addressed, that of (iv) expansion of



Extracted from Reference[12] (elementary schools, N = 64; junior high schools, N = 60)

Figure 9 : Frequency with which environmental education and learning are addressed

venues and opportunities. These results appear to indicate the need for enhanced support for environmental learning and further promotion of environmental learning at all levels of schooling.

(2) Environmental education in higher education

Educational research related to the environment takes place in many university faculties and departments. Universities also independently and voluntarily undertake measures for human resource training related to the environment. Currently, 52 national universities and 133 other public and private universities have faculties or departments with "kankyou" ("environment" or "environmental") in their names. All told, universities of all types offer 576 classes related to the environment[10]. In addition, universities certified under the ISO 14001 environmental management system standard have begun developing hands-on environmental education initiatives through student participation in the construction of environmental management systems (EMS). As a result, environment-related education has been established at many universities and is steadily improving. It is to be hoped that, in the future, even more students, including those currently with a low awareness of environmental issues, will take environment-related classes and acquire the ability to undertake environmental conservation activities.

In order for environmental education in primary and secondary schools, as described above, to be more effective, more teachers must learn the basics of environmental education. However, as can be seen in the results illustrated in Figure 8, about 20 percent of teachers "Don't know how to address" the subject. Comprehensive environmental education for teachers is thus an urgent issue. Environmental education is not a required course in current university teacher training curricula. Therefore, in order to move towards in-depth environmental education in primary and secondary schools and in order to develop adequate human resources, it is highly desirable that this subject be made a requirement in teacher training courses.

(3) Environmental education as part of social education

Environmental education for a broad range of age groups from children through to adults, should be actively promoted in a variety of social venues, not just in schools.

Environmental education in social education facilities takes place mainly in community centers, libraries, museums, and so on. Model projects are underway that comprehensively address various kinds of local issues, including environmental problems, and integrate project planning, implementation, and evaluation. Environmental education is promoted as part of social education through the spreading of project results nationwide. Particular emphasis is being placed on the promotion of experiential environmental learning systems that have children plan and continuously carry out hands-on environment-related activities based on local environmental issues[10].

Currently, many government agencies are implementing initiatives on the "expansion of venues and opportunities" for environmental education in the field of social education, as shown in Table 3. Figure 10 gives the example of "Junior Eco-Club" in which any elementary and junior high school student may participate. According to a Ministry of the Environment survey, awareness of the clubs' environmental activities is still only 23.9 percent. It is therefore necessary to be more proactive in providing information about these activities.

3-2 Examples of environmental education in advanced environmental countries

(1) Rankings on a world environmental index

The Environmental Performance Index (EPI) sets goals for environmental performance and evaluates each country's achievements in terms of environmental sustainability[14, 15]. The EPI was developed by environmental specialists at the environment school at Yale University and the Earth Institute at Columbia University. Its results are released annually and, by quantitatively evaluating the results of pollution prevention and the management of natural resources, the EPI serves as a useful reference tool for environmental policymaking. In the 2006 EPI environmental performance rankings by country (Pilot 2006 EPI), New Zealand was first, followed by Sweden, Finland, the Czech Republic, and the UK, while Japan was 14th. The USA was 28th. Although the USA scored highly in the environmental health category, it had only a low score in other important areas such as reusable energy, greenhouse gas emissions, and water resources.

(2) Environmental education in Sweden

Here we will discuss environmental education in Sweden, an advanced, environmentally aware country that was ranked second on the EPI. Distinctive characteristics in Sweden include preschool education and extensive social

Table 3 : Policies related to environmental education

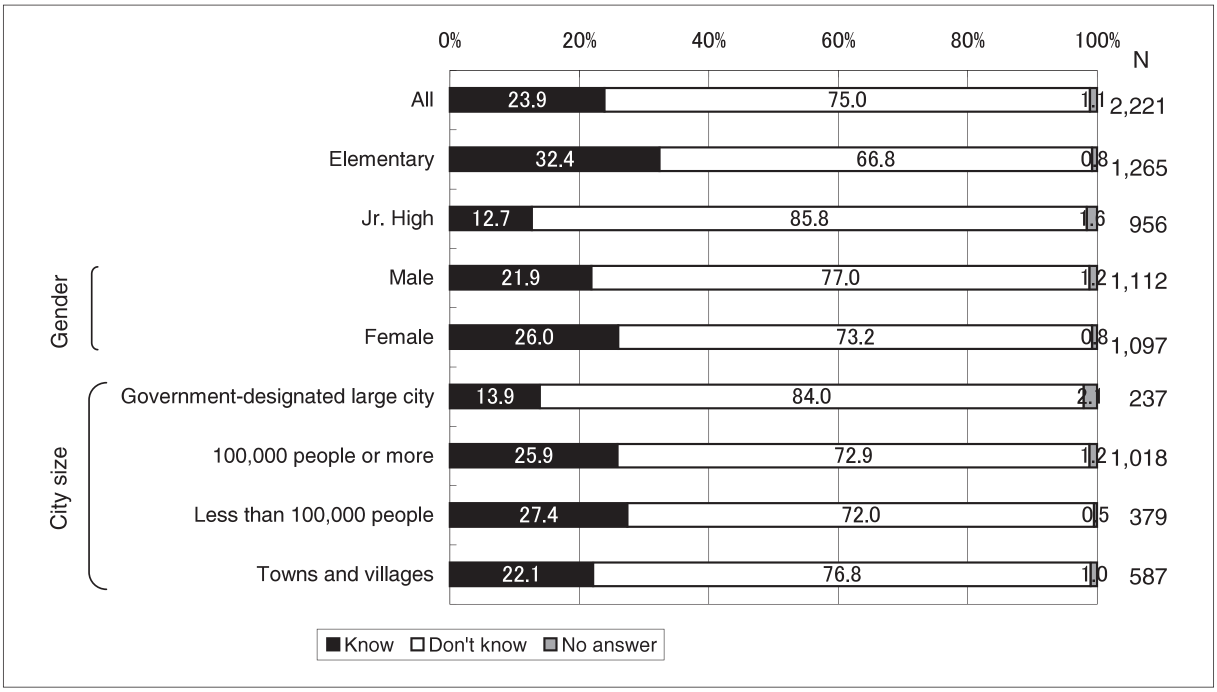
	Policy	Agency	Summary	
Human resource development	Basic training seminars for environmental education leaders	MEXT MOE	Ongoing	Training that emphasizes hands-on learning and acquiring basic knowledge of environmental education for educators and local activity leaders; promotion of environmental education and learning by children in schools and adults in the community
Human resource development	Promotion of forest environmental education	MAFF MEXT (partial)	Ongoing	Training of leaders and planners/managers in hands-on learning about forests; preparation for children's forest clubs; setting conditions in preparation for school forest establishment and activities, and establishment of model school forests
Human resource development	Environmental learning fairs	MEXT	Ongoing	Holding environmental learning fairs in order to improve the quality of environmental educators
Human resource development	Seashore expert training seminars	MLIT	Ongoing	Development of leaders with sufficient knowledge and skills to safely carry out activities at the seashore; targets males and females at least 18 years of age
Human resource development	Human resource development related to conservation activities of the natural environment	MOE	Ongoing	Training for leaders at natural parks; development of park volunteers; development of interpretive guides to nature, and so on
Program preparation	Environmental education practice and dissemination project	MEXT	Ongoing	Promotes outstanding environmental education efforts through designation of Global Learning and Observations to Benefit the Environment (GLOBE) model schools and model communities; disseminates the results nationwide
Program preparation	Expo 2005 Aichi environmental education and learning dissemination project	MOE	Ongoing	Studies dissemination projects on environmental education and learning at Expo 2005 Aichi
Program preparation	Project on effective environmental education for children and students regarding global warming	MOE	New	So that children and students correctly recognize and understand the importance of global warming and "habitually" take action to prevent it; creates teaching materials for schools and performs model lessons for their effective use
Provision of information	Comprehensive provision of information on environmental education and learning	MEXT MOE	Ongoing	Opens and operates a comprehensive database that collects diverse information on environmental education and learning and disseminates it widely over the internet
Provision of information	Promotion of voluntary consumer activity	METI	Ongoing	Promotes voluntary activities by consumers
Provision of information	Project on education and dissemination related to conservation of the atmospheric environment	MOE	Ongoing	Campaigns for Air Pollution Prevention Month, which disseminates simple measurement of acid rain involving public participation; continuous nationwide observance of stars; acoustical environment model city project; other educational activities related to protection for the atmospheric environment
Provision of information	Project on education and dissemination related to the conservation of the aquatic environment	MOE	Ongoing	Water quality surveys involving aquatic organisms living in rivers; educational activities regarding the improvement of nearby watersides and other means of protection for the aquatic environment

Table 3 : Policies related to environmental education (continued)

	Policy	Agency	Summary	
Expansion of venues and opportunities	Project to promote interagency hands-on environmental learning for children	MEXT MAFF MLIT MiOE	Ongoing	Hands-on learning projects planned and sustained by children, based on the theme of nearby local environments
	Eco school pilot model project	MEXT METI MAFF MOE	Ongoing	Promotion of environmentally friendly model school facilities (eco schools) that utilize solar power generation, wood materials, rainwater, insulation, etc. (FY 2004: 98 schools designated)
	"Children's Waterside Activities" rediscovery project	MEXT MLIT MOE	Ongoing	Promotion of rivers as sites for children's hands-on activities
	Activities for environmental learning in target areas for nature restoration	MAFF MLIT MOE	Ongoing	In nature restoration projects in various areas, works for cooperation needed so that the target area can be a site for learning about the natural environment
	Child park ranger project	MEXT MOE	Ongoing	So that children can learn the importance of protecting nature and conserving the environment, implements projects to participate in environmental conservation activities at national parks in association with park rangers
	Project to promote valuable hands-on activities	MEXT	Expanding	Along with designating "communities and schools that promote hands-on activities", "schools that promote inter-regional exchanges", and "schools that promote long-term overnight experiences", carries out research on effective hands-on activities to reinforce appreciation for the value of life
	Environmental learning projects in national youth education facilities	MEXT	Ongoing	Implements projects that contribute to environmental learning by youth through national educational facilities such as Youth Outdoor Learning Centers
	Development and dissemination of safety management methods for hands-on learning about forests, etc.	MAFF	Ongoing	Develops and disseminates safety management methods through analysis, classification and implementation at the national level and research regarding safety management involving hands-on learning about forests, etc.
	"Yuyu no mori" (Fun forests)	MAFF	Ongoing	Designates national forests as "Yuyu no mori" (fun forests) for hands-on learning for schools, etc.
Expansion of venues and opportunities	Establishment of contacts for forest environmental education	MAFF	Ongoing	In order to provide a general consultancy service on nature, sets up contact windows on forest environmental education activities in forest-related agencies around the country
	Promotion of "Manabi no mori" (Learning forests)	MAFF	New	Implements forest and facility improvements at sites used for forest environmental education involving ongoing children's hands-on forest activities, and hands-on forest learning that contributes to public participation and helps in fostering future foresters
	Promotion of forest-building activities with public participation	MAFF	Ongoing	Supports forest conservation activities such as forest improvement involving educational activities such as tree festivals and other "greening events" and corporate social contribution activities, forest volunteer activities, and temporary home stays for high school students in mountain villages
	Seaside nature schools	MLIT	Ongoing	Provides sites and opportunities for the public to experience the natural richness of tidelands, marine forests and sandy beaches in bays, improving public understanding of seaside environments and promoting environmental conservation and the formation of safe and abundant seaside environments
	"Mizube no gakkou" (Waterside fun schools) project	MLIT	Ongoing	Creates safe watersides with rich natural environments in order to promote environmental education involving rivers
	Center for Supporting Children's Waterside Activities	MLIT	Ongoing	Operates the Center for Supporting Children's Waterside Activities to promote the use of watersides by lending lifejackets and so on and carries out education on water-related issues (http://www.mizube-support-center.org/)
	Project to improve urban parks as centers of environmental learning	MLIT	Ongoing	Prepares fields to contribute to environmental learning in government-managed parks, provides environmental conservation and environmental learning programs, and prepares environmental contacts in nearby natural areas through links with local governments
	Children's World Water Forum follow-up	MLIT	New	Provides venues for children to think about water-related problems in an ongoing way
	My Family's Minister of the Environment project	MOE	New	In order to promote environmental conservation activities in homes, the center of life, this initiative implements "eco-family" projects using the internet and "family eco club" projects joining together multiple families for community activities
	Junior Eco-Club project	MOE	Ongoing	In order to support elementary and junior high school students' voluntary environmental activities in their communities, this project forms, registers, and recruits "Junior Eco-Club"
	School eco improvement and environmental education model project	MOE	New	Implements model projects that promote remodeling of facilities to reduce the environmental impacts of school buildings, and integration of environmental education and other projects in the schools and communities that use them
	Improvement of national park facilities, etc.	MOE	Ongoing	Promotes improvement of footpaths, basic facilities such as campgrounds, fields for advanced nature learning and sightseeing, and ecology museums in national and quasi-national parks

MEXT : Ministry of Education, Culture, Sports, Science and Technology.
MOE : Ministry of the Environment
MAFF : Ministry of Agriculture, Forestry and Fisheries.
MLIT : Ministry of Land, Infrastructure and Transport

Extracted from Reference[16]



Extracted from Reference[13]

Figure 10 : Awareness of "Junior Eco-Club"

education[17, 18], as described below.

- Children who have not yet begun school are at an important stage in laying the foundation for all kinds of learning. Such children in daycare centers are taken to visit local nature spots such as watersides, mountains, forests and so on. Through play and fun activities (experiencing nature), they develop an interest in the environment and activities involving learning about natural cycles (Mulle activities*1) are common.
- A diverse range of primary actors are involved in environmental education, ranging from local governments through to educational institutions such as public and private daycare centers and kindergartens, elementary schools, junior high schools, high schools and universities, corporations, foundations and other nonprofit organizations. Because the different facilities and institutions share common policies and goals, they act cooperatively with one another rather than separately.
- Local government legislatures and government policies are closely connected with actual education in the schools, so local governments are actively involved with Local Agenda 21*2 activities. These activities are widespread and widely recognized by the public.
- Social education facilities (museums, etc.) are used effectively for environmental education.

In Sweden, the emphasis placed on environmental education through experiencing nature using the five senses from early childhood onwards is based on the idea that the younger children are when they encounter nature, the greater their future interest in it is likely to be. By teaching them about natural cycles such as the water and air cycle and cycles of living things (e.g. the food cycle), they learn that human beings are part of all nature's great cycles, a basic concept in helping prevent future environmental problems. Moreover, it is expected that as children talk at home about what they have learned, entire families will start to think about the environment, thereby educating parents as well.

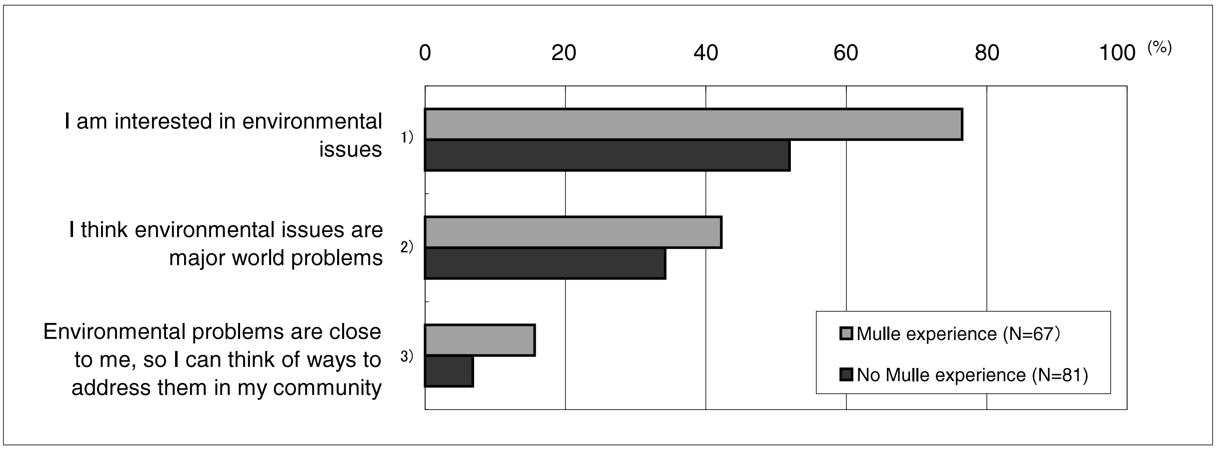
Ichijimacho, in Hyogo Prefecture, has adopted the outdoor activities, "Forest Fairy Mulle", a part of Swedish environmental education, since 1990. Figure 11 shows some of the findings of a questionnaire survey (2000) on the educational effects of these activities (in this case, the awareness of environmental problems among second-year junior high school students)[18]. There was a significant difference between the responses of students who had participated in Mulle activities and those who had not, when referring to the statements "I am interested in environmental issues" and "I think environmental issues are major world problems". This demonstrates the effectiveness of Mulle activities in Japan as well as Sweden.

The nature-experience learning that occurs in Swedish daycare centers from early childhood onwards provides a good example for the enhancement of Japanese environmental education. In addition, Japan has much to learn from the strong cooperation among actors in environmental education in Sweden, public involvement in Local Agenda 21 activities, and so on.

