NIES International Advisory Board 2015

Preparatory Reference Materials
（Outline）

June 2015
National Institute for Environmental Studies

Contents

I Outline of NIES

1 Histrory of the Institute

During the 1950s and 1960s, Japan experienced serious environmental pollution problems accompanying rapid economic growth. The Environment Agency was established in 1971 as part of the Japanese government to develop measures to counteract serious problems associated with environmental pollution, such as Minamata disease, which was caused by poisoning from organic mercury in factory wastewater, and chronic bronchitis and asthma caused by sulfur oxides from factories in large industrial complexes. Understanding that research on environmental sciences was necessary and could address public needs, the Environment Agency established the National Institute for Environmental Studies (NIES) in Tsukuba Science City, about 50 km north of Tokyo, in 1974. It is now Japan's primary institute for comprehensive research in environmental science.

During the two decades following the establishment of NIES, rapid technological progress, structural changes in industry, and lifestyle changes, created additional issues for environmental science to confront. Moreover, global environmental problems such as climate change; depletion of the stratospheric ozone layer; acid deposition; destruction of tropical rain forests; and desertification, attracted greater concern worldwide. NIES subsequently underwent a major reorganization in 1990, including the establishment of the Center for Global Environmental Research, to enable it to conduct more intensive research on conservation of the natural environment and on global environmental changes and their effects.

January 2001 saw the transition of the Environment Agency into the Ministry of the Environment as part of structural changes within the Japanese government, and the establishment of a Waste Management Research Division at NIES. That year also marked the establishment of NIES as an Incorporated Administrative Agency, giving it a degree of independence from the national government. The change in the administrative status of the institute allows more prompt and flexible responses to societal demands. Concurrently, NIES prepared a five-year plan (2001–2005) in line with the objectives of the Ministry of the Environment.

2 The Third NIES Five-year Plan

Following the second five-year plan (2006-2010), the third five-year plan (2011–2015) was adopted in 2011. Eight fundamental fields of environmental research – global environment; material cycles and waste management; environmental risk; regional environment; environmental biology and ecosystems; environmental health; social and environmental systems; and environmental measurement and analysis - are identified, and the research centers to be responsible for these areas are specified (Fig. 1).

At the same time, we designate ten research programs for those topics which we consider to require an urgent or priority response (Priority Research Programs), or research which is issue-driven or requires the efficient deployment of research resources in order to be addressed (Advanced Research Programs), with research now developing with an emphasis on the tying-up of these different fields (Fig. 2). Research is carried out under our designated research programs and we also actively pursue ties with many institutions both in Japan and overseas.

We are further involved in the maintenance of medium- to long-term initiatives in step with the sustainment and furtherance of environmental research. This includes maintaining the equipment and facilities needed for initiatives such as global environmental monitoring - including that by satellites - and those initiatives that use ground-based systems, commercial airlines, and shipping to monitor and analyze the global carbon cycle (Fig. 2). Other examples of such initiatives include the maintenance of a greenhouse gas (GHG) emissions inventory; the storage and provision of environmental specimens; the maintenance of reference laboratory functions; and the creation and updating of many kinds of environmental databases. Another important topic at NIES is the advancement of research using the NIES Supercomputer. Also, the Japan Environment and Children's Study (JECS) is continuing in a satisfactory manner.

Research activities to respond to and recover from the Great East Japan Earthquake have been ongoing since the direct aftermath of the disaster (Fig. 2). Intermediate outcomes of this research have been summarized as "An Overview of Research on Disaster Environment" and are available from our homepage. In March 2013 the five-year plan was revised following a directive of the Minister of the Environment. Our

mid-term objectives were modified to facilitate effective, integrated environmental emergency research. NIES is currently preparing the establishment of a branch in Fukushima Prefecture. As part of this initiative the following three research programs were also established: (1) Environmental Recovery Research Program (2) Environmental Renovation Research Program and (3) Environmental Emergency Management Research Program, in order to further contribute to recovery and environmental creation in Fukushima.