4 Measures to promote environmental conservation activities

4-1 The process to environmental conservation activities

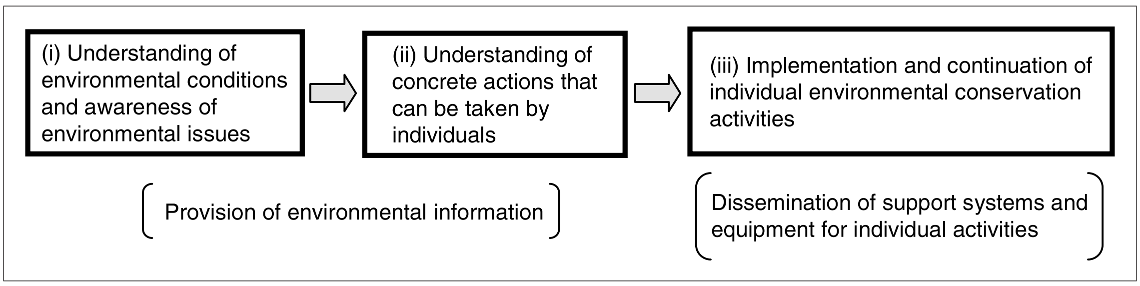
As described above, policies are needed that further advance environmental education in Japan and link it with individual environmental conservation activities. The aim of environmental education, namely the "process to environmental conservation activities", can be roughly divided into the following three stages: (i) understanding of environmental conditions and awareness of environmental issues, (ii) understanding of concrete actions that can be taken by individuals, and (iii) implementation and continuation of individual environmental conservation activities (see Figure 12). In stages (i) and (ii), it is necessary to provide easily understandable information about the environment, while stage (iii) requires the effective dissemination of



2nd-year junior high school students, N = 148

Prepared by the STFC based on Reference[18]

Figure 11 : The effect of Mulle activities on raising awareness of environmental issues



Prepared by the STFC

Figure 12 : The process to environmental conservation activities

support systems and equipment.

In order for this process to be effective, we propose the following measures for each stage:

4-2 Raising awareness of environmental problems and promoting understanding of concrete actions for environmental conservation (stages (i) and (ii))

(1) Raising awareness of environmental problems (stage (i))

In general, environmental issues have aspects that can make them difficult to recognize and personally realize. A major reason for this is that it is often difficult to visually grasp the status of the environment or the changes occurring in it. For example, even if large volumes of CO_2 (the main cause of global warming) are emitted, because it is a colorless and odorless gas, any actual changes are difficult to discern. In other words, the use of familiar indexes and easily understood measurements are effective means of getting people to address environmental issues (such as the degree of air and water pollution, energy consumption, and so on) by presenting problems in terms that people can more readily identify with. For example, converting the amount of energy used to the volume of CO_2 emitted and presenting this as a concrete measurement can increase awareness of the issue.

Furthermore, instead of merely displaying measurements, comparing items of information (such as the seriousness of pollution) with environmental standards (such as goals and reference values) and warnings (such as examples of problems that may occur if the present situation continues) can also be an effective means of increasing awareness.

(2) Promoting understanding of concrete actions for environmental conservation (stage (ii))

The next stage involves getting people to understand concrete actions that individuals can take against environmental problems. One effective approach, when providing information on concrete activities, is the "presentation of the results of environmental conservation activities and the effects obtained". Showing concrete figures (such as the relationship between decreased distances driven by cars and decreased CO_2 emissions, between the volume of cooking oil washed down sinks and the volume of water needed to treat that much oil, or between the amount of electricity used by appliances on standby and CO_2 emissions) is an effective means of encouraging people to take action.

(3) Transmission of environmental information by the media (stages (i) and (ii))

Through environmental monitoring, environmental conditions and changes can be easily quantified and visualized. In order to get people to understand concrete actions that can be taken for environmental conservation, this information must then be transmitted via various media. Information transmission must particularly target people with a low awareness of environmental issues.

Provision of information over the Internet is extremely effective for people who already have a high awareness of environmental issues. For example, much information on air pollution obtained from atmospheric monitoring stations in Japan can be obtained in real time over the Internet via the Atmospheric Environmental Regional Observation System (Soramame Kun)[19]. People with a low awareness of environmental issues, however, are unlikely to access the site that transmits this information. For such people, it is more effective to add visual effects to the data obtained via environmental monitoring and to then process the data so that as many people as possible can easily understand it and be made aware of the problems in question. For example, information could be effectively transmitted via electronic billboards (liquid-crystal billboards) in locations with heavy foot traffic or by liquid-crystal displays on trains as well as via the still-popular media of television and radio. For young people with a relatively low awareness of environmental problems, youth-oriented television programs and information displays in areas where younger people congregate could also be effective.

Account categories

	Category	Unit	CO_2 emission coefficient	Amount consumed (purchase price)	CO_2 emission volume (kg)
Energy / resources	Electricity	kWh	0.12		
	Natural gas (LPG)	m^3	0.64(1.8)		
	Kerosene	l	0.69		
	Water	m^3	0.16		
	Gasoline (diesel)	l	0.64(0.72)		
	Garbage	kg	0.24		
Food/everyday necessities	Sweets	¥1,000	0.46		
	Purified water	¥1,000	0.61		
	Alcoholic beverages	¥1,000	0.40		
	Tobacco	¥1,000	0.20		
	Books/magazines	¥1,000	0.43		
	Cosmetics	¥1,000	0.40		
	Clothing	¥1,000	0.41		
	Furniture	¥1,000	0.52		
	Home electronics	¥1,000	0.49		
Total					

*Enter the amount consumed (purchase price) for each category according to the unit given.
The amount consumed (purchase price) multiplied by the CO_2 emission coefficient is the volume of CO_2 emitted.

Extracted from Reference[21]

Figure 13 : Example of a household environmental account book

4-3 Continuation of environmental conservation activities (stage (iii))

The crucial final stage is the implementation and continuation of environmental conservation activities. In order for people to continue environmental conservation activities, it is very important to establish frameworks that provide feedback on the effects that individual actions are having on environmental conservation, in terms of concrete indexes. Furthermore, in order for economic incentives to come into play, money is also an effective index for such feedback. Some examples of this activity that are already underway are shown below.

(1) Household environmental account books using CO_2 emissions as an index

Some experts recommend entering environmental conservation activities and actions taken in daily life that impact on the environment in a "household environmental account book". Using a household environmental account book, each home can readily determine the amount of CO_2 that it emits. Because this provides continuous feedback on the effects of actions taken to cut CO_2 emissions, sustaining environmental conservation activities becomes easier. Consumers can see concrete figures telling them how much of an impact their homes have had on the environment, making it easy for them to connect environmental impact with cutting back on energy use or garbage volume. At the same time that they reduce household environmental impacts, economic incentives also come into play[20]. Figure 13 shows an example of a household environmental account book[21]. If the use of the household environmental account book system can be extended to groups such as workplaces and communities, then even greater results can be expected.

(2) On-board automobile monitors showing fuel consumption

Automobile emissions account for about 30 percent of household CO_2 emissions. The dissemination of "eco driving" (a method of driving that reduces fuel consumption and contributes to a reduction in CO_2 emissions) is, therefore, one environmental conservation activity that people can undertake individually as an important countermeasure to global warming. On-board monitors that display fuel data in real time are an effective tool for sustaining eco driving. Because drivers can see, in real time, how different driving conditions affect fuel consumption, it becomes easier for them to constantly be aware of saving energy and to sustain eco driving activities[22].

Making this kind of equipment, with its built-in feedback function, available at low cost will further accelerate the spread of eco driving.

(3) Electricity consumption monitoring that indexes CO_2 emission volume and utility fees

Real-time conversion of electricity consumption into concrete indexes of CO_2 emission volume and utility fees, displayed on a monitor, makes it easier for individuals to sustain energy-saving activities.

Distributing these monitors to schools, workplaces and homes, at low cost, or equipping various devices with such monitors could, therefore have significant effects.

5 Conclusion

Individual lifestyle changes are necessary in order to solve environmental and energy problems. The spread of environmental education connected with individual environmental conservation activities and the utilization of environmental monitoring data are effective ways of bringing this about.

Environmental education for the general public must encompass a broad range of ages in schools and various other social venues, and a number of methods can be used for disseminating this education. In schools, enhanced support for environmental education and its further promotion are especially desirable. To encourage implementation of environmental conservation activities, it is necessary to increase awareness of environmental problems and provide information on concrete actions that can be taken to conserve the environment. In order to sustain environmental conservation activities, it is important to have systems and equipment in place that provide feedback on the results of each action. The following three points are particularly noteworthy:

(i) Enhanced support for environmental education in primary and secondary schools and further promotion of environmental education in higher education

Currently, environmental education in primary and secondary schools is carried out during the "integrated study" and as part of various other subjects. However, enhanced support for environmental learning is needed because there are gaps in the frequency with which different schools address environmental topics and the leadership ability of the teaching staff can be improved.

In higher education, students with a low awareness of environmental issues should be encouraged to take classes in environmental education subjects. In addition, environmental education should be a required class for university students in teacher training courses because these students will be responsible for the environmental education of children and students in the future.

(ii) Raising awareness of environmental problems and promoting understanding of concrete actions that can be taken for environmental conservation

The first stage in moving towards environmental conservation activities is raising public awareness of environmental problems. An important part of this process is being able to monitor the environment and any changes in it and then being able to quantify and visualize the results. When doing this, displaying concrete units of data in comparison with environmental standards and warnings is particularly effective.

The second stage in moving towards environmental conservation activities is the provision of information linked to concrete actions on environmental conservation. In this case, it is preferable to display the effects of environmental conservation activities.

It is especially important to transmit such information to people who have a low awareness of environmental issues. It is therefore necessary to use visual effects and suchlike to process the information so that even people with a low awareness of the issues can easily understand the problems. Effective media for the transmission of this sort of information include electronic billboards (liquid-crystal billboards) in locations with heavy foot traffic, and television.

(iii) Dissemination and development of support systems and equipment that provide feedback to help facilitate environmental conservation activities

It is essential that individual environmental conservation activities be carried out on an ongoing, continuous basis. The use of concrete indexes to provide feedback on the environmental conservation effects of activities is an effective means to get people to sustain their activities. For example, household environmental account books that index CO_2 emission volumes, on-board automobile monitors showing fuel consumption, and electricity consumption monitoring that displays CO_2 emission volumes and utility fees are all very effective. Further efforts are therefore needed to develop such systems and equipment, to reduce their price, and to promote their dissemination.

Acknowledgements

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Glossary

*1 Mulle activities

Based on a nature education program for five- and six-year-olds developed by Sweden's Friluftsfr_mjandet (Association for the Promotion of Outdoor Life), Mulle activities have been expanded to daycare centers. Over the past 40 years, over 2 million children have participated in these preschool environmental education activities closely linked to local communities. (Sweden's current total population is 8.8 million.)

*2 Local Agenda 21

Local Agenda 21 refers to local action plans on environmental policy intended to meet the sustainable development goals set forth in Agenda 21 at the United Nations Conference on Environment and Development (UNCED) in 1992.

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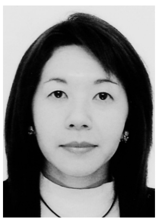

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5

Patent Application Trends in the Field of Nanotechnology

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1 Introduction

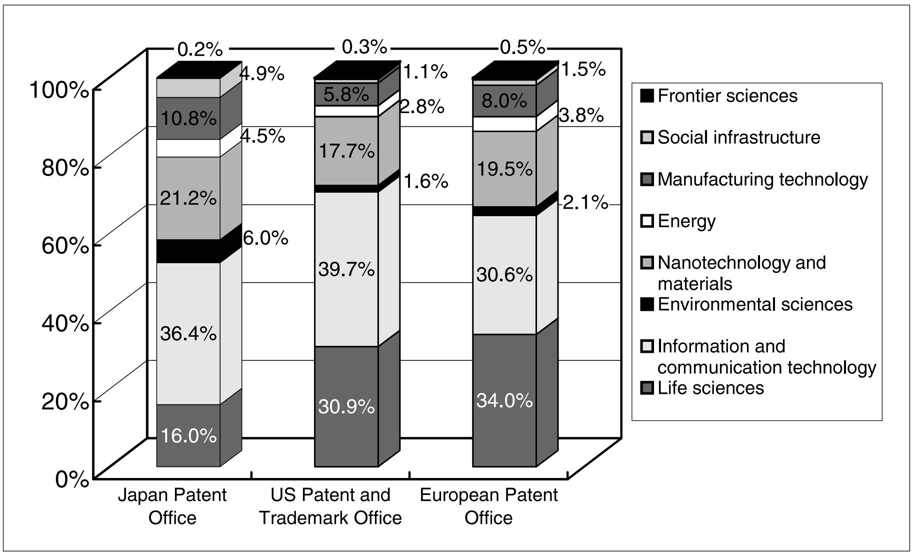
Nanotechnology became a prioritized area of research in the US in 2000. In Japan, the government prioritized the areas of nanotechnology and materials in 2001. Nanotechnology has a wide range of possible applications, and several years have passed since it became a prioritized area; as such expectations for nanotechnology are growing, from the standpoint of innovation creation and social contribution. In March 2006, the Council for Science and Technology Policy formulated the "Promotion Strategy for Prioritized Areas" which states "in order to strengthen industrial competitiveness in the nanotechnology and material fields, it is necessary to promote R&D activities and to link the outcomes of basic research to intellectual property in order to facilitate the effective application of such outcomes to industry", thus stressing the need to implement an intellectual property strategy targeted at specific areas of application.

The Japan Patent Office has produced reports on patent application trends by area with a focus on elemental technology, which seems to warrant particular attention among the eight prioritized areas[1]. However, almost no research has been conducted to obtain an overview of patent application trends in the field of nanotechnology. Therefore, this article outlines these trends by country, sector and application, with the objective of providing a brief overview of patent application trends.

This article was compiled by reorganizing the results of research and analysis conducted by the Nanotechnology Researchers Network Center of Japan[Note1], together with the cooperation of the same center.

2 Background: patent application trends within each prioritized area in Japan

The Third Science and Technology Basic Plan continues to address the eight prioritized areas, which were designated as such in the Second Science and Technology Basic Plan. This prioritization has been reinforced through further selection and concentration. In this Third Basic Plan, the prioritized areas have been re-designated into "four priority promotion areas" and "four promotion areas" (Some changes have been made to the names given to those areas covered). Information on the number of patent applications in these eight areas is available from the Japan Patent Office[2] and these figures show where nanotechnology is positioned among the eight areas. Figure 1 shows patent applications by technological area, based on the number of applications to the Japanese, American and European patent offices in 2004. It is easy to see that Japan is far behind the US and Europe in terms of the percentage of applications from the area of life sciences. The areas in which Japan is ahead of the US and Europe in percentage terms are the environmental sciences and social infrastructure, although the applications in these areas account for only a fraction of the total number of applications lodged with the patent office in Japan. Among the three patent offices, the United States Patent and Trademark Office received the largest number of applications from the information and communication technology area. In Europe, the percentage of applications from the life sciences area is higher than in the



Prepared by the STFC based on Reference [2]

Figure 1 : Percentage of patent applications to patent offices in Japan, the US and Europe according to eight specified areas (2004)

US and Japan. Nanotechnology and materials account for approximately 20% of the total applications at each of the three patent offices, with the figure for Japan being the highest.

3 Analysis of patent application trend in the area of nanotechnology

3-1 Classification[6]

The Nanotechnology Researchers Network Center of Japan defines the world's four largest patent organizations as the Japan Patent Office, the United States Patent and Trademark Office, the European Patent Office and the World Intellectual Property Organization (WIPO)[Note2]. The center extracts nanotechnology-related patents from monthly patent publications released by these patent organizations using preset keywords. Extracted patents are then categorized according to nine defined technology areas. The center makes a list that includes the name of the inventor, invention and applicant and other information, and compiles a database.

The areas of technology targeted are materials, medicine and life sciences, electronic devices, information and communications, optoelectronics, measurement and testing, environment and energy, processing, printing and photography. These nine areas of technology cover almost every potential field of application for nanotechnology. Table 1 shows the technologies designated for each of the nine areas.

Based on the following principles, patents retrieved from the keyword search were screened to be nanotechnology-related patents (hereinafter referred to as nanotechnology patents).

(a) There are two main directions for nanotechnology: the first is to alter and develop materials at the atomic or molecular level or add new characteristics to existing materials, and the second is to process materials and fabricate a nanostructure. For the purposes of this article, both of these areas were screened.

(b) Also screened were nanotechnology patents that include the manipulation or processing at the nano-scale, or predicted “time,” “wavelength,” “mass” and “volume.” One example is the nanotechnology patent that proposes a method of using a picogram amount of protein to screen crystallization conditions.

(c) Nanotechnology patents that selectively use a nanotechnology technique were also included. For example, patents for conductive polyamide compounds that include the application of nanomaterials were screened, even if electrically conductive particulate materials were selectively used from among graphite, carbon black and carbon nanofibers.