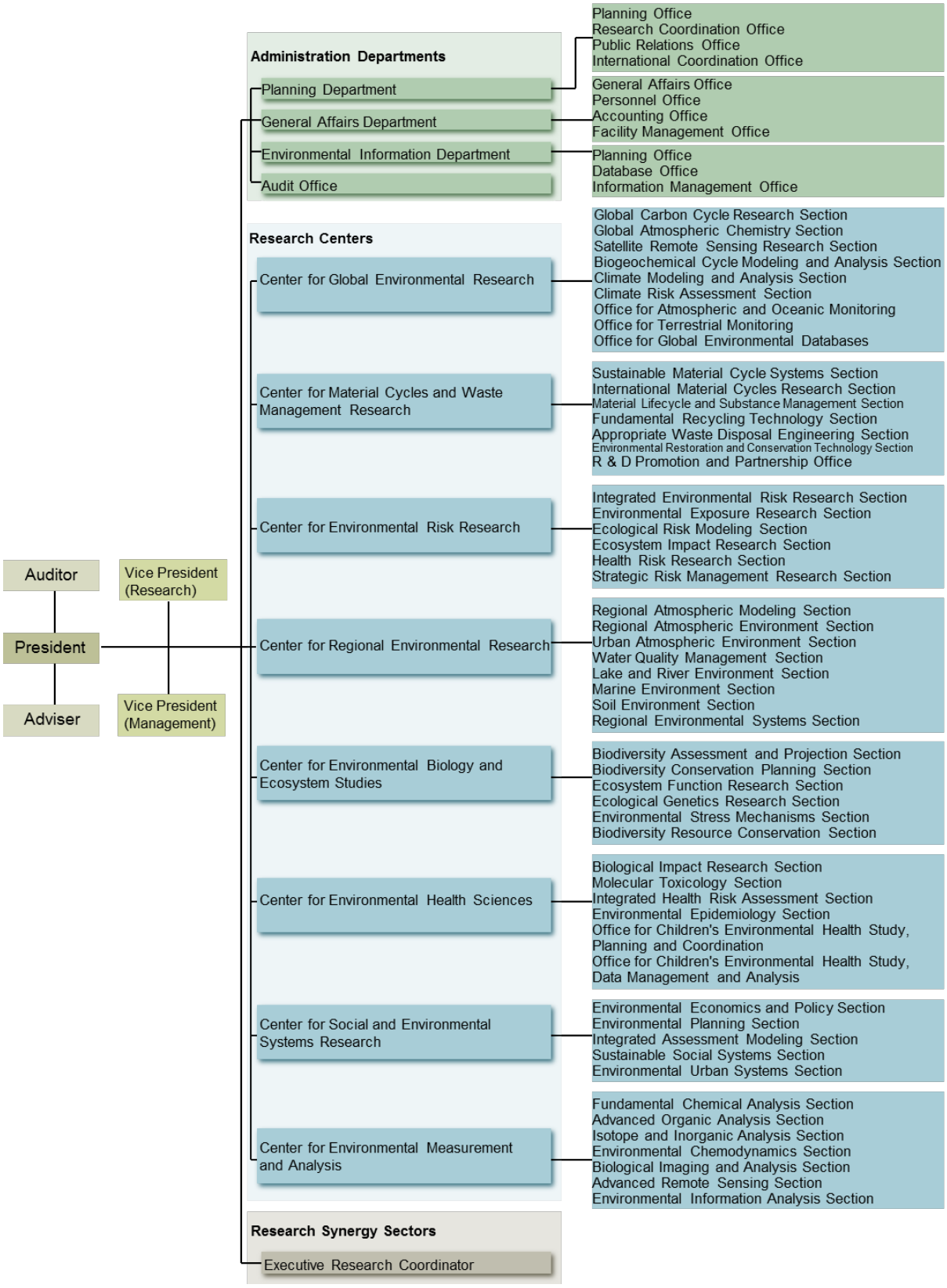


Fig. 1 Organization

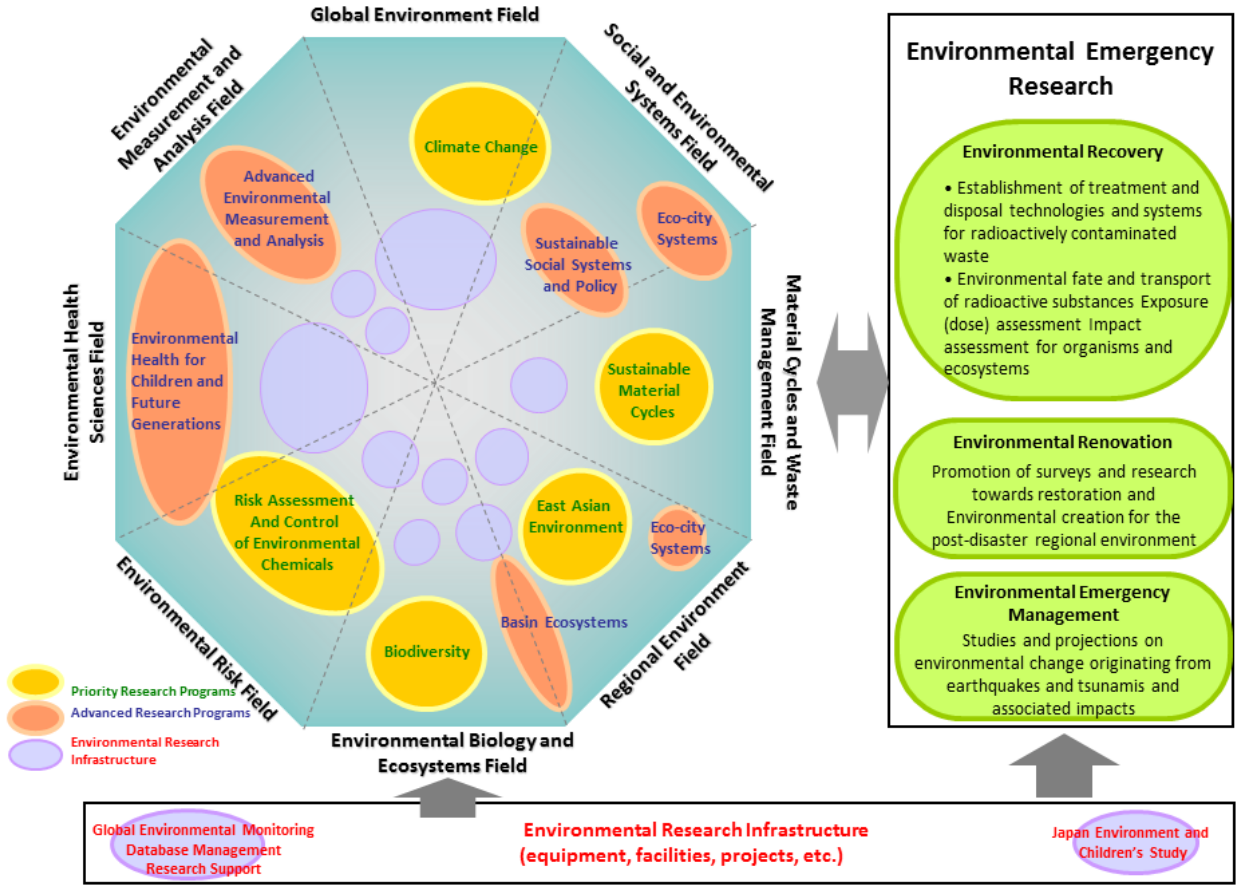


Fig. 2 Overall research structure

3 Human Resources, Budget, and Facilities

3.1 Human Resources

As of April 1, 2015, the total number of NIES regular permanent staff is 274 (Fig. 3), and there are 619 non-permanent researchers (Fig.4). Most (96%) researchers at NIES hold doctorates covering wide-ranging research fields (e.g., physics, chemistry, biology, engineering, agricultural sciences, medical sciences, and law) (Fig. 5). NIES also have accepted many visiting researchers and collaborative researchers as well as research students to facilitate and expand our research activities (Fig. 6).

Administration Departments	:	58	
Research Centers	:	211	(6)
Executives	:	5	
Total		274	(6)

Notes:
1. Data is as of April 1, 2015.
2. Figures in parentheses indicate number of non-Japanese.

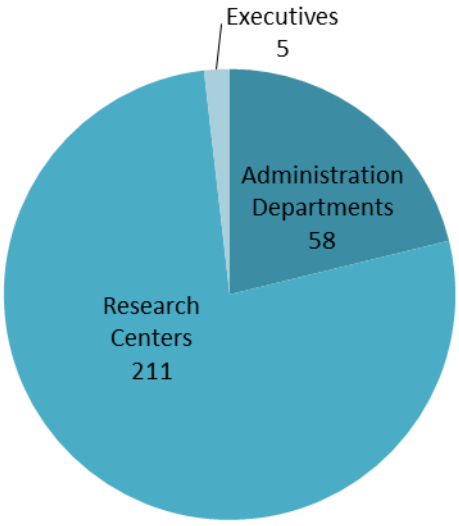


Fig. 3 Permanent staff breakdown

Fellow	:	18	
Research Associate	:	90	(21)
Junior Research Associate	:	14	(4)
Research Assistant	:	29	(5)
Specialist	:	198	(6)
Assistant Staff	:	261	(1)
Senior Staff	:	9	
Total		619	(37)

Notes:
1. Data is as of April 1,2015.
2. Figures in parentheses indicate number of non-Japanese.

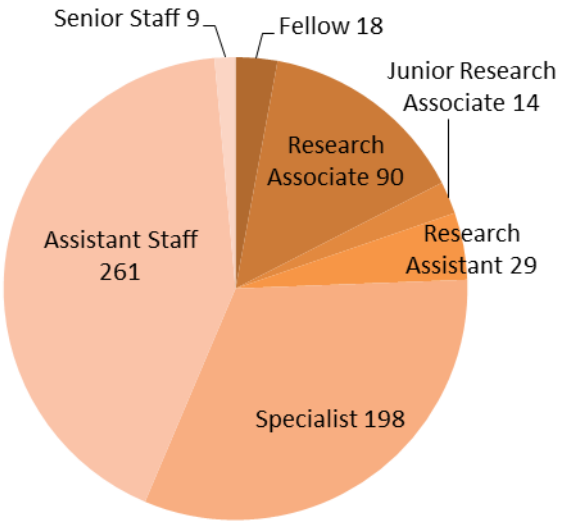


Fig. 4 Contract Staff Breakdown

Basic Sciences (Physics, Chemistry, Biology)	:	79	38.54%
Engineering	:	68	33.17%
Agricultural Sciences	:	34	16.59%
Medical Sciences	:	11	5.37%
Pharmaceutical Sciences	:	5	2.44%
Fisheries Sciences	:	1	0.49%
Economics	:	2	0.98%
Sciences	:	3	1.46%
Law	:	1	0.49%
Veterinary Medicine	:	1	0.49%
Total		205	

Notes: Data is as of April 1,2015.

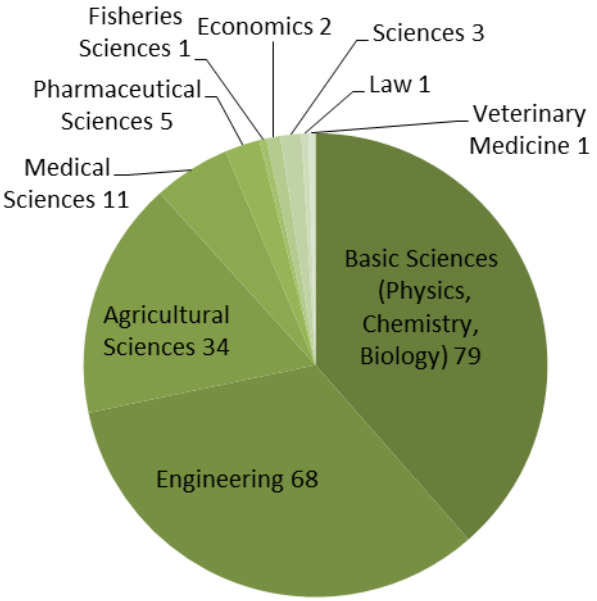


Fig. 5 Fields of researcher expertise

Visiting Researchers	256	(9)
Research Students	58	(13)
Collaborative Researchers	89	(28)
Total	403	(50)

Notes:
1. Data is the total number accepted in FY2014.
2. Figures in parentheses indicate number of non-Japanese.

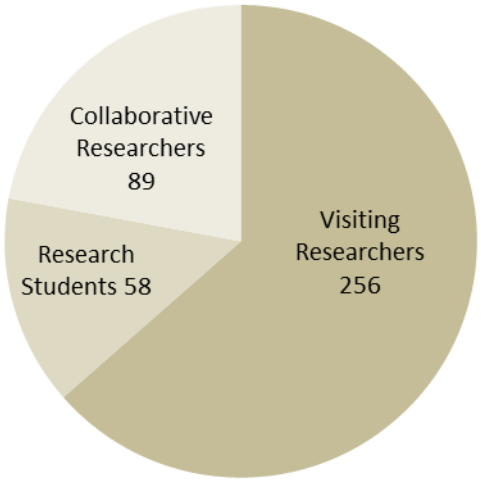


Fig.6 Visiting and Collaborative Researchers and Research Students

3.2 Budget

The total budget for the third five-year plan (2011-2015) is 88,264 million yen (e.g., 16,018 million yen for FY2015) (Table .1). The details of the revenue and expenditure are listed in Table 1.

3.3 Facilities

The NIES headquarters in Tsukuba cover an area of around 23ha, and includes approximately 30 facilities such as the Main Research Buildings (I, II, and III), Climate Change Research Hall, Research Laboratory of Material Cycles and Waste Management, and Environmental Risk Research Laboratory (Fig. 7).

In addition, NIES has a number of external experimental and research facilities to facilitate the furtherance of its activities. For example, Kasumigaura Lakeside Laboratoy located on shores of lake Kasumigaura close to Tsukuba is used for researching the causes, and subsequently the means of prevention, of eutrophication in inland waterways (Fig. 8). Global Environmental Monitoring Stations, which observe atmospheric compositions of greenhouse gases, suspended particulate matters, and weather factors, have been built on Hateruma island located on the southernmost inhabited island of Japan and Cape Ochi-ishi located at the furthest point northeast in Japan, in order to monitor the baseline atmosphere (atmosphere which has been subject to minimal impacts of human activities) (Fig.8).

Table 1 Budget for the third five-year plan (in millions of yen)

Category		2011-2015 budget (5 years)	Fiscal 2015 budget
Revenues	Grant for operating costs	68,519	12,051
	Subsidies for facilities	1,540	330
	Commissioned work	18,057	3,611
	Others	147	25
	Total	88,264	16,018
Expenditures	Project costs	50,918	8,581
	Facility improvements	1,540	330
	Expenses for commissioned work	18,057	3,611
	Personal expenses	15,516	3,050
	General administrative expenses	2,232	445
	Total	88,264	16,018

Note: The budget for each annual work plan will be requested and decided each fiscal year, based on the five-year Plan.

Fig. 7 Layout of NIES headquarters

Fig. 8 External view of observation sites: Kasumigaura Lakeside Laboratory (left), Hateruma Global Environmental Monitoring Station (center) and Cape Ochi-ishi Global Environmental Monitoring Station (right)

II Center for Global Environmental Research

Hitoshi MUKAI, Director, Center for Global Environmental Research

1 Overview of research outcomes

1.1 The third NIES five-year plan

Conservation of the global environment is essential; and an issue of the utmost concern for all humankind. Climate changes, including, in particular, global warming caused by the huge emissions of anthropogenic greenhouse gases (GHGs), and depletion of the ozone layer caused by anthropogenic emissions of halogenated organic substances, are having serious and long-range impacts on the entire ecosystem of the Earth and on human life. To create a society which is sustainable over long periods of time, it is therefore important to consider the medium- and long-term consequences of ongoing human activities.

As part of the research on these issues, we conducted several studies that focused, in particular, on atmospheric observations of GHGs over the Asian–Pacific region; clarification of the relationship between variations of GHG concentrations and climate from the past to the future; assessment of risks associated with climate change; and international measures to adapt to and mitigate global warming.

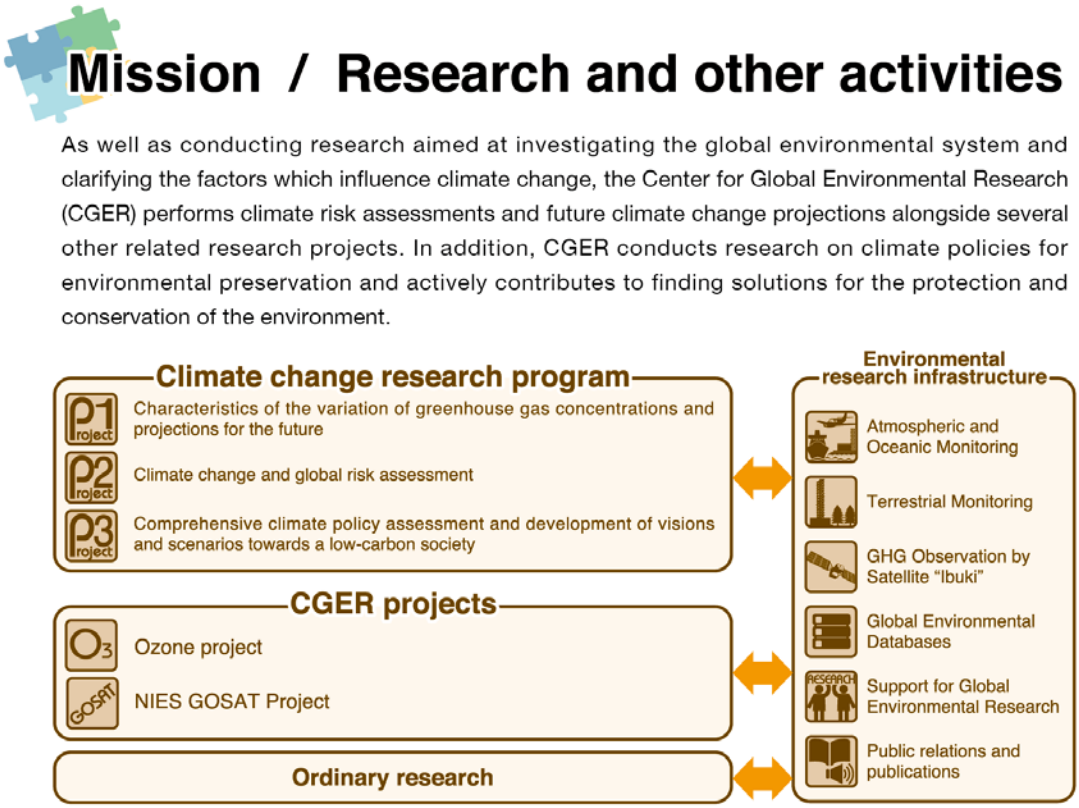


Fig. 1 Overview of studies in CGER

Furthermore, we have conducted long-term monitoring of the global environment and have produced a Global Environmental Database (GED). Because satellite measurements of CO_2 and CH_4 are very important elements of monitoring initiatives, we have continued to develop a monitoring system that uses the Greenhouse gases Observing SATellite (GOSAT, GOSAT-2) in addition to other platforms such as ground stations, cargo ships and aircraft. We expect that the use of GOSAT data will result in new insights on the global distribution of GHGs.

Other activities include our support for domestic and international research concerned with the global environment. We also facilitate studies of other fundamental issues of relevance to the global environment, such as development of new technologies for measurement and modeling of the future earth.

The following activities comprise the principle components of our studies:

1) GHG observations in both the Asian–Pacific region and on a global scale. These are conducted in the context of both long-term monitoring and the Climate Change Research Program. A major goal of this research is clarification of characteristics in the long-term trends of GHG concentrations in this region and the mechanisms responsible for temporal variations.
2) Development of climate modeling techniques. We will endeavor to improve the precision of estimates on the influence of global warming and future projections of climate change.
3) Assessment of the risks associated with climate change to provide scientific information that can help to guide climate policy.
4) Provision of scientific information about adaptation to and mitigation of global warming in the context of international relationships.
5) Creation of three forms of research infrastructure: long-term monitoring; databases; and infrastructure in support of global environmental research activities, including international offices.