Table 1 : Classification of technology areas related to nanotechnology

Classification Number	Technology Area	International Patent Classification	Technology Content
1	Materials	B01J	Catalysts/colloid science (scientific or physical method) / hydrophobic magnetic particles
		B81B	Microstructure devices and systems / carbon nanotubes
		B82B	Microstructure techniques and nanotechnology / carbon nanotubes / functional nanostructures
		C01B	Carbon structure / manufacturing of fullerenes / manufacturing of carbon nanotubes / synthetic porous crystalline substances
		C01G	Metal-bearing compounds / metal particles
		C03B	Manufacturing, molding or supplementary processes
		C03C	Glass or glassy enamels
		C04	Artificial stone/ceramics
		C07	Organic chemistry
		C08	Organic polymer compounds / biopolymer nanoparticles / conductive polyamide compounds / toughened polymers through introduction of carbon nanotubes / photopolymers
		C09	Inks / dyes / resins / adhesives
		C22	Metals / Iron or non-ferrous alloys, and their processing
		C23C	Coatings / dispersion across surfaces / surface finishing through chemical transduction or substitution / diamond coating / nanoparticle coating
		C30	Crystal growth / synthesis of organic nanotubes / synthesis of ultra-thin nanowires
2	Medicine and Life Sciences	A61	Medical science / cosmetics containing electrochemically and biologically active particles / biodegradable nanocapsules / stents coated with nanoparticles / using optical contrast factor consisting of quantum dots / optically active nanoparticles for treatment and diagnosis / cancer drugs / personalized medicines
		C12	Microbiology / enzymology / genetic engineering / determination of nucleic acid molecule sequence / measuring equipment
3	Electronic Devices	H01L	Basic electric elements/semiconductor equipment / patterning of silicon nanoparticles / membrane sensors consisting of semiconductor film containing nanocrystals / quantum dot phosphor / monoelectron transistors
		H01J	Field emission type electron source
4	Information and Communications	G06N	Signaling polymers / quantum computers
		G11	Information storage / memory with nanomagnets / memory media with nanometer-order memory layer
5	Optoelectronics	G02	Microstructure optical fibers / accumulation type photonic circuits / microlens EUV lithography / silicon nanoparticle luminescent devices / optical waveguide that creates a core and clad with nano-porous materials
		H01S	Optic amplifiers and lasers formed on the surface of semiconductor nanocrystals
6	Measurement and Testing	G01	Method of analysis that uses nanocrystal index / nanopumps / gene sequencers / manufacturing of DNA chips / ultramicro liquid dispensers / nanothermometers
7	Environment and Energy	C02F	Treatment of water, wastewater, sewage or sludge / treatment of exhaust gas
		H01M	Batteries / positive electrode of a rechargeable lithium battery
8	Processing	B01	Separation / mixing / manufacturing of self-cleaning surfaces
		B21	Processing / forming / diamond polishing of coated layers
		B23	Machine tools / use of femtosecond lasers / forming of silicon nano-scale dots
		B32B	Laminated bodies
9	Printing and Photography	B41J	Printing / ink jet heads / forming of nano thickness images of goods
		G03	Photographs / electronic photographs

Prepared by the STFC based on Reference[6]

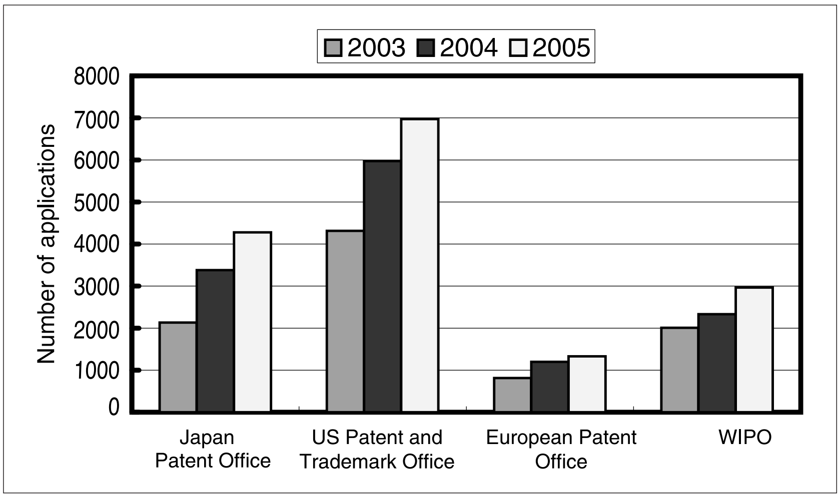
(d) As for MEMS (Micro Electro Mechanical System), superlattice structures, photonic crystals and quantum wells, a large number of applications, such as machines with a microstructure (electric elements and lights) and electric elements, were proposed. The screening decision was made based on whether the patents used nanotechnology described in (b) as a material or as part of the fabrication process.

3-2 Nanotechnology patent trends at the four largest patent organizations

First, this article outlines the number of nanotechnology applications lodged with the world's four largest patent organizations, which were screened and classified according to the above screening criteria (Figure 2). This chart shows that all four patent organizations saw a significant increase in the number of nanotechnology applications from 2003 to 2005. In recent years, the total number of applications to the Japan Patent Office has remained at a level slightly exceeding 400,000. Nanotechnology patents thus accounted for approximately 1% of the total number of patent applications submitted to the Japan Patent Office in 2005. Similarly, the figure for the United States Patent and Trademark Office was approximately 1.5%, that for the European Patent Office was approximately 1%, and that for the WIPO was approximately 2.5%[6].

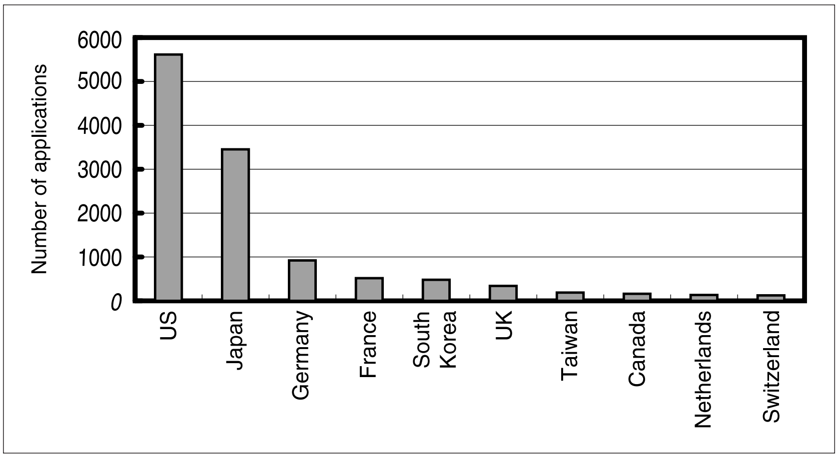
3-3 Nanotechnology patent application trends by the applicant's nationality

In this section, I examine the nationality of applicants[Note3] filing nanotechnology patent applications to the world's four largest patent organizations. Figure 3 compares the nationality



Prepared by the STFC based on Reference[6]

Figure 2 : Number of nanotechnology patent applications submitted to the four largest patent organizations

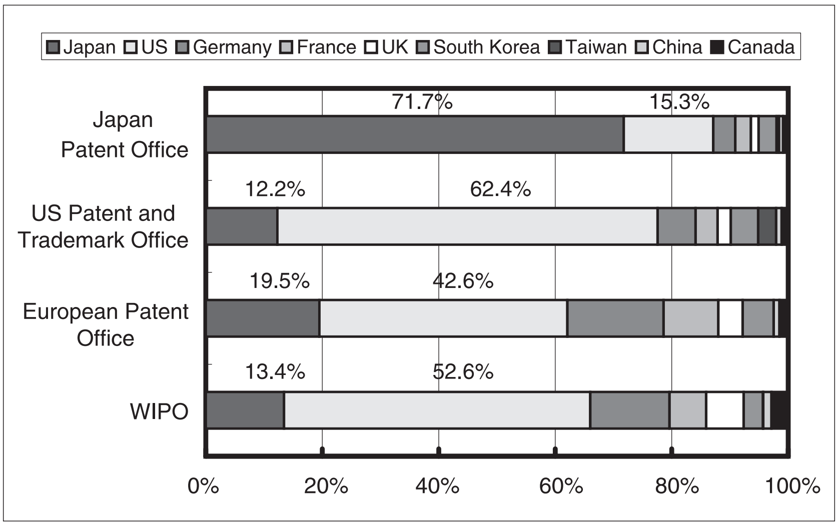


Prepared by the STFC based on Reference[6]

Figure 3 : Number of nanotechnology patent applications submitted to the four largest patent organizations according to nationality of applicant (2004)

of applicants in ten countries that received a large number of applications in 2004. These figures show that US applicants were ahead with approximately 5,600 patent applications, which was approximately 1.6 times the number of applications filed by Japanese applicants (ranked second) and approximately 6.1 times that by German applicants (ranked third)[6].

The next chart shows the classification results for the nationality of applicants who filed applications to the patent organizations in 2004 (Figure 4). In Japan, approximately 72% of applications submitted to the Japan Patent Office were filed by Japanese applicants. In comparison, approximately 62% of applications to the United States Patent and Trademark Office were filed by US applicants, which was a smaller proportion of native applicants than that for Japan. According to the report released by the Japan Patent Office, similar trends were observed in other fields[3]. To manufacture or sell goods in a foreign country, it is necessary to obtain a patent right in that country. Looking at this another way, filing applications to a patent organization in a foreign country may reflect the applicants strong intention to develop, manufacture and sell goods in that country. I examined patent applications from Asian countries from that



Prepared by the STFC based on Reference[6]

Figure 4 : Breakdown of the nanotechnology patent applications submitted to the four largest patent organizations by nationality (2004)

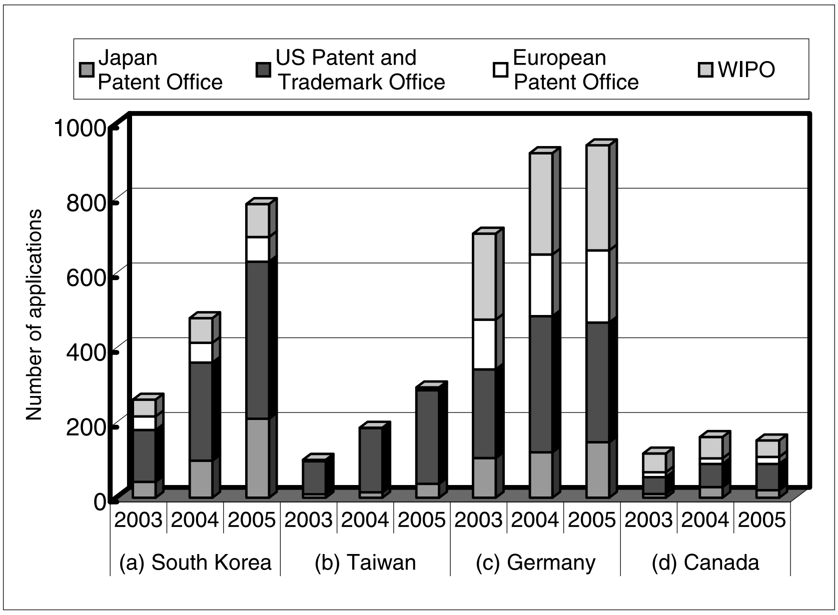


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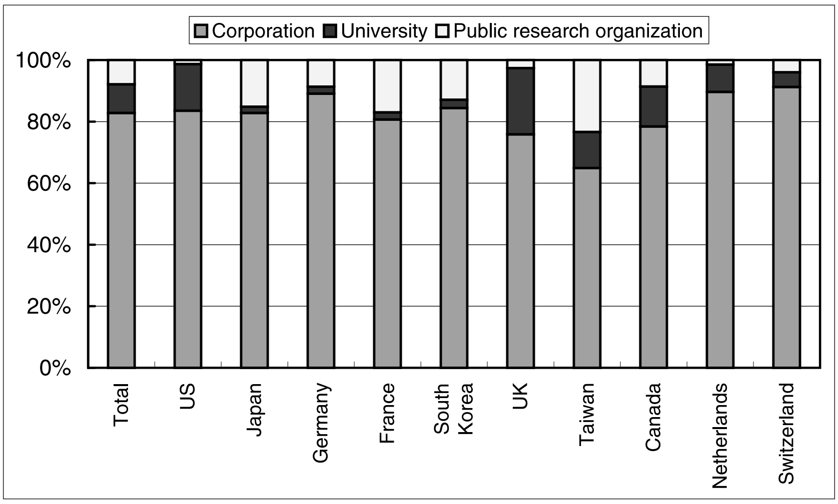
Figure 5 : Nanotechnology patent applications by nationality (South Korea, Taiwan, Germany and Canada) (2004)



Prepared by the STFC based on Reference[6]

Figure 6 : Percentage of nanotechnology patent applications by sector (1)

perspective. The examination revealed that, for example, South Korea and Taiwan submitted a large number of applications to the United States Patent and Trademark Office (Figure 5 (a) and (b)). By contrast, the number of applications to the European Patent Office and the WIPO from these countries was small. These countries strive to strengthen their competitiveness in the field of nanotechnology, particularly in ICT and electronics. The fact that the US is a leading force for these industries is probably one of the factors that determine their application behavior. Therefore, it is necessary to give consideration to more specific subsections of the area of technology concerned when comparing and examining patent application trends by nationality.

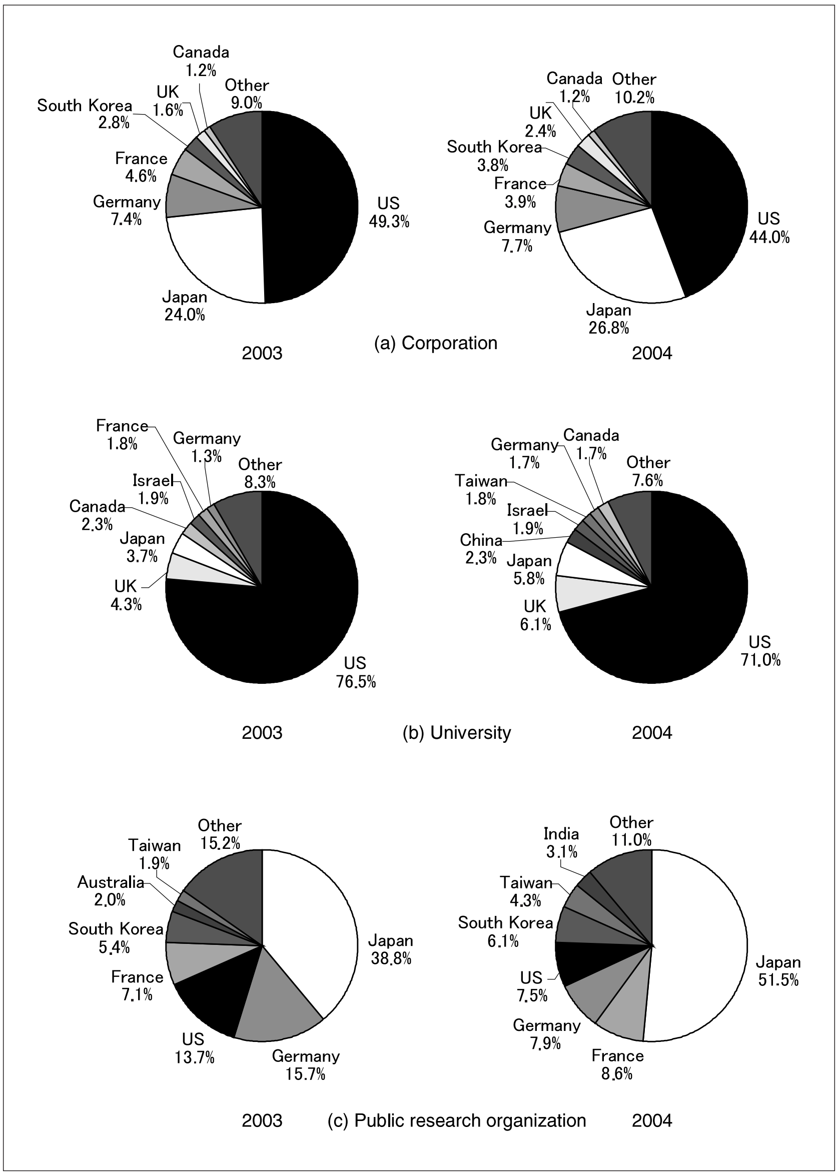
For reference, Figure 5 (c) and (d) show patent applications lodged with the world's four largest patent organizations by German and Canadian applicants. A high proportion of patent applications from these countries were to the United States Patent and Trademark Office and the WIPO. More interestingly, patent applications from these countries continued to increase until 2005 when they suddenly either leveled off, or alternatively began to decrease. This trend was also observed among other European countries.

3-4 Percentage of nanotechnology patent applications by corporation, university and public research organization

This section shows the results of an analysis of the percentage of nanotechnology patent applications by sector: corporations, universities and public research organizations. The chart below shows the percentage of nanotechnology patent applications by sector in the top ten countries in terms of the greatest number of applications in 2004 (Figure 6). Overall, corporations filed more than 80% of the total number of nanotechnology patent applications. This trend is expected to continue, with figures showing a small but steady increase between 2003 (81%) and the first half of 2005 (83.3%)[6]. Corporations filed the largest number of nanotechnology patent applications, and this was common to all countries. Interestingly, while universities filed the second largest number of applications in such countries as the US, the UK, Canada and the Netherlands, it was public research organizations that were the second largest applicants in such countries as Japan, Germany, France and South Korea. Hence, two major trends are observed; the US-type trend and Japanese-type trend. The chart also shows that the percentage of applications from corporations was approximately 63% in Taiwan, which was the lowest among these countries.

The following charts show the percentage of nanotechnology patent applications by sector for each country (Figure 7 (a), (b) and (c)). In 2004, the US accounted for the largest proportion of nanotechnology patent applications by corporations, which was followed by Japan. These results correspond to the overall ranking.

The charts also revealed that the US accounted for an overwhelming percentage



Prepared by the STFC based on Reference[6]

Figure 7 : Percentage of nanotechnology patent applications by sector (2)

of the nanotechnology patent applications by universities, which is totally different from the trend observed for corporations. In this category, the US headed up the table, followed by the UK (ranked second) and Japan (ranked third). It is worth noting that China and Israel were ranked among the top ten countries in this category, although they were not among the top ten countries in the overall ranking. In particular, Israel is filing an increasing number of nanotechnology patent applications in the field of medicine and life sciences.

The percentage of nanotechnology patent applications by public research organizations shows that, unlike the figures for the corporation category, Japan accounted for the largest percentage of applications, followed by France, Germany and the US. It is worth noting that many applications from Japan were filed by such public research organizations as the Japan Science and Technology Agency and the National Institute of Advanced Industrial Science and Technology.

Looking at changes over the 2003 to 2004 period, there were no noticeable shifts in rankings for the corporation and university categories. However, there was a slight decrease in the percentage of applications from the US. In the public research organization category, Japan upped its percentage sharply, while Germany and the US saw their percentage cut in half. Such organizations as the Max-Planck-Institut and the Fraunhofer Gesellschaft filed many applications in Germany and the Centre National de la Recherche Scientifique (CNRS) in France.

The following chart shows the top ten organizations in terms of the number of nanotechnology patent applications filed in 2004 (Table 2). Rankings for the previous year are also indicated. It is worth noting that three of the top five organizations (including the top and the second-ranked organizations) that filed applications to the Japan Patent Office were public research organizations. The Japan Science and Technology Agency[Note4] was also ranked first in terms of the number of applications to the European Patent Office and the WIPO. The names of US public research organizations are not to be found in the rankings. Only three US institutions - the University of California, the Massachusetts Institute of Technology, and Northwestern University - featured in the rankings for the United States Patent and Trademark Office and the WIPO. As already mentioned, the number of nanotechnology patent applications has been increasing in recent years. It is expected that there will be major changes in the ranking of applicant organizations, especially for PCT-route applications.