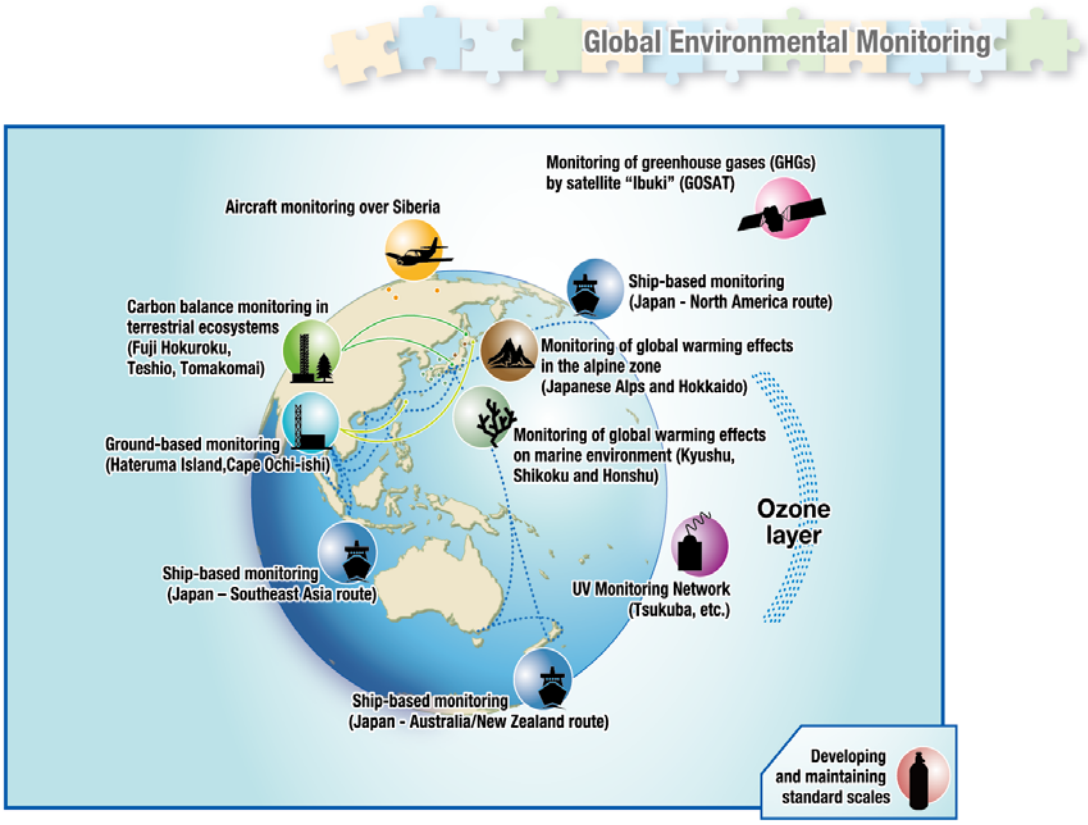


Fig. 2 CGER monitoring platforms

1.2 Research, other outcomes, and self-assessment under the third NIES five-year plan

1.2.1 Research programs: the Climate Change Research Program

Research under the Climate Change Research Program is conducted in the form of three projects: Project 1, Observational studies of GHGs and other atmospheric constituents; Project 2, Study of future climate change and associated risks at a global scale; and Project 3, Study of climate change policies and pathways toward a low-carbon society.

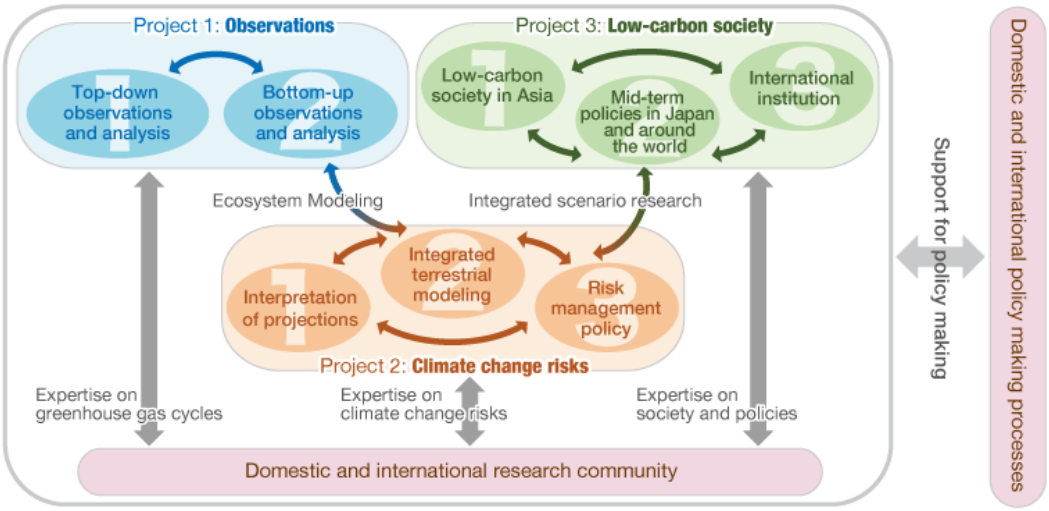


Fig. 3 Overview of Climate Change Research Program and the relationships among the components of the program.

1.2.1.1 Project 1: Characteristics of the variations of greenhouse gas concentrations and projections for the future

Project 1 has aimed to evaluate and predict vertical profiles and temporal patterns in the distributions of the concentrations of atmospheric GHGs, particularly CO_2, CH_4, and CFCs. To estimate emissions and sinks of these gases to a high degree of accuracy, essential technologies have been developed for "top-down approaches" based on atmospheric observations and inverse models, and for "bottom-up approaches" using ground observations and process models for scale-up.

For top-down approaches, observation platforms have been established based on use of GOSAT, airplanes, ships, and ground stations to capture the long-term trends of atmospheric GHG concentrations. Inverse models have been improved to better evaluate the spatial and temporal distributions of surface fluxes in Siberia, Southeast Asia, China, and Japan.

For bottom-up approaches, the accuracy and reliability of scaling-up estimates have been tested using different types of process models. An intercomparison between top-down and bottom-up approaches has been started to improve our understanding of the current situation and future trends in Asian and global distributions of GHGs.

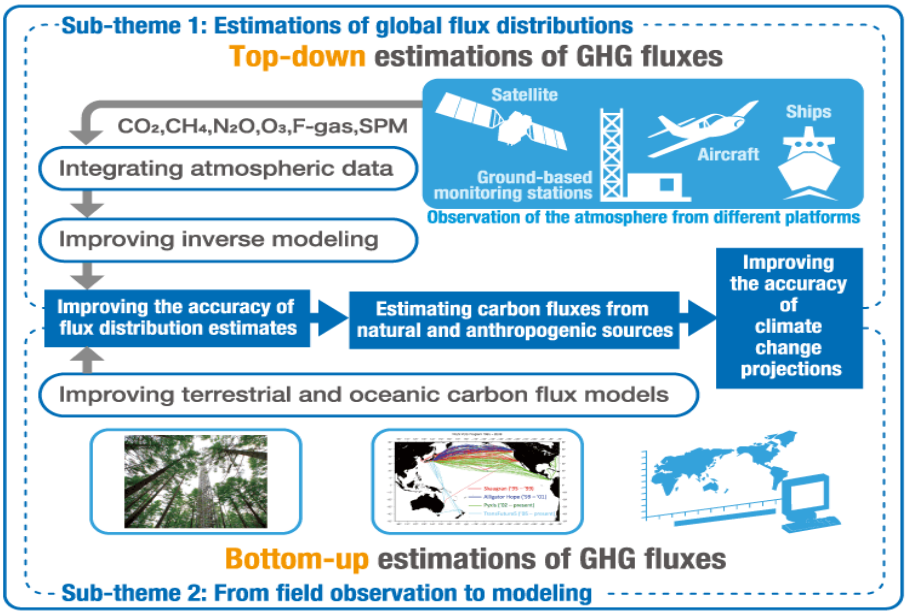


Fig. 4 Framework of Project 1.

1.2.1.2 Project 2: Climate change and global risk assessment

In Project 2, a set of ensemble climate model experiments has been constructed and analyzed to quantify and understand the range of uncertainty of climate change projections (Sub-theme 1). We have also studied "pattern scaling" methods and have achieved a better understanding of their scenario dependence. Moreover, we have improved the performance of our climate model with the goal of contributing to the IPCC Sixth Assessment Report (AR6).

In our analysis of models, we have integrated, inter alia, water resoures, ecosystems, and land-use (Sub-theme 2). We have made some progress on model integration, and by conducting and analyzing experiments on future climate impacts and adaptation with each model for a single sector, we have made contributions to international model intercomparison projects.

With respect to global climate change risk management (Sub-theme 3), we have made some progress on framing risk management and comprehensive characterization of risks, and we have improved an integrated assessment model and analyses using it. We are planning to present a set of risk management strategies as part of a collaboration with experts in other institutes and universities in Japan as part of the 10th Strategic Research and Development area (S-10) of the Environmental Research and Technology Development Fund, the Ministry of the Environment (MOE), Japan.

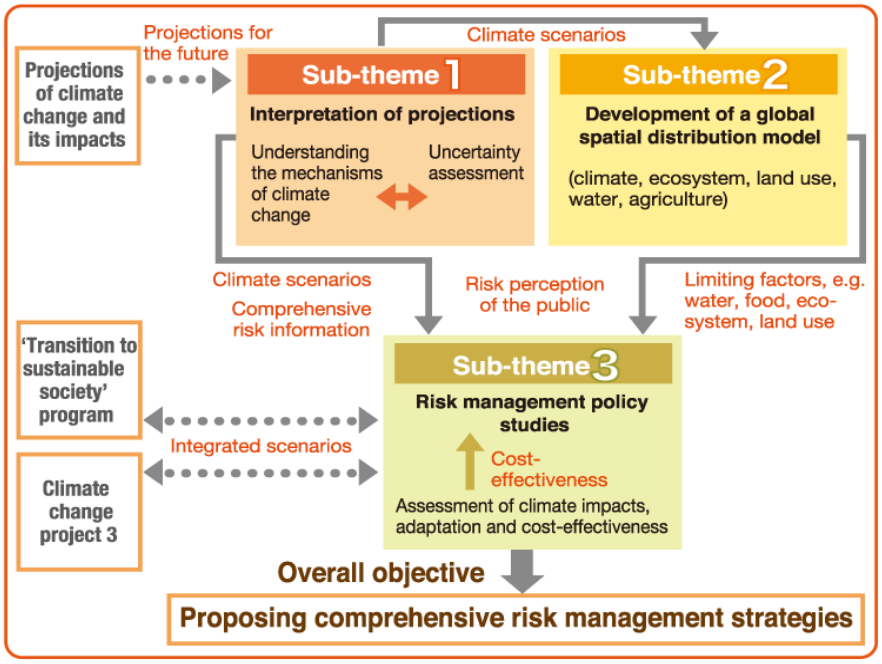


Fig. 5 Framework of Project 2.

1.2.1.3 Project 3: Comprehensive climate policy assessment and development of visions and scenarios leading to a low-carbon society

Project 3 has aimed to provide scientific knowledge from the perspectives of modeling and analysis, scenario development, and negotiation processes towards the achievment of a low-carbon society at the local, national, regional, and global levels.

In the research on development of scenarios and implementation strategies for a low-carbon society in Asia (sub-theme 1), we carry out, using various methods, quantitative and qualitative investigations of the socioeconomic trends, policies, and institutional systems that are necessary for achieving a low-carbon society in Asia.

In the quantitative assessment of climate change mitigation policies in Japan and around the world (sub-theme 2), we develop various types of integrated assessment models for Japan and the world, and we quantify the energy supply and demand and greenhouse gas emissions of future societies. We also estimate

the potential for emission reductions and the costs of countermeasures, both in Japan and in different regions of the world.

As a part of the study of international institutions and negotiation processes for the development of a low-carbon society (sub-theme 3), we investigate and analyze the international negotiation processes under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, identify those factors that hinder the negotiation process, and investigate the pathways that lead to international agreements.

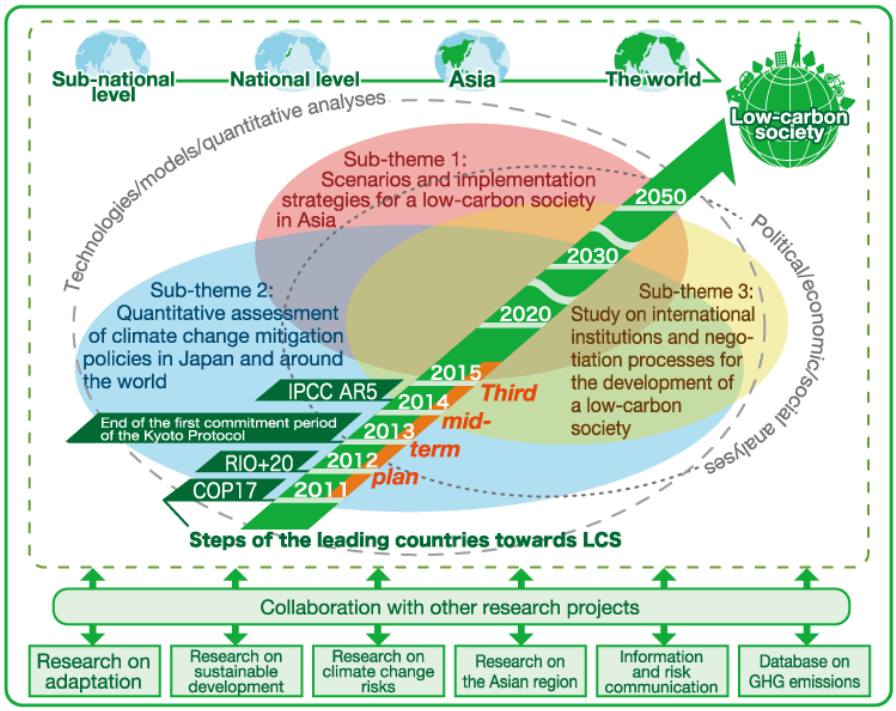


Fig. 6 Framework of Project 3.

1.2.2 Environmental Research Infrastructure

1.2.2.1 Long-term monitoring of GHGs and other trace gases

Atmospheric GHGs (e.g. CO_2, CH_4, and N_2O) and other chemical species (CO, NOx, and SOx) are monitored from various platforms to determine the long-term trends in the concentrations of these gases and their spatial distributions. We have two ground-based stations, one at Hateruma Island (more than 1000 km southwest of the Japanese mainland) and the other at Cape Ochi-ishi (in northeastern Hokkaido). Commercial ships operating between Japan and Australia, New Zealand, North America, and Asian countries are used to observe the latitudinal or longitudinal distributions of GHGs and the partial pressures of CO_2 in the surface waters of the Pacific. Routine sampling is conducted from aircraft over three sites in Siberia to measure the vertical distributions of GHGs. Ultraviolet (UV) type A and B radiation at ground level are monitored, and real-time UV indexes obtained at 15 sites in Japan are made available to the public via our homepage.

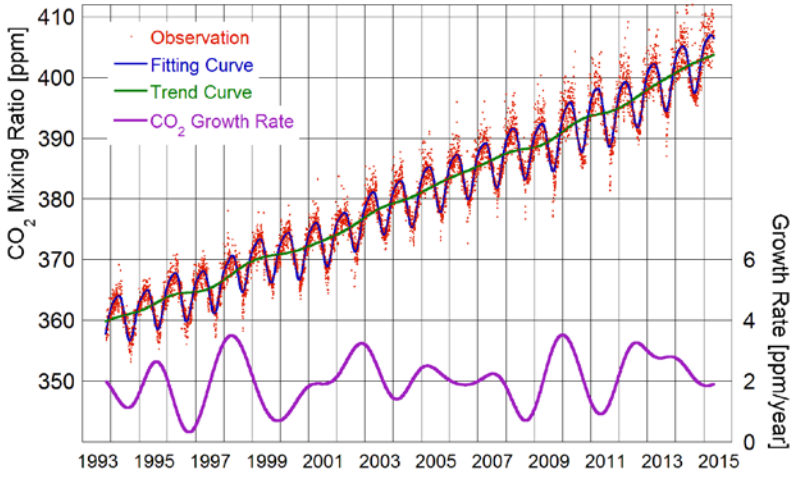


Fig. 7 Time series of CO_2 mixing ratios at Hateruma Station. Red dots, observation data; blue sold line, fitting curve; green solid line, trend curve; purple solid line, growth rate

The trend curve for the CO_2 mixing ratio at Hateruma exceeded 400 ppm at the end of 2013 (Fig. 7). The CO_2 mixing ratio has increased by 40 ppm over the past 20 years; this corresponds to a 10% increase. The growth rate of the CO_2 mixing ratio has also increased, from 1.6 ppm/year in the 1990s to 2.3 ppm/year after 2010. The recent interannual variations in the growth rate have shown large variability, with a 2- to 3-year cycle, but there has been almost no correlation with the El Niño–La Niña cycle.