Table 2 : Top 10 applicant organizations submitted to the four largest patent organizations (2004)

Ranking (Previous year)	Japan Patent Office	Number of applications
1 (1)	JAPAN SCIENCE AND TECHNOLOGY AGENCY (Japan)	137
2 (4)	NATIONAL INSTITUTE OF ADVANCED INDUSTRIAL SCIENCE AND TECHNOLOGY (Japan)	115
3 (3)	SONY CORPORATION (Japan)	96
4	NATIONAL INSTITUTE FOR MATERIALS SCIENCE (Japan)	73
5 (7)	MITSUBISHI CHEMICAL CORPORATION (Japan)	70
6 (6)	CANON INC. (Japan)	59
7	SHARP CORPORATION (Japan)	48
8 (8)	HITACHI, LTD. (Japan)	47
9	RICOH COMPANY LTD. (Japan)	46
10 (2)	FUJI PHOTO FILM CO., LTD. (Japan)	44
10	MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD. (Japan)	44

Ranking (Previous year)	US Patent and Trademark Office	Number of applications
1 (1)	IBM (US)	89
2 (2)	MICRON TECHNOLOGY (US)	63
3 (3)	THE UNIV. OF CALIFORNIA (US)	58
4 (7)	EASTMAN KODAK (US)	53
5 (9)	L'OREAL (France)	50
6 (5)	XEROX (US)	49
7 (8)	GENERAL ELECTRIC (US)	43
8	SAMSUNG ELECTRONICS (South Korea)	42
9	HITACHI LTD. (Japan)	39
10	INDUSTRIAL TECHNOLOGY RESEARCH INSTITUTE (Taiwan)	38
10	CANON INC. (Japan)	38

Ranking (Previous year)	European Patent Office	Number of applications
1 (8)	JAPAN SCIENCE AND TECHNOLOGY AGENCY (Japan)	36
2 (1)	L'OREAL (France)	27
3 (4)	SAMSUNG ELECTRONICS (South Korea)	25
3 (4)	HEWLETT-PACKARD (US)	25
5	CNRS (France)	16
6 (4)	EASTMAN KODAK (US)	13
7 (3)	SONY CORPORATION (Japan)	12
7	BASF (Germany)	11
9	CANON INC. (Japan)	9
10	INFINEON (Germany)	8

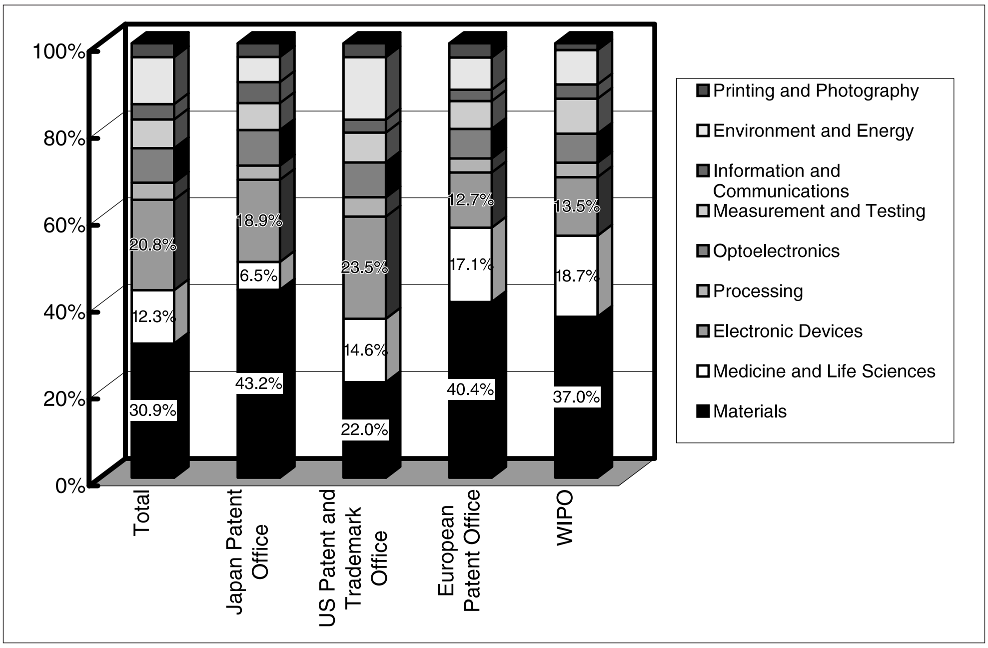
Ranking (Previous year)	World Intellectual Property Organization (WIPO)	Number of applications
1 (1)	JAPAN SCIENCE AND TECHNOLOGY AGENCY (Japan)	33
2 (3)	THE UNIV. OF CALIFORNIA (US)	32
3	PHILIPS (Netherlands)	30
4	DU PONT DE NEMOURS (US)	25
5	CNRS (France)	22
6	COMMISSARIAT A L'ENERGIE ATOMIQUE UNIVERSITE (France)	18
7	INFINEON (Germany)	17
8 (5)	MASSACHUSETTS INSTITUTE OF TECHNOLOGY (US)	16
9 (9)	SONY CORPORATION (Japan)	15
9	NORTHWESTERN UNIV. (US)	15
9 (4)	3M INNOVATIVE PROPERTIES (US)	15

Prepared by the STFC based on Reference[6]

3-5 International comparison of nanotechnology-related patents in nine designated areas of technology

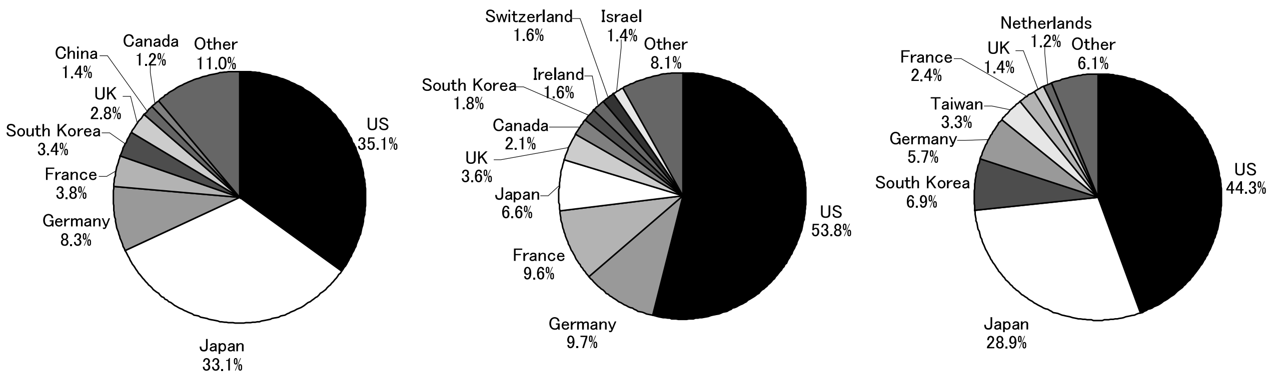
Finally, nanotechnology patent applications have been categorized into nine specific areas of technology in order to compare trends by country (Please refer to Table 1 for details of classification). Figure 8 shows the results of classification for all nanotechnology patent applications submitted to the world's four largest patent organizations, according to the nine areas of technology. The largest number of patent applications was found in the field of materials, followed by electronic devices, then medicine and life sciences. Patent application trends within these nine areas vary significantly from one patent organization to another. In the case of the Japan Patent Office, the percentage of applications from the medicine and life sciences area was small. By contrast, the United States Patent and Trademark Office received a small percentage of applications from the materials field, which was offset by a large percentage of applications from the electronics device area. Patent applications lodged with the European Patent Office and the WIPO showed the same tendency.

Next, an international comparison of the number of nanotechnology patent applications filed in 2004 by three specific areas of technology - materials, electronic devices, medicine and life sciences - was also carried out, as these areas constituted a large proportion of the total number of applications (Figure 9 (a), (b) and (c)). In the area of materials, American patents accounted for the largest percentage, with Japanese patents falling a little short of the American figure. Together, American and Japanese patents accounted for approximately 70% of the total number of patent applications in the materials area. American and Japanese patents also lead others in the electronic device area, in which South Korea and Taiwan were ranked third and the fifth, respectively. The US dominates in the area of medicine and life sciences, with Japan accounting for only a fraction of the applications submitted in this area[Note5]. It is important to remember that Ireland and Israel were ranked among the top ten in this field. Ireland achieved a remarkable breakthrough when it was ranked fifth in the first half of 2005, compared to a position of 13th in 2003. This leap in the rankings reflects the country's stance of placing importance on the areas of medicine and life sciences[6].



Prepared by the STFC based on Reference[6]

Figure 8 : Percentage of nanotechnology patent applications by nine designated areas of technology (2004)



Prepared by the STFC based on Reference[6]

Figure 9 : Percentage of nanotechnology patent applications by country in the three major areas of technology(2004)

4 Summary

As stated above, nanotechnology patent applications submitted to the world's four largest patent organizations were analyzed from various angles by examining application trends by country, by sector (such as corporation, university and public research organization), and by the area of technology concerned. The analysis was carried out with the cooperation of the Nanotechnology Researchers Network Center of Japan. The principal results of the analysis are as follows.

- The number of nanotechnology patents registered with the Japan Patent Office accounts for approximately 1% of the total number of patent applications. The figures for the United States Patent and Trademark Office, the European Patent Office and the WIPO were approximately 1.5%, 1% and 2.5%, respectively.
- The number of nanotechnology patent applications is increasing yearly in the case of all patent offices.
- Nanotechnology patent applicants are predominantly American, followed by Japanese and German applicants. The top two nationalities (American and Japanese) account for more than 70% of the total number of applicants.
- The percentage of patents registered by the country's own citizens varies depending on the patent office. For example, approximately 72% of patents registered with the Japan Patent Office are of Japanese origin. Approximately 62% of patents registered with the United States Patent and Trademark Office are American.
- Patent applications by sector show that the largest percentage of all applicants, approximately 80%, is from corporations. This is true for all countries. University applicants account for the second largest percentage in such countries as the US, the UK, Canada and the Netherlands. Meanwhile, public research organizations account for the second largest percentage in such countries as Japan, Germany, France and South Korea. Hence, two major trends are observed; the US-type trend and Japanese-type trend.
- A cross-country comparison of the areas of technology in which nanotechnology is applied reveals that different countries have different characteristics. The US comes out on top in all areas of technology in terms of the number of applications. Japan compares favorably with the US in the materials area, but is far behind the US in the medicine and life science areas.

5 Conclusion

This article classified patent applications in the field of nanotechnology from several different perspectives. In closing, I would like to draw attention to differences in the patent application behavior of universities and public research organizations in Japan and the US. Industry-university cooperation has been stepped up on a global scale and technology transfers from universities have been increasingly attracting attention. Data presented in this article suggest that at least in the field of nanotechnology we should discuss the technology transfer system as a nation including public research organizations, instead of simply comparing technology transfer trends by universities.

However, although these data on patents provide a range of information on technical knowledge they do not necessarily cover all inventions and intangible assets[4]. In other words, patent applications merely reflect one aspect of technical knowledge, which takes various forms; some types of technical knowledge are disclosed in the form of academic papers, while others are accumulated and kept within an organization as technical know-how[Note6]. The significance and value of individual patents vary widely, depending on the type of industry. Thus, the value and nature of individual patents differ significantly, which makes a difference to the significance of data on patents[Note7]. It is also necessary to be aware of the patenting systems and policies (e.g. patent application fee) of different countries when we interpret data on patents.

I hope that the data and main conclusions presented in this article will lead to more discussion on the current state of nanotechnology research in Japan, on how to measure its international competitiveness, and on various other issues surrounding nanotechnology.

Acknowledgements

I would like to thank Dr. Eiichi Ozawa of the Nanotechnology Researchers Network Center of Japan, who both conducted the investigation and analyzed the investigation outcomes which have been presented in this article. I am grateful for his kind assistance in providing information and sharing his extensive knowledge with me, including his knowledge on individual patent publications.

Presently, the Nanotechnology Researchers Network Center of Japan is categorizing and analyzing US patents state by state as part of its ongoing research of nanotechnology patents[6].

Notes

[Note 1] The Nanotechnology Researchers Network Center of Japan is part of the Nanotechnology Support Project of the Ministry of Education, Culture, Sports, Science and Technology. It began its activities in July 2002. The center carries out comprehensive support in order to promote the development of nanotechnology. This support includes the provision of the latest equipment and information from both Japan and abroad, and the promotion of exchange among researchers. The National Institute for Materials Science operates the center.

[Note 2] When applying for an international patent, one may follow what is called the Paris Convention route by applying to the patent agencies of various countries, or one may follow what is known as the Patent Cooperation Treaty (PCT) route by applying through a unified international procedure. By applying through the PCT route, one can obtain results equivalent to applying in each member country, but one cannot obtain an actual patent right through the PCT. In order to obtain the patent right, the process must shift directly to those countries where the patent is desired. Patents applied for through the PCT route are published by the World Intellectual Property Organization (WIPO). The European Patent Office (EPO) serves the same function for its member countries as the PCT does. Unlike the PCT, however, the EPO has the authority to grant patent rights.

[Note 3] “Nationality of applicant” is defined herein as the nationality of the cheif inventor. In some cases, inventors applying to foreign countries do so through their local patent offices. These cases are also counted by the nationality of the chief inventor.

[Note 4] It should be noted that the Japan Science and Technology Agency is not itself a research institute. When researchers employed in its sponsored R&D projects file for patents based on their results, the Japan Science and Technology Agency becomes the applying institution.

[Note 5] Although this is not indicated in the chart, Japanese percentage in this field has been slowly increasing. In the first half of 2005, Japan moved slightly ahead of France into third place, almost equal level with Germany[6].

[Note 6] Suzuki et al. point out that although the increase in the actual number of patent applications is not particularly significant, the number of claims per patent application filed by the top 10 major electronics manufacturers is increasing[5]. In cases such as these, it is important to understand both the number of claims as well as the number of applications.

[Note 7] The September 2005 Patent Agency survey, "Survey of Intellectual Property-Related Activities 2004," analyzes the use and nonuse of corporate patents by size of firm. (Website: http://www.jpo.go.jp/shiryou/index.htm)

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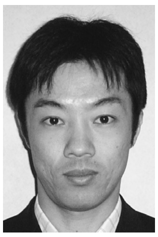

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6

Trends in Research on the Utilization of Microgravity
— Competition and Collaboration between Research in Space and Research on the Ground —

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1 Introduction

The Former Soviet Union launched Sputnik 1, the world's first space satellite, in 1957. Sputnik 2, launched in the same year, carried a female dog making possible the first animal experiment in space. This dog became the first orbital animal and made a pioneering contribution to the life sciences in space. Since then, the special characteristics of space, such as strong radiation and high vacuum, have been gradually revealed by space exploration using many satellites. In particular, scientific experiments that proactively utilize the long-term microgravity environment in satellites are being carried out.

It is more than 20 years since Japan started experiments utilizing the space environment, and a great deal of new fundamental knowledge has been obtained. The next step is the implementation of industrial applications and utilization for consumer products including using microgravity to produce products with nonconventional functions and to develop new pharmaceuticals. Using the U.S.A. and Russian modules on the International Space Station (ISS), Japanese scientists have conducted space experiments including the development of original techniques such as the creation of high-quality protein crystals and three-dimensional photonic crystals. It may even be possible in the future to continuously manufacture products in space. Furthermore, it is anticipated that the operation of the Japanese experiment module (JEM), "KIBO," on the ISS will allow the full-scale utilization of the space environment by Japan. However, it is expected to take a few more years to complete this experimental module. Until then, it is necessary to move on from the creation of high-quality protein crystals and three-dimensional photonic crystals, and make the most of all possible experimental opportunities to explore new subjects such as the creation of high-value-added materials.

This article describes the major topics of experiments using a microgravity environment, outlines the experimental opportunities, and introduces the applications that are likely to advance in the future. Experiments that utilize a microgravity environment (scientific elucidation of phenomena that depend on gravitational acceleration) must be promoted using not only ISS/KIBO but also various other means both in space and on the ground.

2 Microgravity environment and subjects of experiment

On the ground, all objects and their inner structures are governed by universal gravitation, the attraction force between the object and center of the earth. The magnitude of gravitational acceleration that is the source of gravitation is defined as "1 G," which is about 9.8 m/s^2. However, in a satellite orbiting the earth, the gravitation is reduced to the quite minute level of 1 $\mu G=10^{-6}$ G (0.000001 G) because the gravity of the earth exerted on the satellite and the centrifugal force balance out. Also, in a freely falling capsule, objects float in the air. Such a condition is called a microgravity environment, and microgravity experiments are conducted in this special environment.

The microgravity experiments that have been conducted by various countries are mostly related to life and materials sciences. The accomplishments and lessons learned from the experiments in space are summarized in the report[1] published by the Japan Aerospace Exploration Agency (JAXA) in March 2005. This report also provides information on the researchers, and the purpose and results of experiments for each subject.

2-1 Life science experiments

According to the Sectoral Classification Table[2] of Japan Science and Technology Agency (JST), life science is classified into seven groups: (i) biological science, (ii) biochemistry, (iii) breeding and quarantine of organisms, (iv) fermentation engineering and utilization of microorganisms, (v) pharmaceutical science, (vi) medical science, and (vii) bioengineering. Microgravity experiments have been conducted for (i), (ii), (iii), and (vi).

(i) Biological science

Biological science is further divided into genetics, cytology, microbiology, botany, zoology, ecology, radiobiology, etc. In these fields, the following experiments are being conducted.

- Experiments on cell culture (differentiation of stem cells, three-dimensional cell culture, and exhaustive analysis of gravity-sensitive genes)
- Experiments on plants (completion of life cycle, experiments on gravitational tropism)
- Environmental Control and Life Support System (ECLSS) (establishment of circulatory system of living organisms, assessment of microbial safety)
- Experiments on small animals (effects on reproduction, bones, and muscles of amphibians, fish, and mice; experiments on the effects of radiation)

(ii) Biochemistry

Experiments on the growth of high-quality proteins and enzyme crystals.

(iii) Breeding of organisms

Plant seeds and animal sperm are carried on the craft for use in the space environment where microgravity and strong radiation act simultaneously to improve varieties of organisms.

(iv) Space medical science

Using astronauts as the test subjects, changes in the functioning of various parts of the human body in space and measures to be taken in preparation for the return to earth have been the subject of a wide range of experiments that have contributed to the development of space medical science.

2-2 Materials science experiments

Materials science experiments include crystal growth, fluid physics, and combustion. Special experimental apparatus has been used for each experiment. It may be possible in the future for researchers to routinely use a microgravity environment to create high-quality, sophisticated nanomaterials.

(1) Crystal growth

Studies on the formation of high-quality single crystals and elucidation of the mechanism of crystal growth are being conducted using special devices such as those for crystal growth from solutions. Effectiveness of the application of microgravity environment has been confirmed not only for the precipitation of crystals from solutions but also for the uniform mixing of several materials. At present, the space experiment on the growth of three-dimensional photonic crystals, which started in December 2005, is the focus of attention[3].

(2) Fluid physics

Although convection caused by differences in temperature and specific gravity does not occur in a microgravity environment, convection caused by the difference in surface tension due to temperature difference becomes apparent. This phenomenon is called Marangoni convection. Experiments that use Marangoni convection, the effect of which cannot be separately studied on the ground, and other experiments such as phase changes between a gas and a liquid are being performed.

(3) Combustion

Combustion conditions are different in a

Space medical science

(1) Developments in research on the effects of the space environment on the human body

When the ISS is completed, Japanese astronauts will stay there for a lengthy period of about six months. In addition, opportunities for commercial space trips are increasing and it will not be long before ordinary people can travel into space. To carry out these activities safely, the effects of space on the human body are being studied.

(i) Bones: Bone mass decreases after a long period of space flight. Ways of avoiding this phenomenon include exercise and drugs to prevent osteoporosis.

(ii) Muscle: Since astronauts do not carry heavy objects in space and can make movements without the restriction of body weight, it is thought that muscle strength decreases after a long period of space flight.

(iii) Circulatory system: In a space flight of extended duration, cardiorespiratory function is depressed. Red blood cell mass decreases, blood and lymph fluid shift to the upper half of the body and excretion of urine is promoted resulting in decrease of body fluid by about 2 litters. For this reason, sports drinks or similar fluids are taken just before returning to the ground to supplement body fluid.

(iv) Sensory organs: Some people suffer from space sickness even during space flights of short duration. Space sickness causes stomach discomfort, vomiting, and dizziness. While there are various theories for the mechanism of such symptoms, the generally accepted theory is that the eyes and ears give different information on the sense of the vertical, thus confusing the senses.

(v) Mental health: A prolonged stay in the closed environment of a spacecraft causes astronauts to suffer from the same kind of mental stress as experienced by Antarctic exploration team members and submarine crews. To cope with such a situation, astronauts are selected who can endure long periods in a closed environment and are trained on the ground to enhance their stress tolerance. Furthermore, while on the spacecraft, they are supported by communication from earth.

(2) Health management in space

If an astronaut suddenly gets sick on the spacecraft, other astronauts on the craft do not always have sufficient medical knowledge and onboard medical instruments are not always adequate. The environment is very poor for telemedicine services due to the limited capacity for transmission of communications between the spacecraft and the ground. Therefore, health management of astronauts is an important issue for the prevention and early detection of disease.

Furthermore, nutrition and metabolism are taken into account in the development of easy-to-eat space foods to maintain the health of astronauts. On the July 2005 space shuttle mission, aggregated instant noodles were adopted as the space food. In the Chinese manned space flight in October 2005, Chinese foods using costly foodstuffs were added to the space foods.

(3) Training in preparation for the return from space

On the former Soviet Union space station, astronauts performed indoor exercises on the spacecraft to maintain their physical capability in preparation for the return to earth. If space flight is continued for a long period without performing such exercises, astronauts may not be able to stand on their own, break bones by careless movements, or damage muscles on their return to earth.

microgravity environment from those observed on the ground. For example, it is known that a flame has a spherical shape in a microgravity environment. Experiments are being carried out in which flame propagation is observed while part of the fuel is nebulized.

(4) Measurements of thermophysical properties, etc.

It is possible to conduct high-temperature melts without using containers in a microgravity environment, and thermal conductivities of semiconductors and molten metals and diffusion constants have been measured. These experiments have not only provided the data on the physical properties required for crystal growth, but have also contributed to the creation of a new technology field called “supercooled high-temperature melt.” Crystal growth that prevents contamination from containers is also drawing attention.

3 Methods for creating a microgravity environment

Methods for creating a microgravity environment include: drop test facilities, aircraft, small rockets, recoverable satellites, space shuttles, and the International Space Station. Figure 1 shows the levels and time range of microgravity for these methods.

3-1 Drop test facility

A drop test facility is where a test device is placed in a falling capsule, which falls freely in a tower or vertical mineshaft. A microgravity environment is created in the capsule for a very short time until the capsule reaches the brake at the bottom. Since the testing time is very short, this method cannot be universally applied. However, the drop test provides the safest, simplest, and least expensive method for obtaining a microgravity environment. The level of microgravity is relatively high and testing is reproducible. Whereas major drop test facilities in the U.S.A. and Europe are owned by public institutions, such facilities in Japan are operated by private companies.

The drop test facility in Toki City, Gifu Prefecture, is owned by the Micro-Gravity Laboratory of Japan (MGLAB)[4]. The testing facility is in one of the vertical mineshafts of the Tono Mine owned by the Japan Atomic Energy Agency. A capsule is dropped freely in the vacuum tube provided in the 150 m mineshaft. The upper 100 m is for the free falling area and the lower 50 m is the braking area, which uses rubber. The vacuum in the tube is maintained at about 4 Pa to prevent deterioration of the microgravity level due to air resistance. A microgravity level of about 10^{-5} G is reached for 4.5 seconds. To use the facility, experimental modules must be designed to fit in the cylindrical space of the capsule of 720 mm D × 885 mm

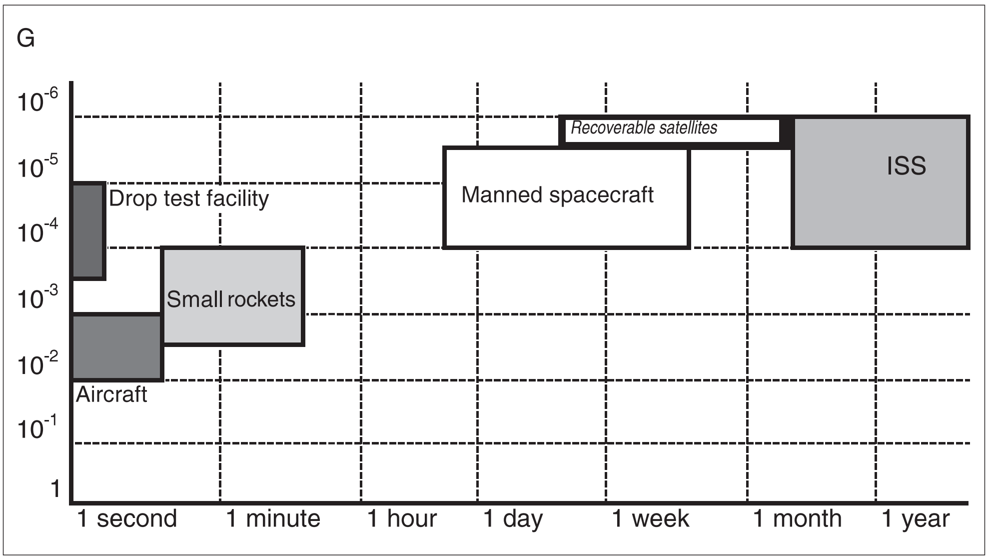


Figure 1 : Microgravity level and period of microgravity by experimental method

H. Currently, 300 to 400 drop experiments are conducted annually. Since the start of operation in 1995, the total number of drop experiments has exceeded 6,000. Most of the experiments are for fundamental studies, which are performed mainly by national and public universities and public institutions aided by the Proposals for the ground-based Facilities program of JAXA. Experiments include fluid experiments, combustion experiments, materials testing, life science experiments as well as technical verification tests of newly developed apparatus for space use. The demonstration of the sampling system using metal projectiles shot by the asteroid exploration spacecraft "Hayabusa" was made using this MGLAB.

In Europe, the Center of Applied Space Technology and Microgravity (ZARM) at the University of Bremen in Germany has a 146 m drop tower and carries out all the drop experiments for European Space Agency (ESA) and European countries. In the U.S.A., the National Aeronautics and Space Administration (NASA) has a 145 m drop tower in the Glenn Research Center (GRC), and in China, the National Microgravity Laboratory of Chinese Academy of Sciences (NMLC) in Zhongguancun, Beijing, has a 110 m drop tower.

3-2 Parabolic flight by aircraft

Microgravity experiments using aircraft are being performed by public institutions and private companies in the U.S.A., Europe, and Japan. It is significant that manned experiments on the ground can only be conducted by this method. In Japan, Diamond Air Service (DAS)[5], located in Toyoyama-cho, Aichi Prefecture, provides a regular service using aircraft such as the Gulfstream-II (Figure 2) and MU-300 in which a parabolic flight path creates microgravity conditions for about 20 seconds. For example, DAS is planning to perform simple experimental flights in April 2006. In these flights, microgravity experiments can be carried out for 100 seconds (20 seconds × 5 times / 1 flight) with an approximate cost of ¥300,000 to ¥400,000 per person. The level of microgravity of about 10^{-2} G is inferior to that of a drop test facility. On the one hand, it is possible to carry relatively large experiment modules because the fuselage is large, however, the person on board is exposed to the physical strain caused by the acceleration of gravity reaching between 1.5 and 2 G before and after the microgravity period.

Figure 2 : Gulfstream-II of DAS (total length: about 24 m)

In the U.S.A., NASA owns a DC-9 in order to provide a service for scientists from various countries wanting to conduct experiments using the space shuttle. A private company, Zero-G, carries out business including a microgravity experience for the general public.

In Europe, the Centre National d'Etudes Spatiales (CNES) and other institutions have carried out microgravity experiments using the Caravelle aircraft since 1988 and the Airbus 0G (A300-0G) since 1997.

3-3 Small rockets

Ballistic flight of a small rocket has been frequently used in the past in Japan to achieve a microgravity environment, and it may also be used in the future using new rockets. When using a small rocket to achieve a microgravity environment, it is necessary to take into account the acceleration at the launching, the deceleration on recovery, as well as the impact. Although the microgravity environment lasts only several minutes, various types of microgravity experiments, mainly in materials science, can be performed. In Europe, Germany and Sweden, microgravity experiments are carried out using small rockets independently.

In Japan, the former National Space Development Agency of Japan (present JAXA) performed seven microgravity experiments using TR-IA rockets between 1991 and 1998. After launching, the rocket entered ballistic flight at an altitude of 100 km where the air resistance drastically decreases. At an altitude of about 270 km, a fairly good microgravity environment of 10^{-4} G was obtained for about six minutes until the rocket again reached the altitude of 100 km. The experiments were mainly in materials science including (i) crystal growth from solution, (ii) colloidal crystals, (iii) fluid physics, (iv) boiling tests, (v) creation of semiconductor materials, (vi) diffusion tests, and (vii) combustion tests.

Currently in Japan, the Hokkaido Aerospace Science and Technology Incubation Center (HASTIC), a specified nonprofit organization (NPO), is improving the performance of the CAMUI hybrid rocket, which uses solid fuel and liquid oxidizing agent as the propellant so that microgravity experiments can be provided[6]. The aim is to obtain a microgravity environment for about three minutes at an altitude of 110 km. Combustion tests are being repeated at the HASTIC Akabira Center located in Akabira City, Hokkaido.

In Europe, Germany has conducted microgravity experiments using the Texus rocket since 1977 and the Maxus rocket since 1991. Since 1987, Sweden has performed 10 microgravity experiments for the European Space Agency using the MASER rocket, and intends to continue the tests.

3-4 Recoverable satellites

The above-mentioned experiments conducted near the ground can provide a microgravity environment from several seconds to several minutes. If unmanned experiments are performed in a satellite and the satellite returns to the earth without any problems, microgravity environments can be provided for dramatically longer periods. Depending on the size of the satellite and the existence of solar battery panels, experiments can be conducted throughout the duration of the whole orbital flight of several days, several months, or even more than one year. It is also possible to conduct multiple experiments simultaneously. Microgravity experiments using such recoverable satellites are being performed by Japan, China, Europe, and Russia and it is expected that these satellites will also be utilized in the future. Japan has launched recoverable satellites such as the Space Flyer Unit (SFU) and EXPRESS for space experiments and space observation, and the Unmanned Space Experiment Recovery System (USERS) is the next generation system. Figure 3 shows the appearance of USERS and the concept of the capsule separation.

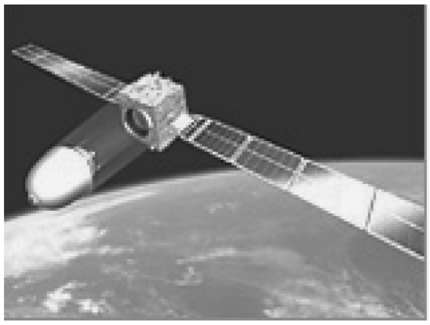


Figure 3 : USERS satellite

The USERS is being developed by the Institute for Unmanned Space Experiment Free Flyer (USEF) as a project started in 1995, sponsored by the Ministry of Economy, Trade and Industry and the New Energy and Industrial Technology Development Organization (NEDO). The purpose of the project is to develop a system that returns to the ground by itself after performing experiments in space for a long period of time. The first system was launched into orbit by H-IIA F3 on September 10, 2002, and performed an experiment on the production of superconducting material under good microgravity conditions for about six months. It returned to the earth by controlling and adjusting its reentry path and landed in the water at the planned point, offshore east of Ogasawara on May 30, 2003, bringing back the results of the space experiments without any problems. This success demonstrated that the heat protection technology required for atmospheric reentry and the trajectory control technology necessary for returning to a planned point in the sea have been established, confirming that the unmanned experimental system is suitable for practical use. The Users Guide[7] for this system has now been published to promote the utilization of USERS. However, no launch is scheduled at present. It is difficult to launch the second flight based on the private sector projects unless the government becomes the anchor tenant and underwrites a definite number of experiments.

3-5 Manned spacecraft (space shuttle, etc.)

The U.S.A. space shuttle had been launched a total of 114 times by the end of 2005. The major missions of space shuttles are to put satellites into orbit, perform space experiments, and construct the ISS. Table 1 shows the breakdown of the missions.

Of the 114 shuttle flights, missions primarily for space experiments include: USML and USMP of the U.S.A. for microgravity experiments; D-1 and D-2 of Germany; International Microgravity Laboratories IML-1, IML-2, and Neurolab; and the First Material Processing Test (FMPT, "FUWATTO '92") of Japan. In the ISS construction missions, which are being sent almost continuously, small-scale experiments were recently performed by students utilizing surplus space and weight.

In the FMPT, which was the first thorough Japanese space experiment, 34 of 43 experiments were from Japan, 2 were collaborations between Japan and the U.S.A., and 7 were from the U.S.A. Japan prepared 21 kinds of experimental apparatus, and astronaut Mamoru Mori managed the experiments as a payload specialist (PS). In the space shuttle, a microgravity environment is continuously maintained for a maximum period of two weeks allowing a range of simultaneous experiments to be managed by the space shuttle crew. However, the U.S.A. is caught between the construction of the International Space Station that will provide long-term space experiments, and the retirement of the space shuttle in only five years resulting in decreased flight opportunities. There is little room for setting up a mission aimed mainly at space experiments using the space shuttle.

In China, a rack for experiments was installed neighbor to the astronaut's seat in the Chinese independent spacecraft "Shenzhou-5" (2003) and "Shenzhou-6" (2005) to carry out microgravity experiments.

Table 1 : Breakdown of major space shuttle missions

Mission		Number
Primarily ejecting, recovery, or repair of satellites		45
Primarily space experiments	Primarily life science	15
	Primarily materials science	7
	Primarily earth observation and astronomic observation	8
Primarily transportation of parts and supply materials for the ISS (including Shuttle-Mir Mission)		27
Others (test flight, unknown mission, etc.)		10
Failure (accident)		2

3-6 International Space Station (ISS)

(1) Recent situation of the ISS

The space station is a facility for continuous manned space flight over an extended period of time and functions as a routine space laboratory or space factory. However, on previous space stations, such as Mir of the former Soviet Union and Skylab of the U.S.A., the majority of missions were on medical research into the effects of long-term space travel, astronautic observations, earth observations, and reconnaissance, and the proportion of microgravity experiments was relatively small.

The International Space Station Program was advocated by President Reagan of the U.S.A. in 1984, and started in 1985 with the participation of Europe, Canada, and Japan. Initially, construction was scheduled to start in the early 1990s and be completed in the 20th century. However, the construction work has been slowed by space shuttle accidents etc., and completion is expected to be delayed by more than 10 years.

In 1993, Russia joined the ISS Program and "Zarya" (=Dawn, built by Russia and owned by U.S.A.), a control module that has the same function as the Russian space station "Mir," was launched in November 1998. After that, the Russian service module, "Zvezda" (=Star), the American experiment module, "Destiny," and the Canadian robot arm were attached in July 2000, February 2001, and April 2001, respectively. Now the initial ISS system has been completed that enables two astronauts to stay aboard all the time. Figure 4 shows the appearance of the ISS as of 2005.