1.2.2.2 Carbon dioxide flux monitoring of terrestrial ecosystems

To determine how they respond to climate change and how those responses depend on the process of recovery from natural and artificial disturbances, long-term monitoring of carbon, water, and energy exchange between larch forests and the atmosphere, as well as of biological processes in these forests, has been conducted in Japan. The Fuji–Hokuroku Flux Observation Site is located in a mature larch forest at the foot of Mt. Fuji. Clear seasonal changes in carbon uptake have been observed here and are related to the phenology of the larch trees. Continuous observation of the fluxes of CH_4, one of the most influential GHGs, have also been conducted over the forest canopy at the Fuji–Hokuroku Site via application of the relaxed eddy accumulation (REA) method. The REA method was developed for gases such as CH_4 and for biogenic volatile organic compounds that could not be measured in the air at the high frequencies needed to apply the covariance measurement technique.

At the Teshio Carbon Cycle and Larch Growth Experiment Site in Hokkaido, 14 ha of forest was clear-cut, and larch saplings were planted in 2003. The clear-cutting resulted in decreased photosynthesis and increased decomposition of dead roots and soil organic carbon. In 2014, eleven years after the clear-cutting and planting, the forest was a weak sink of CO_2. The effect of disturbances such as clear-cutting on the long-term trend of net carbon balance was larger than that of climatic variations.

1.2.2.3 Global Environmental Database

Since the early 2000s, the Office for the Global Environmental Database at the Center for Global Environmental Research (CGER) has been constructing and providing databases on several topics related to Earth's global environment. There are five major tasks in this project: (1) construct, maintain, and renew the database servers that provide our databases; (2) construct databases and provide the public and researchers with data gathered by the Earth environmental monitoring project at NIES; (3) construct databases on social environmental science related to global warming; (4) develop convenient tools to analyze Earth environment datasets; and (5) achieve international cooperation on database-related issues.

In 2013, the homepage of the Global Environmental Database (GED) was revised to provide quality-controlled open data on global environmental monitoring projects in original format or National Aeronautics and Space Administration Ames format. The GED covers multiple environmental issues, including global warming (GHG observations, carbon sources or sinks, material flows, and the effects and measurement of global warming); atmospheric environmental science (the stratospheric ozone layer, UV, air pollution, and acid rain); marine and freshwater environmental science; biology; satellite remote-sensing and geographic information systems; and other related topics. We have renewed the Real Time Data menu of the GED to highlight the availability of the most up-to-date information to users, and we have added an Analysis Support menu to provide offline tools and online applications for data analysis and visualization (e.g., for trajectory analysis).

1.2.2.4 Greenhouse Gas Inventory Office of Japan

The Greenhouse Gas Inventory Office of Japan (GIO) was established in July 2002 at CGER to perform various tasks and implement various projects, including the compilation of a national GHG inventory (GIO's primary mission) and other tasks and projects as listed below. Tasks and projects at the national level are: (1) annually preparing Japan's national GHG inventory, (2) providing support for the technical review of the national GHG inventory of Japan, and (3) providing support for inventory-related policies and actions.

Japan's total greenhouse gas emissions in fiscal year (FY) 2013 were 1408 million tons of carbon dioxide equivalents (Mt CO_2 eq). Total emissions increased by 1.2% when compared to those of FY2012. The main factor responsible for the rise in emissions in FY2013 as compared to FY2012 was the increase of energy-origin CO_2 emissions, which was caused by an increase of coal consumption in thermal power generation and increased consumption of electricity or petroleum products in the Commercial and Other

sectors. The main factors responsible for the rise in emissions in FY2013 compared to FY2005 were the rise in hydrofluorocarbon emissions from refrigerants following their substitution in place of ozone-depleting substances and the increased energy-origin CO_2 emissions caused by the increased fossil fuel consumption accompanying the increase of thermal power generation.

International tasks and projects include: (1) convening the Workshop on Greenhouse Gas Inventories in Asia (WGIA), (2) participating in an international initiative to facilitate the improvement of national GHG inventories, and (3) contributing to the technical review of national GHG inventories of other Parties as reviewers for the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. Since 2003, the Ministry of the Environment of Japan and the GIO have organized the Workshop on Greenhouse Gas Inventories in Asia, which has helped Asian countries develop and improve their GHG inventories in cooperation with participating countries such as Cambodia, China, India, Indonesia, Japan, the Republic of Korea, Lao PDR, Malaysia, Mongolia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam.

1.2.2.5 NIES GOSAT Project

The GOSAT Project is a joint effort of MOE, Japan, the Japan Aerospace Exploration Agency (JAXA), and NIES. The NIES GOSAT Project has carried out its tasks by related CGER researchers and dedicated contract members. The role of this project is to develop GOSAT data retrieval algorithms and inverse-modeling techniques for estimating carbon fluxes; to establish a computer system, the GOSAT Data Handling Facility (DHF), for data processing, re-processing, data storage, and data distribution to the registered researchers and general users; to disseminate information about the GOSAT Project via its homepage; and to publish the GOSAT Newsletters in Japanese and in English. We have published 31 issues in the six years since 2009.

We have continued to process GOSAT data at the NIES GOSAT DHF, and we have continued online distribution of GOSAT data products to researchers and the general public via the GOSAT User Interface Gateway (GUIG, http://data.gosat.nies.go.jp/). The latest product version of GOSAT TANSO-FTS (Fourier Transform Spectrometer) SWIR (Short Wavelength Infra-Red) band Level 2 XCO_2 and XCH_4 column concentrations, which are the major products of this project and have been processed and provided via the GOSAT DHF, is Ver. 02.21 (Fig. 8) for the entire past observation period. These products have been validated with various methods, including Total Carbon Column Observing Network data. The GOSAT Level 4 data products are also essential outputs of the project. They are monthly regional CO_2 and CH_4 net sources and sinks (fluxes), which are estimated with inverse modeling using GOSAT Level 2 data and ground-based monitoring data, and model-simulated 3-dimensional gas concentrations using the GOSAT regional carbon fluxes. The project has provided Level 4 CO_2 products (Ver. 02.03) and Level 4 CH_4 products (Ver.01.02) via the GUIG.

NIES GOSAT Project also serves as the secretariat of GOSAT RA (Research Announcement) activities. We have established and managed the GOSAT RA selection and evaluation committee. As for the GOSAT RA Principal Investigators (PIs) meetings, we have held a meeting once a year, and a total of seven meetings have been held since FY2008. Moreover, a further role of the NIES GOSAT Project is to serve as the secretariat of GOSAT Science Team, who have held more than 100 times since FY2004.

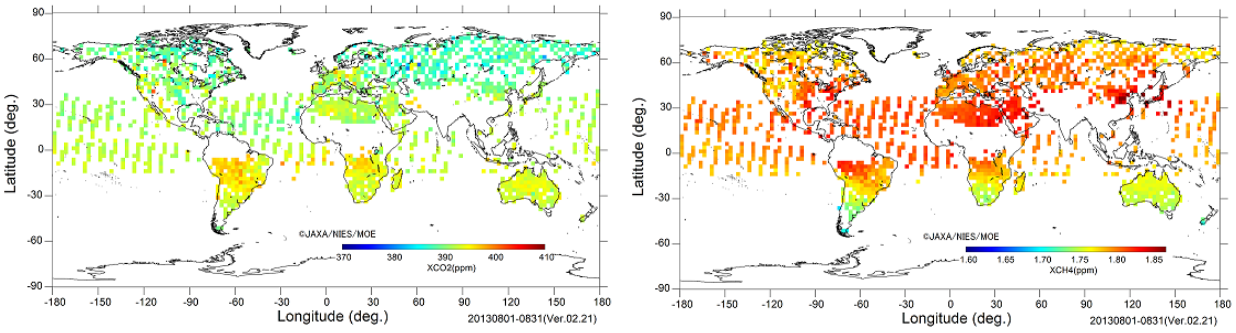


Fig.8 GOSAT TANSO-FTS SWIR Level 2 data (version 02.21)
Shown in the figure are samples of XCO_2 (left) and XCH_4 (right) column concentrations averaged in 2.5° grids for August 2013 (JAXA; MOE)

The GOSAT project website and GUIG continue to be maintained, and we have updated important information on GOSAT data products for GOSAT data users.

1.2.2.6 NIES GOSAT Project 2

GOSAT-2 is the successor to GOSAT and is being developed by the MOE Japan, JAXA, and NIES. Its major observation targets are carbon dioxide, methane, carbon monoxide, and black carbon in the atmosphere. The launch of GOSAT-2 is scheduled for FY2017.