Figure 4 : Appearance of the ISS as of 2005

At present, two astronauts, one from the U.S.A. and one from Russia, are always on the ISS and data on space medicine related to long stays in space, which the U.S.A. has not undertaken in the past, is being recorded and space experiments by participant countries are being conducted.

In the future, the European experiment module, “Columbus,” and a Japanese experiment module, “KIBO,” are scheduled to be attached; in the Heads of Agency (HOA) meeting held on March 2, 2006, it was agreed to launch the space shuttle 18 times (including two reserves) by 2010. “KIBO” is scheduled to be sent three times in the eighth, ninth, and twelfth launch. According to the agreement of the HOA in March 2006, it is possible that “KIBO” will be launched in FY2007 although a definite time has not been decided yet. The key to the success of this project is whether or not the resurgent second “KIBO” is successfully launched in July 2006. Space experiments will move into full swing when all the experimental modules of the U.S.A., Europe, Japan, and Russia start operation with astronauts, including Japanese astronauts, present on the station all the time.

(2) Access to the ISS

The transportation of crews and supply materials to the ISS are solely dealt with by the Russian spacecraft Soyuz (accommodating three astronauts) and the Progress resupply vehicle.

Russia sent the spacecraft Soyuz to the space station Mir in April 2000 for the last transfer of crew, and since October of the same year, Soyuz has been launched solely to transport the replacement crews to the ISS every April and October. Since it takes about eight days to take over the job, opportunities are offered to civilian travelers to make use of the spare seat in the Soyuz spacecraft and experience short-term space travel to the ISS. It is possible for a Japanese traveler to ride on the craft in October 2006.

With regard to materials supply, Progress has been launched 25 times in the period of nearly six years from February 2000 to December 2005, and the reliable Russian transportation capability is widely appreciated by the international partners of ISS.

4 Trends in research on the application of microgravity - High-quality protein crystals growth

4-1 Overview of research on protein

To maintain life, living beings have vital functions such as food digestion, energy supply, nervous transmission, and the capacity for immune response. It is said that these functions rely upon more than 20,000 different proteins. The kinds and functions of proteins are determined by the arrangement of amino acids and the steric structure of the protein. Establishing databases for protein structures and functions will allow both qualitative and quantitative understanding of complex vital phenomena. Furthermore, understanding the structures and functions of target proteins permits rational and effective design of therapeutic medicines. Attempts to apply drug discovery and personalized medicine to innovative technologies for prevention, diagnosis, and treatment of diseases and the development of new foods through the analyses of the structure and functions of proteins are being made by universities, research institutes, and private companies.

To conduct research on protein structures, it is necessary to prepare samples for analysis by separating the target proteins. Although samples prepared on the ground have been mainly used in research on protein engineering, it is quite difficult to obtain high-quality samples. In one case, a researcher could obtain only one crystal in the first five years of research.

It was planned to prepare crystals utilizing microgravity in space in the early days of space experiments and the technology has been available for more than 20 years. Among the microgravity experiments that have been performed, high-quality protein crystals growth is one of the best developed technologies so far. In the spacecraft, where the gravity of the earth and the centrifugal force balance out, the gravity is around 10^{-6} G so that the convection caused by the difference in density of the solvent does not occur in the neighborhood of the protein crystal, providing a uniform growth rate of the crystal and reducing the crystal defects. At the same time, the number of nucleations of crystals is suppressed resulting in a smaller number of larger-sized crystals.

The Japan Aerospace Exploration Agency (JAXA) has performed a series of space experiments, including several experiments that utilized the shuttle and those of the "High-quality Protein Crystallization Project" conducted on the ISS, in order to obtain protein crystal samples, and reached a stage in which the creation of high-quality protein crystals became possible in space. The results are published in "Progress and Problems in High-Quality Protein Crystal Growth Technology Using Microgravity Environment"[8].

In Europe and the U.S.A., however, in addition to the skepticism about the sense of obtaining high-quality crystals from space experiments, experimental results were lost due to an in-flight disintegration of the space shuttle, and the space experiments on the preparation of protein crystals have made little progress.

4-2 Structural analysis of proteins

X-ray diffraction is often used for the determination of protein structure, and requires that the protein must first be crystallized. Furthermore, it is desirable to use larger crystals. The RIKEN Harima Institute located at the Japan Synchrotron Radiation Research Institute (JASRI) in Sayo-cho, Hyogo Prefecture, has established an experimental automated system that enables the acquisition of several tens of high-precision structural images daily from small crystals using the large-scale synchrotron radiation facility JASRI SPring-8.

The RIKEN Yokohama Institute has developed a method for structural analysis of relatively small protein samples (with a molecular weight of 60,000 or less) prepared on the ground without crystallization, using a Nuclear Magnetic Resonance (NMR) apparatus.

With regard to magnetized proteins, the National Institute of Advanced Industrial Science and Technology (AIST) and National Institute for Materials Science (NIMS) are attempting to prepare high-quality crystals in a pseudo-microgravity environment created by magnetic levitation using superconducting magnets.

In the future, it may be possible to conduct x-ray spectroscopic analysis of proteins of large molecular weight using an X-ray Free-Electron Laser (X-FEL) that provides a peak radiance 100 million times stronger than that of the SPring-8. Such a device is expected to be available in 2010 at the earliest. At present, it is difficult to predict whether or not the preparation of protein crystals in space will still be required when the X-FEL is operational. It will be appropriate to determine the optimum methodology from a comparison of ground-based and space-based techniques.

4-3 Four issues concerning protein crystal growth in the space environment

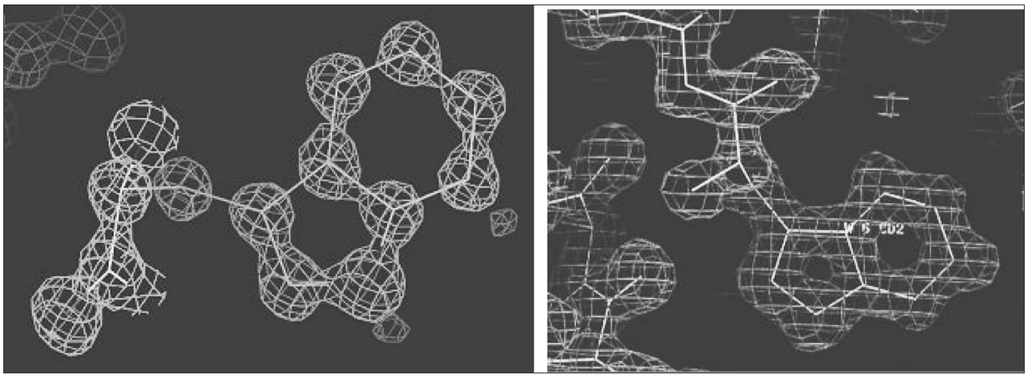
Issues to be resolved for achieving protein crystal growth in space are: (i) achieving a higher quality that cannot be achieved on the ground, (ii) cost reduction, (iii) reduction of turnaround time (time required for the results to be returned to the researcher), (iv) improvement of support systems. The present status and future targets for resolving these issues are as follows:

(1) Method for the quality evaluation of protein crystals

The quality of protein crystals is expressed as the resolution of the crystal structure. The resolution is expressed in angstroms (Å, 0.1 nanometer); the smaller the value, the higher the resolution and the higher the quality of the crystal. For example, when the resolution is about 2 Å, the structure of the side chain can be accurately determined, and when it is 1 Å, even a hydrogen atom can be identified. To compare the quality of a crystal prepared in space with one prepared on the ground, a check test was performed using alpha amylase and lysozyme. Using the 12B2 beam line of SPring-8, the X-ray diffraction of the alpha amylase crystallized in space had a resolution of 0.89 Å. This value represents the highest resolution that had ever been obtained. However, the resolution of a crystal of alpha amylase prepared on the ground was 1.12 Å. Figure 5 shows the electron density maps of these crystals. For the lysozyme crystal, the resolution of a crystal prepared in space was

Preparation of single crystals of diamagnetic proteins on the ground

Depending on the type of protein, crystallization may take from several days to several weeks. However, crystals can be formed in reduced gravity, but not necessarily microgravity, environments. For example, diamagnetic proteins such as fructose bisphosphatase and lysozyme can be crystallized under the low gravity (about 0.7 G) obtainable with a strong magnetic field. In collaborative research between the National Institute for Materials Science (NIMS) and Hiroshima University, high-quality crystals of diamagnetic protein were successfully formed in a pseudo-microgravity environment (about 10-3 G) created by a strong magnetic field of about 10 tesla using superconducting magnets. NASA has succeeded in creating a pseudo-microgravity environment on the ground using laboratory equipment of the rotating vessel type. These are examples of low gravity and pseudo-microgravity environments that can be achieved and maintained for long periods relatively easily on the ground.



Left: prepared in space, Right: prepared on the ground. See the color photo on the front cover. (Obtained on SPring-8 BL-12B2)

Figure 5 : Electron density maps of alpha amylase crystals

0.88 Å while that of a crystal prepared on the ground was 1.08 Å.

In some cases, the resolution of about 3 Å for a crystal prepared on the ground can be improved to about 1.5 Å with ingenuity and trial and error. However, it is quite difficult to obtain a crystal with a resolution better than 1 Å (<1 Å). The European researcher who succeeded in obtaining an image with a resolution in the order of 0.6 Å, which is thought to be the best in the world, has a very high expectation for the quality of protein crystals prepared in space. He once commented that he would like to take every opportunity available to prepare crystals in the space environment, e.g., using Japanese apparatus if possible, paying a fee, regardless of the cost, time, and limitation of launch opportunities. It is also necessary to assess what kinds of protein samples should be sent into space and the timing necessary to obtain effective results taking into account cost and restrictions on availability.

(2) Reduction in the cost of growing protein crystals

It was confirmed by space experiments conducted on the ISS from 2003 to 2005 that high-quality protein crystals can be created in a long-term microgravity environment. The noteworthy technologies that have been developed in the above-mentioned experiments are as follows.

(i) Temperature control: It is important to maintain the ambient temperature of the apparatus at 20°C. In the initial experiments, some crystals that had been created after considerable effort melted due to an increase in temperature in the spacecraft. To keep the temperature at a constant 20°C, an alkane with a melting point of 21°C

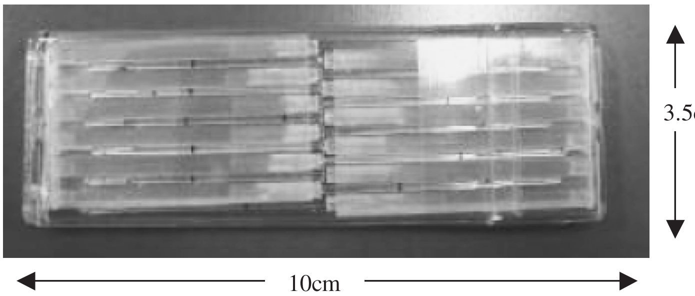


Figure 6 : Appearance of the JAXA Crystallization Box (JCB)

Table 2 : Major previous experiments related to proteins

Month and year	Spacecraft	Country	Contents and number of experiments
1983 ~ 2002	Space shuttle	U.S.A.	Insulin separation, etc., 54 cases
1983 ~ 2002	Space shuttle	Europe	13 cases
1992.1	Space shuttle	International	IML-1
1992.9	Space shuttle	Japan	FMPT (enzymes, etc.)
1993~ 2000	Space shuttle	U.S.A., etc.	SPACEHAB (private sector)
2003.1 Failure to return	Space shuttle (STS-107)	Japan	Enzymes, pathogenic proteins, animal lectins, etc., 10 cases
2003.2~ 2006.4	ISS Destiny/Zvezda	Japan	High-quality protein crystal growth project (conducted 6 times)

(heptadecane) was placed with the sample in a vacuum insulator, and the internal temperature of the Soyuz carrying the crystals back to the earth was decreased. These methods established a fail-safe technology for preparing high-quality protein crystals at a constant temperature and bringing them safely back to the earth.

(ii) Improving the apparatus for preparing protein crystals: The apparatus for the preparation of protein crystals, the "GCB" (Granada Crystallization Box) that was jointly developed by the European Space Agency (ESA) and the University of Granada in Spain, had defects such as solution leakage. JAXA eliminated these defects by using a gel tube (GT) method to guarantee crystal growth. The improved apparatus is called the GCB-GT.

Furthermore, JAXA developed apparatus for preparing protein crystals called the "JCB" (JAXA Crystallization Box) that allows about a 10 times higher packaging density than the GCB. Figure 6 shows the appearance of the JCB. While the GCB-GT uses six glass capillaries for only one kind of protein, JCB is equipped with 12 glass capillaries allowing a maximum of 12 different kinds of proteins or 12 different testing conditions. This improvement contributes to a reduction in the cost of crystal growth.

On December 22, 2005, Japanese protein preparation experimental apparatus was launched to the ISS in its 400km orbit on the Russian resupply craft, Progress, and experiments were performed for three month on the Russian service module "Zvezda" until the apparatus was brought back on the Soyuz spacecraft on April 9, 2006. This experiment was the last stage of the development by Japan of high-quality protein crystal preparation technology. In this experiment, 42 kinds of proteins were launched in a set of apparatus consisting of 11 JCBs and 34 GCB-GTs. In the future, it is hoped to increase the opportunities for low-cost experiments by adopting JCBs so that private companies and foreign researchers can easily utilize the space environment for experiments.

(3) Reduction of turnaround time for protein crystal preparation

Some of the experiments that have been performed by various countries relating to proteins are shown in Table 2.

In the past, the U.S.A. and Europe took a lead in space experiments related to proteins and Japan tried to catch up.

Of the experiments shown in Table 2, the separation of insulin differs from crystal growth and aims to separate high purity insulin for production. It is unlikely that insulin will be produced in space because of the quality and cost. However, crystal growth of proteins has potential because it is difficult to prepare them on the ground. An obstacle to the impetus for these experiments is the length of time it takes for the finished crystals to be returned to the researcher.

According to the staff in charge of the space shuttle payload at the NASA Johnson Space Center, although it took 44 months in the initial stage of the protein crystal growth experiments from shipment of samples to the space shuttle to receipt of samples by the researcher, the time has now been reduced to 14 months. For experiments that use the Russian module, the total time required for sample shipment, the space flight period, and return to the researcher has been reduced to about 7 months. However, many researchers are very keen for an even shorter turnaround time for the preparation of crystals in space.

In order to shorten the turnaround time, it is necessary to increase the frequency of access to the ISS and select the timing of launches so that the samples are recovered more frequently. After the space shuttle is retired and to avoid delays, it will become necessary for international cooperation to establish appropriate transportation schedules using the Japanese H-II transfer vehicle (HTV), the European automated transfer vehicle (ATV), and the new U.S.A. and Russian transportation systems. It is desirable to reduce the total time required for transportation and experiments to three to four months.

(4) Improvement of support systems

In Japan's "High-quality Protein Crystallization Project," the Japan Space Forum (JSF) has been commissioned by JAXA to support researchers by preparing apparatus, and the mounting and recovery of samples.

In space experiments, as in any other research activity, the development of experimental equipment is the means by which data is obtained and functions confirmed rather than the research itself. However, since data cannot be obtained without the development of experimental methods, part of the funding and human resources are naturally allocated to the development of experimental equipment and implementation of experiments. Not all the scientists and researchers who are going to perform experiments in life science and materials science are good at developing experimental apparatus and implementing experiments in the microgravity environment; and it is necessary to improve the comprehensive support system for such scientist and researchers. Therefore, from a long-term perspective, it is necessary for space-related organizations like JAXA, which play such a role, to secure research support personnel and accumulate know-how about testing and the development of experimental equipment.

4-4 Plan for commercial protein crystal growth

It is fairly clear that high-quality protein crystals that cannot be created on the ground can be created in the microgravity environment of space. Since the difficulty of preparation of high-quality samples is the bottleneck in protein research, the microgravity environment in space is likely to be utilized frequently as a means of removing this bottleneck.

Taking this into account, JAXA, which has developed crystal growth apparatus for proteins such as JCB, is planning to transfer these technologies to private-sector institutions from 2006. When this plan is achieved, it is expected that the growth of high-quality protein crystals will be carried out continuously on the ISS.

According to the previous plan, "KIBO" was supposed to be almost completed in 2006, making it possible to start full-scale experiments. However, it will take two or three more years to complete "KIBO" due to the delay in the flight schedule caused by the space shuttle accident. In this time, demonstration in space must be brought forward as far as possible by finding any available opportunities to use the microgravity environment. It is expected that crystal growth will be performed on a large scale using Japan's dedicated experimental rack after "KIBO" is completed around 2007.

In the U.S.A., Dr. DeLucas of the University of Alabama at Birmingham (UAB), who traveled on board the space shuttle STS-50 as a payload specialist, conducted protein crystal growth experiments using the U.S. module, "Destiny." Since the space shuttle is not operating regularly, it is proving difficult to recover these experimental samples.

The important points in the promotion of commercial growth of protein crystals are: (i) high quality, (ii) low cost, (iii) shorter turnaround time (or timely provision of samples to researchers), and (iv) support systems. By the time the ISS is in full use, all of these four factors must be improved.

5 Opportunities for manufacture of products in the microgravity environment

5-1 Utilization of existing ISS modules

Because the ISS participating countries have agreed to allow private visitors to stay on the orbital space station, it has become possible for private citizens to travel on board the Soyuz spacecraft and stay on the ISS for about a week. There is a plan for a Japanese person, who is currently on a training course, to travel on the spacecraft in October 2006. Assuming that this person does travel on board the spacecraft as part of the Space Open Lab[9], JAXA is inviting applications for scientific experiments, applied experiments, educational experiments, and cultural experiments to be conducted by the passenger on the spacecraft. Costs for the experimental equipment and loading of the samples are to be borne by the applicants.

5-2 Microgravity experiments using Japanese experiment module "KIBO"

The protein crystal growth experiments, currently performed on a limited scale in the Russian module etc., will be expanded when "KIBO" is completed. It will be possible to prepare experimental samples as well as carry out pilot production of raw materials for pharmaceuticals.