The NIES GOSAT-2 Project was started in FY2013. Its major responsibilities are as follows:

a) Research on processing and validation of GOSAT-2 data,
b) Development and operation of the ground data system for processing, archiving, and distributing GOSAT-2 data,
c) Preparation and operation of the GOSAT-2 data validation plan,
d) Research on applications of GOSAT-2 data in carbon cycle science and climate change-related policies,
e) Outreach activities for GOSAT-2, and
f) Procurement and maintenance of computing facilities necessary for processing, archiving, and distributing GOSAT-2 data and for research using GOSAT-2 data.

Activities and achievements of relevance to GOSAT and GOSAT-2 are being introduced at various international conferences and exhibitions such as the UNFCCC Conference of the Parties and the Group on Earth Observation (GEO) Plenary Meeting/Ministerial Summits.

1.2.3 Other research

Global environmental problems encompass issues from climate change to the depletion of the stratospheric ozone layer. Here we would like to introduce studies other than climate change research.

We have a single dedicated project on the theme of stratospheric ozone layer at our center. The project includes a study of the process of the recovery of the ozone concentration in the stratosphere and its relationship to global warming phenomena. In particular, we have developed a simulation model of the ozone concentration and compared the results to satellite data to investigate a case study in Argentina, where a UV increase occurring in November in 2009 was related to ozone depletion around the Arctic region. Simulation results were congruous with observed data and elucidated the role of the process of regional ozone depletion around the Arctic at that time of year.

Individual researchers in the center implement their own research on given topics. Many researchers have used other research funds to advance their scientific studies. These individual studies can be classified into three broad categories.

1) Research on new monitoring networks and databases for global environmental studies
2) Research on future global environmental studies
3) Research on new technologies for environmental measurement systems

We continuously endeavor to elucidate new research fields requiring attention for the furtherance of the field of global environmental research. These activities include seeds for the next large research projects. Research on analysis of volatile organic carbon compounds (VOCs) and water cycle modeling activities, in particular, is introduced in the detailed overview.

2 Research budget, human resources, and papers during the third NIES five-year plan

2.1 Research budget per each fiscal year

	FY2011	FY2012	FY2013	FY2014	FY2015
Grant for Operating Costs (for GOSAT)	1,134 (678)	1,170 (692)	1,255 (674)	1,470 (654)	1,470 (654)
Other External Research Funding	922	1,737	1,178	994	944
Total	2,056	2,907	2,433	2,464	2,464

(Unit: million yen)

2.2 Human resources

Cumulative total number of staff during the third five-year plan: 767

2.3 Total number of papers and conference presentations during the third five-year plan

Papers		Books	Presentations		Patents
Peer Review	Others		Domestic	International	
470	130	91	661	589	0

2.4 Major papers and patents (up to 5)

(1) Hideki Nara, Hiroshi Tanimoto, Yasunori Tohjima, Hitoshi Mukai, Yukihiro Nojiri, Toshinobu Machida, (2014) Emissions of methane from offshore oil and gas platforms in Southeast Asia., Sci. Rep., 4, 6503; DOI:10.1038/srep06503.

(2) Nakaoka, S., M. Telszewski, Y. Nojiri, S. Yasunaka, C. Miyazaki, H. Mukai and N. Usui (2013), Estimating temporal and spatial variation of ocean surface pCO_2 in the North Pacific using a self-organizing map neural network technique, Biogeosciences 10, 6093–6106, doi:10.5194/bg-10-6093-2013.

(3) Hirata R., Takagi K., Ito A., Hirano T., Saigusa N. (2014) The impact of climate variation and disturbances on the carbon balance of forests in Hokkaido, Japan. Biogeosciences, 11 (18), 5139–5154

(4) Maksyutov S., Takagi H., Valsala V.K., Saito M., Oda T., Saeki T., Belikov D.A., Saito R., Ito A., Yoshida Y., Morino I., Uchino O., Andres R.J., Yokota T. (2013) Regional CO_2 flux estimates for 2009–2010 based on GOSAT and ground-based CO_2 observations. Atmospheric Chemistry and Physics, 13, 9351–9373

(5) Kamae, Y., H. Shiogama, M. Watanabe, and M. Kimoto (2014) Attributing the increase in Northern Hemisphere hot summers since the late 20th century. Geophysical Research Letters, doi:10.1002/2014GL061062

III Center for Material Cycles and Waste Management Research

Masahiro Osako, Director, Material Cycles and Waste Management Research

1 Overview of research outcomes

1.1 The third NIES five-year plan

A negative legacy of mass disposal is often attributed to the mass production and mass consumption which characterized our society in the late twentieth century. One solution to this problem is promoting the establishment of a sustainable material-cycle society. The Center for Material Cycles and Waste Management Research (CMW), founded in 2001, is tasked with surveying and investigating the current circumstances of, and future prospects for, the use of materials in society and the various environmental loads accompanying their usage. We also assess materials, both as potential resources and for their toxic properties; conduct studies on resource recycling and the proper disposal of wastes and waste water; develop technologies for restoring the environment; and investigate the implementation of these technologies in the field.

In line with the third NIES five-year plan (2011–2015), the center has the leading role in promoting the NIES Priority Research Program on Sustainable Material Cycles. This research program consists of three research projects. It also promotes fundamental research and conducts the research required to cater to national policymaking on material cycles and waste management. In addition, in the aftermath of the Great East Japan Earthquake and the accident at the Fukushima Daiichi Nuclear Power Plant, emergent research on disaster and radioactively contaminated waste management has also been implemented to support the decision-making of the national government from a scientific point of view.

Fig. 1 Overview of research activities on material cycles and waste management

1.2 Research and other outcomes, and self assessment under the third NIES five-year plan

1.2.1 Research Programs

We engage with environmental issues on three fronts: international environmental issues that affect Japan and extend throughout the rest of Asia; issues that affect developing countries in Asia; and domestic issues. Our initiatives are related to the scientific and technical aspects of the efficient use and appropriate

management of resources and waste. On this basis, we intend to actively support sustainable material societies—both in Japan an overseas—that reconcile climate change policy and implementation strategies.

The three research projects being implemented as part of the Sustainable Material Cycles Research Program are as follows:

1.2.1.1 Project 1: "The appropriate management of materials with hazard and resource potential in harmony with international material cycles"

This program aims to facilitate an understanding of international material flows and to propose management measures internationally. Each country has indirect and hidden flows associated with economic activity, and natural resource consumption through their supply chains accelerates environmental impacts at locations far removed from the site of consumption. We analyzed the international material flow and found that the worldwide flow of nickel through trade in 2005 was 2.7×10^6 t.

As a field study of product and material cycles for managing resources and chemical risks, we also carried out environmental investigations of electronic waste (E-waste) recycling sites in Vietnam and the Philippines. The open storage and burning of E-waste were then determined to be important factors contributing to the emission of hazardous substances derived from E-waste. We also organized workshops on E-waste in the Philippines and Thailand and shared our knowledge and experiences in the environmentally sound management (ESM) of e-waste in the Asian region.

1.2.1.2 Project 2: “Establishment of appropriate technological systems for municipal waste in Asia”

This program aims to provide technological systems appropriate to waste found in Asia. Performance with regard to greenhouse gas (GHG) emissions and water pollutant reduction by using semi-aerobic landfills was investigated through the test cell experiment in Thailand and by numerical modeling. A pilot-scale wetland that was built in Thailand effectively reduced the amount of leachate through evapotranspiration. We have developed on-site wastewater treatment technologies. Parallel experiments using three types of reactor: a newly developed anaerobic reactor with siphon-driven agitation, an unmixed conventional reactor, and a continuously mixed conventional reactor, revealed that the newly developed reactor achieved successful operation under a higher organic loading rate and also improved the dispersion of solids.

In addition, we have developed tools for planning waste management systems in Asia. In a pilot study in Ho Chi Minh City, Vietnam, waste that was separated as other waste at home could be managed at incineration plants and, because of its relatively high heating value, could be used to generate electricity.

1.2.1.3 Project 3: “Establishment of material-cycle systems by utilizing regional characteristics”

This program aims to design proper regional material-cycle systems in Japan. We put forward five potential orientations for regional recycling systems based on literature reviews. We then conducted systems analysis to estimate local biomass resource circulation imbalances. We also assessed the advantages of the use of a municipality incineration plant by more than one municipality in terms of cost and environmental load, with consideration to a decrease in population. In parallel with these systems analyses, we attempted to examine the more practical aspects that constitute a local strategy: rational, practical, negotiatory, and institutional. Our historical analysis of seven cases showed the practical importance of the non-rational aspects. We complied 640 items of data regarding regional issues and solutions collected from those seven cases in order to facilitate improved decision-making when establishing regional material-cycle systems. We are now writing guidelines for establishing regional material-cycle systems.