For Japan to fully utilize the space environment on the ISS, the parts of "KIBO," which are waiting to be launched, must be launched and assembled in orbit so that the Japanese space laboratory can be constructed.

It is planned to mount the following experimental equipment on "KIBO" in the initial stage[10].

(i) Experiments in life science: protein crystal growth apparatus, cell culture equipment, a clean bench, and a refrigerator,

(ii) Experiments in materials science: temperature gradient furnace, experimental equipment for fluid physics, and equipment for observing the crystal growth solution.

These instruments are integrated into the international standard payload rack (ISPR), and will be launched and stored in the pressurized storage room before the main unit is launched. After the main unit of "KIBO" is attached to the station, these instruments will be transferred to the pressurized section so that experiments can be performed. After the process is started, it will also be possible to exchange racks as required. The development of experimental equipment and determination of research topics are inseparable so both must be considered together. Since the number of ISPRs that can be loaded is limited, it must be noted that experiments being conducted at any particular time will not necessarily continue forever.

5-3 Opportunities other than the ISS

Future opportunities for the utilization of the microgravity environment are not limited to the ISS.

(i) USERS satellites can be used for long-term microgravity experiments when human support is not required. However, the flexibility of launch and recovery schedules for USERS satellites are limited by various setting-up difficulties.

(ii) When human support is required during the experiment, experiments can be performed rapidly for short durations using an aircraft as described in Section 3-2.

(iii) When developing various types of experimental equipment to be carried by the ISS, recoverable satellites, or aircraft, the drop test described in Section 3-1 provides the simplest microgravity environment for the confirmation of structures and performance or rough estimation of various parameters. Drop tests will remain an effective method for carrying out microgravity experiments in the future.

(iv) When the enhanced hybrid rocket, as described in Section 3-3, is completed, a microgravity environment that lasts longer than that possible in aircraft will become available. In Hokkaido, the Hokkaido University and HASTIC are conducting combustion tests at the Akabira Center to develop a hybrid rocket.

(v) When the experimental process, such as the growth of single crystals of silicone, is completed in a microgravity environment of short duration, a mass production system can be established by installing a drop tower in the production line. In the Microgravity Utilization Laboratory of Kyosemi Corporation located in Eniwa City, Hokkaido, a new drop tube has been installed to establish a mass production system for high-value-added spherical solar cells[11].

In research on such subjects as high-quality protein crystal growth, where full-scale space experiments are carried out on the ISS, drop test facilities and aircraft were frequently used for the confirmation of functions in the initial stages when the experimental equipment was developed. In view of the fact that tremendous amounts of research work are required in preparation for space experiments, it is desirable that microgravity experiments are more easily performed on a wider range of subjects.

6 To enhance the status of Japan as a science and technology oriented nation through research on the application of microgravity

In research on microgravity, there is competition or trade-off in quality and cost between space experiments and alternative methods on the ground. This means that space is not the only available means of carrying out microgravity experiments. Sometimes, achievements in space may be enhanced by combination with the results obtained by experiments on the ground. In order to prepare the best possible samples for protein research, it is important to retain competition between experiments in space and on the ground to raise the level of research through creative ingenuity and hard work.

By the time "KIBO" is completed, ending the initial training and beginning the new stage of research in space experimental technology, it will be necessary for Japan to strengthen its competence in space experiments with a long-term perspective, not only for proteins but also for other fields, taking into consideration proposals for new experimental topics, research and development of instruments required for the implementation of experiments, and the application of results.

The desirable focus of various sectors are summarized below.

(1) Promotion of research on microgravity leading up to the full-scale operation of "KIBO"

Because the resumption and full-scale use of the space shuttle is foreseeable and the long-awaited "KIBO" may be launched in FY2007, utilization of the microgravity environment in space that has been at a standstill is approaching a new stage. The types of experiments to be performed on "KIBO" must be carefully selected and refined by repeated preliminary experiments on the ground with regard to the development of experimental equipment and the application of results. Currently, universities and private companies are using drop test facilities and aircraft to improve equipment and conduct experiments to obtain new information. Researchers are keenly committed to the utilization of an experimental environment that cannot normally be obtained on the ground. However, in Japan at the moment, facilities are not fully utilized due to the national budget system and insufficient public subsidies. With the recognition that research on microgravity is not just for the utilization of the space station but also to carry out valuable experiments on the acceleration of gravity, every existing opportunity for experiments must be utilized to promote research on microgravity.

(2) Promotion of industrial applications of microgravity

As a result of space experiments that have been conducted for over 20 years, materials and products that cannot be obtained under normal gravity on the ground are now being produced. The current period is a period of preparation for the full-fledged utilization of the space environment by Japan. It is expected that the current stage will progress in a step-by-step fashion to the next stage where both industrial and consumer applications will begin with microgravity applied in a wider range of uses.

Experiments specifically attracting interest are:

(i) High-quality protein and three-dimensional photonic crystal growth on the ISS.
(ii) Long-term space experiments using USERS satellites of USEF.
(iii) Application of drop test facilities, aircraft, and small-scale rockets on the ground.

Proactive participation of public institutions and private companies in the preparation of materials and developmental experiments must be promoted taking into consideration the required level of microgravity, cost, accessibility to facilities, and availability of public support.

As a matter of course, in order to achieve full-scale industrial and consumer applications, progress in technical development from an overall perspective of utilizing the space environment is required, including the operation of “KIBO” and HTV supply craft for the space station. With regard to basic studies for creating new seeds for industrial applications, there are research areas in which not only space experiments but also experiments on the ground are effective. It is necessary to continue to provide opportunities of microgravity experiments for such areas.

(3) Other possible benefits

Since Japan intends to become a science and technology oriented nation, it is important to nurture human resources in science and technology, but it is difficult to obtain new knowledge without developing new experimental methods. The experience of the step-by-step process of developing an idea, the performance of experiments, through to research application utilizing the special environment of microgravity (including experience in a parabolic flight) would be a valuable method for training people in science and technology. It would also assist young researchers develop the basic technical capabilities necessary for a range of future applications. It is recommended that a strategy for training young people is established by fully utilizing opportunities for microgravity experiments on the ground and unmanned satellites.

In the face of serious concerns about the rapidly aging population and a very low birthrate, it is timely to consider how people can feel happier in their lives. In a company that began the production of space application equipment, jobs related to space applications were given to employees in addition to their conventional jobs. Following success in the new jobs related to the space applications, the morale of employees was greatly strengthened. The slogan, “a science and technology oriented nation,” achieves nothing by itself. It is the spontaneous activities of individuals and private companies that create values.

Prior to the routine operation of full-scale space experiments, creative ingenuity in research and development, including activities in the preparatory stages, will lead to the awakening of public pride in Japan's science and technology.

Acknowledgment

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Abbreviations

•*DAS*	Diamond Air Service
•*ECLSS*	Environmental Control and Life Support System
•*FMPT*	First Material Processing Test
•*GCB-GT*	Granada Crystallization Box-Gel Tube Method (improved GCB)
•*HASTIC*	Hokkaido Aerospace Science and Technology Incubation Center (nonprofit organization)
•*HOA*	Heads of Agency
•*ISPR*	International Standard Payload Rack
•*ISS*	International Space Station
•*JASRI*	Japan Synchrotron Radiation Research Institute
•*JCB*	JAXA Crystallization Box
•*JEM*	Japanese Experiment Module
•*JSF*	Japan Space Forum
•*MGLAB*	Micro-Gravity Laboratory of Japan
•*NMLC*	National Microgravity Laboratory, Chinese Academy of Science
•*S*	Starboard
•*UAB*	University of Alabama at Birmingham
•*USEF*	Institute for Unmanned Space Experiment Free Flyer
•*USERS*	Unmanned Space Experiment Recovery System
•*USML*	United States Microgravity Laboratory
•*USMP*	United States Microgravity Payload
•*X-FEL*	X-ray Free-Electron Laser
•*ZARM*	Zentrum für angewandte Raumfahrttechnologie und Mikrogravitation (Center of Applied Space Technology and Microgravity) (University of Bremen)

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7

Report on the Annual AAAS Forum on Science and Technology Policy

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1 Introduction

Since 1976, the American Association for the Advancement of Science (AAAS) has held an annual Forum on Science and Technology Policy each spring in Washington, DC, as a venue for discussion of US science and technology policy. This year's annual forum, the 31st, was held on April 20 and 21, 2006[1].

The themes of the annual forum are the budgets and hot topics facing the US scientific community. The agenda is set months before the meeting. It is a major science and technology policy forum in the US. This year's program included speeches by Secretary of the US Department of Energy (DOE), Samuel W. Bodman, and Science Adviser to the President, Dr. John H. Marburger as usual.

Since the 9/11 terrorist attacks, the use of military force in Afghanistan and Iraq and major tax cuts have had profound effects on various budgets in the US. Furthermore, with the jump in crude oil prices, interest in energy is also high, and increased longevity has created interest in health insurance for the elderly. Because there is much interest in climate change and other issues related to environmental destruction, the three parallel sessions covered the themes of “energy,” “infectious diseases,” and “homeland security.” In addition, the theme of unethical behavior in science and technology, a topic of much recent interest, was also discussed. Over 400 people attended, including scientists from national institutes, those in charge of the conference, university faculty and scientists, analysts from relevant think tanks, representatives of various academic societies, and people involved with science and technology policy in other countries.

This article will give an overview of forum discussions on R&D-related federal government budget requests for fiscal 2007 (October 2006 through September 2007), energy policy, and ethical problems facing scientists.

2 Opening remarks by the Chair of the AAAS Board of Directors and the Science Adviser to the President

In his welcome address, Dr. Gilbert S. Omenn (University of Michigan and AAAS Board of Directors) referred to several recent articles from Science and Nature on topics such as biotechnology, national energy issues, and chemistry and chemical engineering for sustainability. He outlined the issues that science and technology policy should set out to solve, asking whether it will be by “science,” “technology,” or an all-inclusive research and development domain. He also explained budgetary difficulties surrounding science and technology policy. When the budget for the National Institutes of Health (NIH) doubled in 2001, there was a $550 billion federal budget surplus, but in 2005 there was a $319 billion official deficit ($760 billion on an accrual basis). Additional issues that could influence budgets over the next five years include expenditures on terrorism and homeland security, major tax cuts, and sharp rises in the price of crude oil. Because of these factors, Dr. Omenn said, “Our challenges are tremendous. This meeting is timely![2]"

Presidential Science Advisor Dr. Marburger began by giving an overview of how the process and circumstances surrounding the federal research and development budget have changed over the past 20 years[3]. During President Bush's first term, federal research and development expenditures increased by 45 percent, the highest rate of growth since the Apollo program of the 1960s and early 1970s. Dr. Marburger also explained the American Competitiveness Initiative (ACI)[4] announced by the Office of Science and Technology Policy (OSTP), which he heads, in February 2006 in conjunction with the budget proposal for fiscal 2007. The ACI sets forth a policy of attempting to raise US global competitiveness through federal investment in research, tax breaks for research and development, and human resources development. Almost $6 billion is set aside for this in the fiscal 2007 budget request. The content of the ACI is as follows.

- Federal investment in cutting-edge basic research that focuses on fundamental discoveries to produce valuable and marketable technologies and processes
- Federal government investment in facilities and large-scale equipment that can promote new discoveries and research and development
- A system of education through the secondary level that eliminates dropping out and institutions of higher education that provide world-class education and research opportunities in mathematics, science, engineering, and technology
- Workforce training systems that provide the opportunity to pursue training, and other services necessary to improve skills and better compete in the 21st century
- Rational immigration policies to allow the entry of outstanding scientists from around the world and to improve their residence conditions
- Private sector investment in research and development that enables the translation of fundamental discoveries into marketable technologies
- An optimal system to protect the intellectual property resulting from public and private sector investments in research
- A business environment that stimulates and encourages entrepreneurship through free and flexible labor, capital, and product markets that rapidly diffuse new products and technologies

Dr. Marburger stated that the ACI will ensure the future economic competitiveness of the US. Various aspects of US competitiveness and innovation have been taken up by government and Congress over the past several months. The upcoming Congressional election is probably a factor underlying this.

3 Fiscal 2007 federal government science and technology budget proposals

Four people spoke about fiscal 2007 research and development budget proposals.

First, Mr. Kei Koizumi (Director, AAAS R&D Budget and Policy Program) spoke as follows regarding fiscal 2007 research and development budget proposals. Use of military force and major tax cuts are factors with a profound influence on budgets. Federal research and development expenditure totals $136.9 billion, a 50 percent increase since President Bush took office in 2001. Regarding fiscal 2007 research and development budgets, however, when one looks ahead to the future of federal budget issues, one must take the pessimistic view that research and development expenditure will have to be cut due to the pressure of the budget deficit. As seen in Figure 1, compared with the previous fiscal year, requested budgets are $3.8 billion, up 14.4 percent, for DOE Office of Science; $4.5 billion, up 8.3 percent, for the National Science Foundation (NSF); $12.2 billion, up 8.0 percent, for the National Aeronautics and Space Administration (NASA); and $450 million, up 6.4 percent, for the National Institute of Standards and Technology (NIST). (In the ACI, the core research activities of the key agencies such as the DOE Office of Science, NSF, and NIST are priority targets for budget doubling

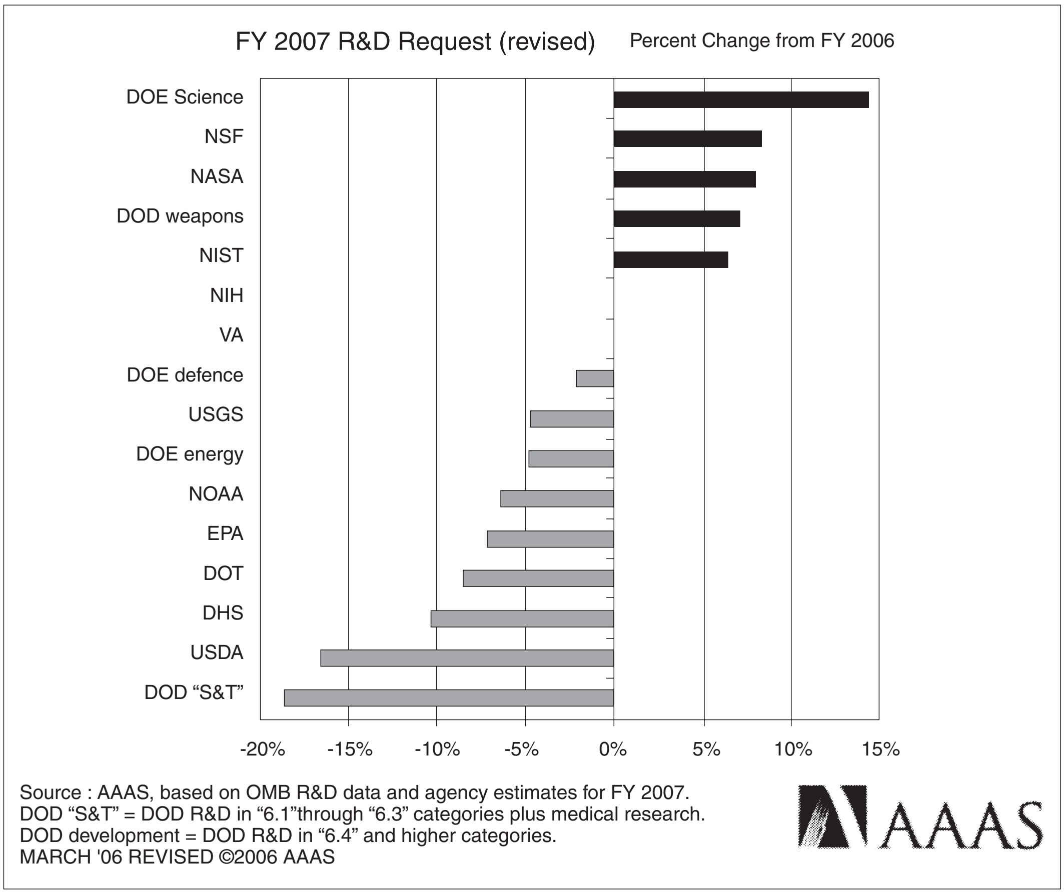


Figure 1 : FY 2007 R&D budget requests from various agencies (compared with FY 2006)

over the next 10 years.) Budget requests for other R&D-related agencies, however, are down from the previous fiscal year. This trend has continued for several years, as some government agencies must necessarily absorb budget cuts of 10-30 percent. Because of this situation, it is unclear whether funding for innovative initiatives now held up by Congress will become available. It is feared that much research will stagnate[5].

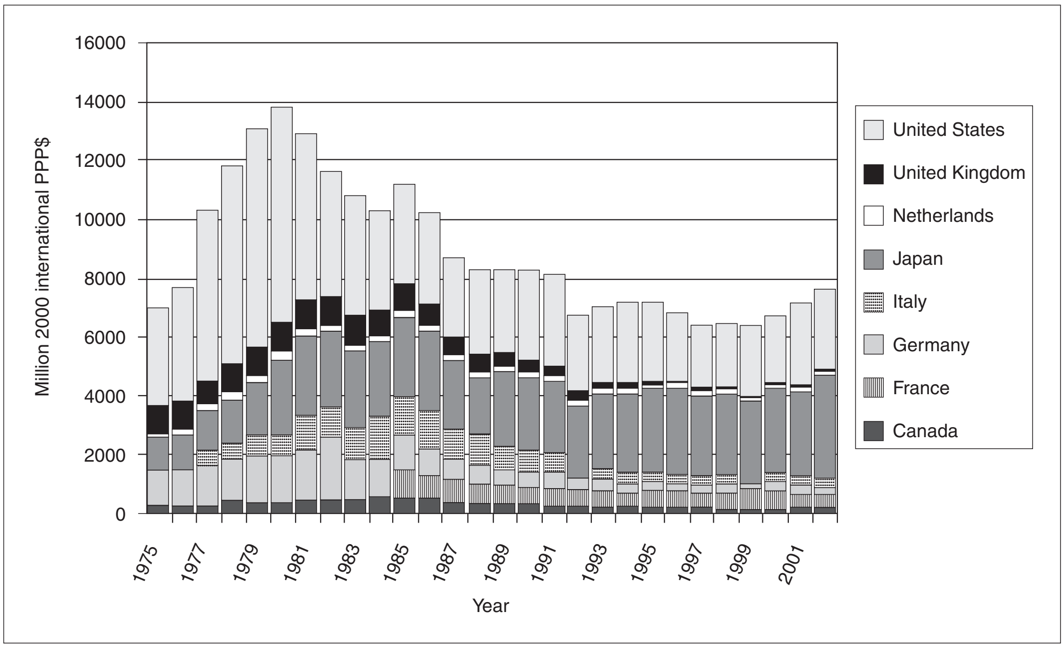
Mr. G. William Hoagland (Office of the Senate Majority Leader) explained that the fiscal 2006 supplemental budget proposal is still being debated in Congress. Because Congress must discuss important topics such as a $92 billion appropriation for hurricane relief and the Iraq war, as well as the implementation of a $70 billion tax cut over five years, the time allocated for discussion of the fiscal 2007 budget is limited. Furthermore, it is clear that phased expansion of long-term costs for Social Security, the healthcare system for low-income people, and the health insurance system for the elderly, growing debt, and other expenditures will continue growing. Unless these factors are offset by a dramatic increase in revenue, the US faces either further large deficit growth or major cuts in the discretionary budget. Defense spending is another source of federal debt. Raising taxes is one way to solve these problems, but that can affect economic growth. There is also concern that the very recent replacement of the top two officials at the Office of Management and Budget (OMB) will also exacerbate the difficult budget environment. In Mr. Hoagland's opinion, it will be very difficult under these circumstances for the fiscal 2007 science and technology budget to be approved as proposed. On the other hand, there are signs that foreign investment in the US may become active and erase debt. Based on the balance of the 2007 budget proposal, some people estimate that the federal government can eliminate all debt for Social Security, the health insurance system for the elderly, and the healthcare system for low-income people by 2035. Mr. Hoagland said that the optimistic view that the political power of voters and political leaders can solve the dysfunctions in the US budget gives rise to such estimates[6].

4 Science and Technology Policy for the Energy Challenges of the 21st Century

In part because gasoline prices in some areas reached $4 per gallon during the conference, there was so much interest in energy issues that the audience could not be contained within the venue. As was remarked in the opening speech, the relevance of environment and energy issues to climate change was one cause of this. During the session, five people made presentations on the theme "Science and Technology Policy for the Energy Challenges of the 21st Century." An overview of their addresses is as follows[7-11].

Obviously, energy policy is a difficult issue when trying to balance the environment and the economy. For example, promotion of nuclear power can look like a successful strategy in terms of satisfying energy demand and reducing CO_2 emissions, but the risks of accidents and terrorism must be considered. Increasing coal-based thermal power means an increase in problems related to CO_2 emissions, air pollution, and health impacts. For renewable energy sources such as wind and solar power, there are still many issues to resolve, such as improving energy efficiency, before they can become major energy sources. In the case of hydrogen energy, there are infrastructure problems and it is still too expensive to be practical. As technologies for renewable energy and energy conservation improve, however, energy consumption and CO_2 emissions relative to GDP can be expected to decrease. Energy policy must always be considered in light of this background. As illustrated in Figure 2, the status of energy-related research, development, and demonstration in various countries is changing, with particularly high growth in Japan. Furthermore, rapid growth in population and energy consumption in China and India means even greater consumption of crude oil, coal, and natural gas, with a corresponding worsening of CO_2-based climate change. According to the Intergovernmental Panel on Climate Change (IPCC), average temperatures in 2100 may be 5°C higher than they are now.

While the Administration's budget requests regarding research on hydrogen energy can once again be categorized as large, Drs. Joseph Romm (Center for Energy and Climate Solutions) and John Holdren (Harvard University) argued that for now it is unrealistic. In other words,



Extracted from John P. Holdren, "The Economic, Environmental, & National Security Challenges of Energy Supply and the Role of Science & Technology in Addressing Them"

Figure 2 : Expenditures by various countries on energy-related research, development, and demonstration

while investment in hydrogen energy R&D remains active, because of infrastructure and supply issues, for now its practical realization, particularly as a fuel for automobiles, is not realistic. The potential for plug-in hybrids was pointed out.

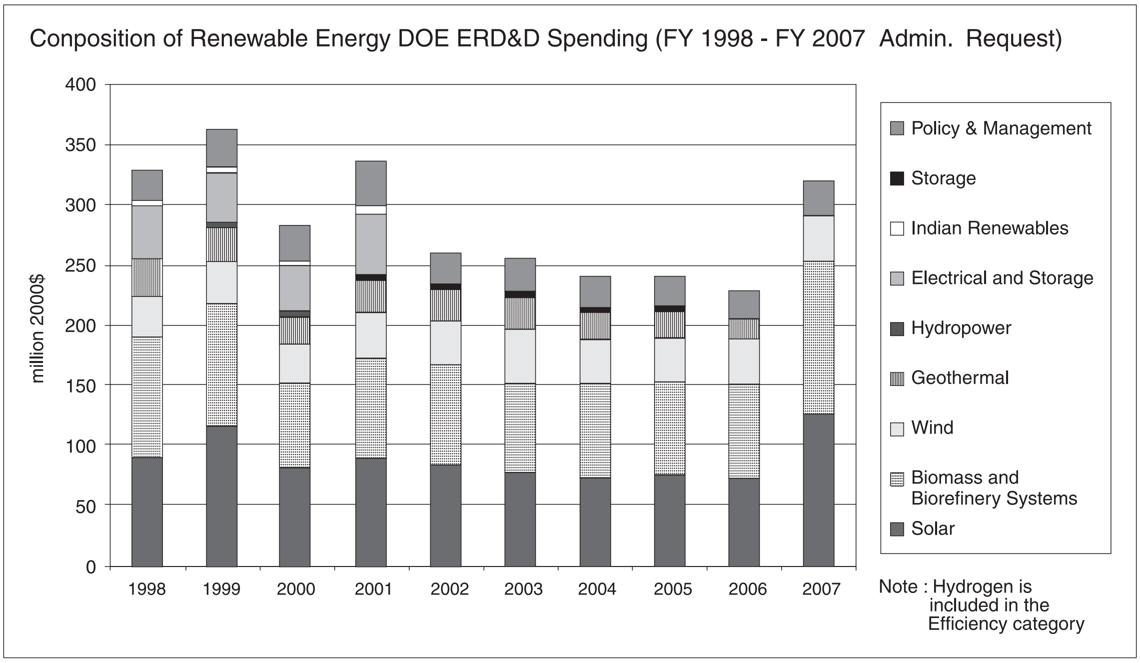
Mr. Jason Grumet (National Commission on Energy Policy) explained the social risks that will be brought about by climate change. Technology is the key to reducing those risks, but who is to invest in that technology is an important question. In order to cut CO_2 emissions, he advocated the necessity of supporting domestic coal gasification, fuel-efficient automobiles, high-performance fuels, and advanced nuclear reactors, as well as doubling the federal budget for research and development to promote demonstration of clean coal technology, nuclear power, and renewable energy technology.

Dr. Kelly Sims Gallagher (Harvard University) described the details of changes in the DOE budget since 1978. The energy research and development budget has been stagnant since about 2001. For the past several years, it has been 1/3 of the 1978 budget. Figure 3 shows budget requests for government investment in renewable energy for each fiscal year. In the fiscal 2007 budget proposal, the budget request for solar power is 75 percent higher than for the previous year and 62 percent higher for biomass. Although it is not shown in Figure 3, the budget request for hydrogen and fuel cells was 23 percent higher. The requested increase in the wind power budget was only 10 percent. On the other hand, the budget request for coal was cut by 5 percent, and research, development and demonstration (RD&D) for geothermal, hydropower, petroleum, and natural gas were cancelled. With the jump in crude oil prices, demand for coal is increasing, but the budget is too small to solve the problem of increased CO_2 emissions related to coal use. Meanwhile, the budget request for the geothermal research program was zero, which Dr. Gallagher explained as an indication of a lack of DOE interest in geothermal research.

5 The situation for scientists

Three people at the forum offered presentations on ethical issues, evaluation, and the integrity of scientists. An overview is as follows[12-14].

Problems related to misuse of research funds, fabrication of data, plagiarism, falsification, and bioethics in the US, Norway, the UK, and South



Extracted from Kelly Sims Gallagher, "The Federal Energy R&D Portfolio"

Figure 3 : DOE budget requests related to renewable energy

Korea were discussed. For example, cases where data was fabricated or falsified when results unsupportive of research plans threatened the continuation or renewal of funding were described. There is often an organizational backdrop to such cases. In order to prevent future occurrences, the purposes, quality, and impartiality of peer review must improve. Furthermore, the scientific community has an obligation to explain matters clearly to the public, and a society in which scientists are well regarded and respected by the public must be built[15]. In fact, the US has been taking measures including passing laws since the 1980s, mainly in the life science field, while in Northern Europe there are committees on improper research that carry out preventative measures and investigate alleged cases of unethical behavior. Similar initiatives are underway in the UK and Germany. It was suggested that because there are cases in which the improper behavior of one scientist has involved other project team members, ethical education for scientists is necessary.

6 Other topics

The forum covered a number of topics that are not currently relevant to Japan (e.g., the emphasis on military research, immigration issues, etc.). The conference coincided with mass demonstrations against a proposed law that would deport as many as 10 million illegal immigrants in the US, which contributed to the formation of the discussion. Like Japan, the US is aging, and many issues related to health insurance were discussed. In addition, one presenter brought up the e-Japan Strategy*1 as an example of how the US should work strategically to construct networks[16].

The author's personal reflections upon attending the forum are as follows.

Policy on the development of fuel cells has been strengthening since the Clinton Administration. In January 2002, the Partnership for a New Generation of Vehicles (PNGV) was canceled and FreedomCAR 9 project began. The goals of PNGV were to raise the international competitiveness of the US automobile industry and to enable application of leading-edge technology to mass-produced automobiles. The goal for fuel efficiency was 80 miles per gallon (33.4 km/l). FreedomCAR is a long-term public-private partnership involving the federal government and the US's "Big 3" (Ford, GM, Daimler Chrysler) that will run through 2010. It carries out high-risk technical development, with particular emphasis on technology related to hydrogen fuel-cell automobiles, and development of component technology applicable to a wide range of vehicles. For this reason, energy projects, particularly on automobile fuels, are ongoing.

Regarding climate change issues, with its emphasis on autonomy and technological response, the US did not sign the Kyoto Protocol, but currently interest is high not just in government or within corporations and universities or among scientists, but also among the public. Regarding CO_2 in particular, the government is actively engaged in addressing the issue. This author's impression is that the US is strengthening its own initiatives regarding every aspect of this issue. One cause of this movement is the increasing number of papers presenting evidence that makes it impossible to deny the connection between industrial activity and climate change. In the opinion of some people, if the major issues other than terrorism were to be listed, climate change would definitely be at the top of the list. The strengthening of the argument that climate change is behind the increasing frequency of major disasters is one reason for the increased interest.

There is no positive movement on budgets for energy conservation, which is an effective policy measure and one that is constantly taken into account in Japan. It may be difficult in the US, where automobiles are the primary means of transportation, but the spread of railways would also reduce CO_2 emissions. Moreover, it is necessary to take steps to change the awareness of individual members of the public regarding energy consumption so that they will believe, as the Japanese do, that "consumption" is "wasteful," while it is necessary at the same time to disseminate energy conservation technology. The energy education for a correct understanding of energy itself is strongly needed. In addition, with prioritized research funding the norm, ethical problems will likely become even greater issues for the scientists who have to deal with it.

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Glossary

*1 e-Japan Strategy

The e-Japan Strategy is based on the Basic IT Strategy. It was adopted as a national strategy on January 22, 2001, at the first meeting of the Strategic Headquarters for the Promotion of an Advanced Information and Telecommunications Network Society (IT Strategic Headquarters). The Basic IT Strategy states that "Japan must take revolutionary yet realistic actions promptly, without being bound by existing systems, practices and interests, in order to create a 'knowledge-emergent society,' where everyone can actively utilize information technology (IT) and fully enjoy its benefits" and "make Japan the world's most advanced IT nation within five years." Priority measures to accomplish this are the building of ultrahigh-speed network infrastructure, widespread dissemination and promotion of electronic commerce, realization of electronic government, and improvement of human resources.

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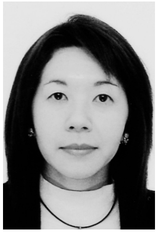

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About SCIENCE AND TECHNOLOGY FORESIGHT CENTER

It is essential to enhance survey functions that underpin policy formulation in order for the science and technology administrative organizations, with MEXT and other ministries under the general supervision of the Council for Science and Technology Policy, Cabinet Office (CSTP), to develop strategic science and technology policy.

NISTEP has established the Science and Technology Foresight Center (STFC) with the aim to strengthen survey functions about trends of important science and technology field. The mission is to provide timely and detailed information about the latest science and technology trends both in Japan and overseas, comprehensive analysis of these trends, and reliable predictions of future science and technology directions to policy makers.

Beneath the Director are six units, each of which conducts surveys of trends in their respective science and technology fields. STFC conducts surveys and analyses from a broad range of perspectives, including the future outlook for society.

The research results will form a basic reference database for MEXT, CSTP, and other ministries. STFC makes them widely available to private companies, organizations outside the administrative departments, mass media, etc. on NISTEP website.

The following are major activities:

1. Collection and analysis of information on science and technology trends through expert network

— STFC builds an information network linking about 2000 experts of various science and technology fields in the industrial, academic and government sectors. They are in the front line or have advanced knowledge in their fields.

— Through the network, STFC collects information in various science and technology fields via the Internet, analyzes trends both in Japan and overseas, identifies important R&D activities, and prospects the future directions. STFC also collects information on its own terms from vast resources.

— Collected information is regularly reported to MEXT and CSTP. Furthermore, STFC compiles the chief points of this information as topics for "Science and Technology Trends" (monthly report).

2. Research into trends in major science and technology fields

— Targeting the vital subjects for science and technology progress, STFC analyzes its trends deeply, and helps administrative departments formulate science and technology policies.

— The research results are published as articles for "Science Technology Trends" (monthly report).

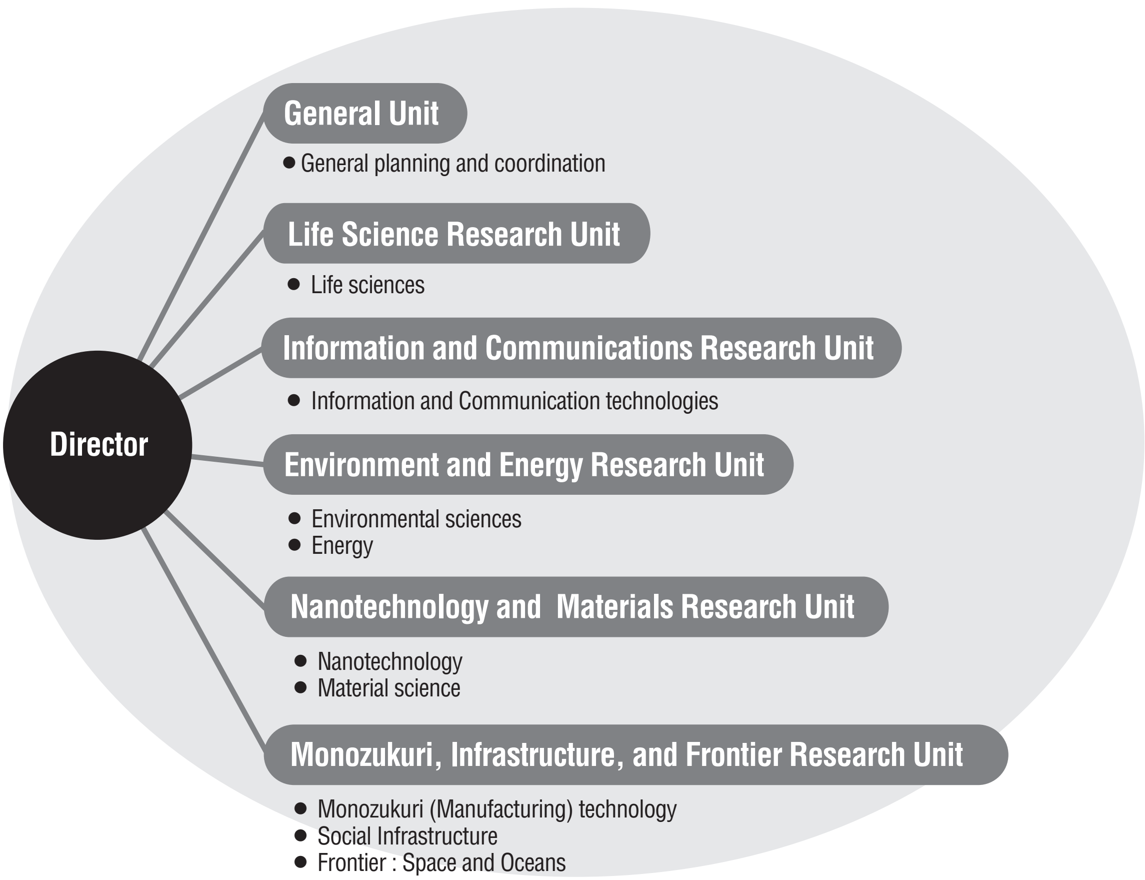
3. S&T foresight and benchmarking

— S&T foresight is conducted every five years to grasp the direction of technological development in coming 30 years with the cooperation of experts in various fields.

— International Benchmarking of Japan's science and engineering research is also implemented periodically.

— The research results are published as NISTEP report.

Organization of the Science and Technology Foresight Center



* Units comprise permanent staff and affliated fellows
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