1.2.2 Other research

1.2.2.1 Waste management research needed in response to national policies

[1] Evaluation of waste incineration systems and development of an energy recovery technology

We investigated the treatment performance of various municipal solid waste (MSW) incineration facilities under criteria such as energy recovery efficiency and the discharge ratio of incineration ash to treated waste. From these results, we developed indicators to evaluate the level of adaptability of MSW incineration plants to a low-carbon and sound material-cycle society.

We investigated the distribution of metals among different incineration residues discharged from a

series of incineration processes by sampling and analyzing the residues collected from two actual MSW incineration plants. We developed a waste incineration simulator to represent this metal distribution based on a multi-zonal thermodynamic equilibrium calculation.

[2] Development of a quality control engineering system for wastes suitable for an advanced sound material cycle society

A lysimeter test estimates a leachate quality and is a stabilization mechanism for landfilled waste. We evaluated the influence of lysimeter geometry, such as length and diameter, on the leachate quality from construction and demolition waste that had been packed into the lysimeter. In case that a change in the leaching quality was arranged by L/S (a passage fluid volume / solid mass), we found that aspects of geometry have no impact. We have also developed a leachate collection system for seashore landfill. Covering the entire area of seashore landfill with a leachate collection layer facilitates rapid improvements in the leachate quality. Both the numerical calculation we modeled and the tank simulation test demonstrated the effectiveness of the leachate collection layer.

An artificial rain column test revealed the importance of soil cover in terms of heavy metals released from stabilized municipal solid waste incinerator fly ash which was to be disposed.

[3] Establishment of appropriate measures for regional environmental restoration and domestic liquid-waste treatment

We revealed characteristics of GHG emissions from *Johkasou* through a field survey. Both CH_4 and N_2O emissions were obviously reduced through anaerobic-aerobic circulation. In fact, anaerobic-aerobic circulation made it possible to not only remove nitrogen but also reduce GHG emissions. We also examined the effects of water-saving devices on water consumption and the characteristics of domestic wastewater. Water-saving devices reduced water consumption but increased the biochemical oxygen demand (BOD) of domestic wastewater. Applying an anaerobic–aerobic circulation process improved the BOD reduction efficiency, allowing us to achieve a 24.8% BOD load reduction.

[4] Development and evaluation of treatment technologies and countermeasure analysis methods suitable for legacy wastes and materials with recycling difficulties

We studied appropriate ways to manage hazardous wastes such as asbestos and persistent organic pollutants (POPs). As for the proper management of asbestos, a rapid screening method using polarized light microscopy was developed. This method can complete asbestos screening within 10 mins, much faster than the official analytical method. Accuracy of identification using this method was also satisfactory. As for appropriate treatment technologies for the POPs, we carried out a series of combustion experiments, in which the destruction and emission behaviors of hexabromocyclododecanes (HBCDs) and organophosphorus flame retardants (OPFRs) were examined. A set of experimental outcome data indicates that even in wastes that contains high levels of these compounds, incineration under the current regulations can control the environmental emissions of HBCDs and OPFRs as well as the unintentional POPs.

To establish a procedure for carrying out field surveys of inappropriate landfill sites, we collected data that would enable us to assess landfill dam stability either by physical investigation or by sampling soil at the landfill site. We also collected information on groundwater leakage to assess the durability of seepage control works in cooperation with the managers at industrial waste landfill sites.

[5] Development, standardization, and application of methods for testing the environmental soundness of chemicals in recycled products

To enable steel slag to be used for marine applications, we investigated the leaching of alkali substances from these products and the subsequent rise in pH of the seawater. Referring to results from a large-scale tank experiment (L 6.5 m × W 0.5 m × H 1.2 m), a combination of a flow-through type test and a single batch test was proposed in order to ascertain and evaluate the acceptability of the level of slag in a marine environment. For use of recycling materials on land, an up-flow percolation test based on ISO/TS 21268-3 was discussed and a validation among the three institutes was carried out to ensure adaptability of the percolation test. The results showed a good level of accordance between the points of maximum concentration and cumulative amounts leached, and less than 20% deviation from the average.

1.2.2.2 Promotion of seeds and fundamental research

[1] Systems approach to, and policy study of, life-cycle resource management

This study has developed the methodology of time-series material flow analysis (MFA) with a global system boundary by extending the authors' existing MFA approach. The global system boundary was achieved by including 231 countries and regions and by considering all possible trade commodities which may contain critical metals. Critical metals emphasized are neodymium (Nd), which is used for motors associated with wind power and electric vehicle (EV), cobalt (Co), for electrodes in EV batteries, and platinum (Pt) for catalysts in fuel cells. The target years for the analysis are from 1995 to 2010 due to the availability of international trade data.

In Japan, much legislation relating to recycling was enacted from the late 1990s to the early 2000s and since then stakeholders have been in conflict over issues surrounding the current relevant acts and their possible solutions (revisions). We mainly focused on the responsibilities with regard to recycling and efficient collection systems. For the former, we conducted the first international survey on perceptions of extended producer responsibility. For the latter, we compared different collection systems for portable batteries.

[2] Study of fundamental technologies required for material cycles and waste treatment

We developed a chemical compound profiling method based on hazardous effects, as determined from in-vitro bioassays of wastes and recycled materials, focusing on POPs and alternatives to POP-PBDE (Polybrominated Diphenyl Ether) flame retardants. Furthermore, we predicted the physicochemical properties of the alternatives and their environmental fates, and selected some that were POP-like. We also measured vapor pressures for some of them.

We developed a dual-fuel production system for converting grease trap waste (GTW), which is not recycled into fuel due to its low quality, into a liquid biofuel and biogas. First, we established a separation technology for recovering oil content from GTW, and then investigated using the obtained oil as an alternative to fossil fuel oil based on its phase equilibrium. We also established stable operating conditions for producing biogas from residues that were discharged in the aforementioned oil recovery process.

We developed a fast charging technology using high pressure for not only a lead acid battery but also a Ni-NH battery. This technology also successfully prolonged the battery lifetime, indicating that it is useful for lifetime-improvement.

We developed a low-temperature gasification and reforming technology. We selected combinations of catalytic metallic salts and support matrices that were effective in terms of cost and conversion efficiency. We then evaluated the conversion performance of these combinations in methanation and reverse water-gas shift reaction from syngas produced by biomass gasification.

1.2.2.3 Strategic establishment of information research fundamentals for resource circulation and waste management

We collected data and created several databases regarding research and policies of sound material cycles and proper waste management. Databases were categorized into policy/management, material flows, composition of waste/recyclables, technology, and disaster waste management. Data for sustainable material management, archives of municipal solid waste (MSW) data, international supply chains, and compositions of WEEE (waste electrical and electron equipment), etc. is also being collected.

1.2.2.4 R&D promotion and partnership activities in the Asian region

The Collaborative Research Laboratory was launched in Bangkok, Thailand in partnership with two Thai universities that lead the field in waste management. This laboratory allows us to conduct more field-based research and to build up the research capacity of researchers from Japan and Thailand. We held a workshop on gasification of waste with researchers from Thailand and Singapore.

The training course entitled "Asian Network for Young Researchers on Sustainable Landfill Management" took place over the course of two months, with 13 young researchers from four Asian countries participating, including one with a Ph.D., seven Ph.D. candidates, and four Master's candidates.

The course aimed to strengthen the capacities of the young researchers, who will become core members of the network of Asian researcher capacities on sustainable landfill management.

We have also begun to disseminate information on disaster waste management. We have conducted two forums in Bangkok to communicate information on flood waste management, and we have also drafted flood waste management guidelines for Bangkok. We also launched a research project on flood-waste management in mid-scale Asian cities; the 2-year project will be supported by the Asia-Pacific Network for Global Change Research. Its aim is to support mid-scale city municipalities that experience floods frequently to plan and prepare for flood-waste management. The Asian region is also extremely vulnerable to natural disasters such as floods and earthquakes. We also plan to further help countries in this region—especially developing countries—to collect case studies to mitigate risks posed by flood waste to the environment and human health.

In addition to our collaborative work in Thailand, we have strengthened our partnership with Singapore's Nangyang Technological University's Residues and Resource Reclamation Center to enable further research collaboration, particularly on the establishment of environmental quality standards for recyclable materials such as slag, incineration ash, and construction and demolition waste. A summary of our overseas research, including our collaborative research, is given in Figure 2.

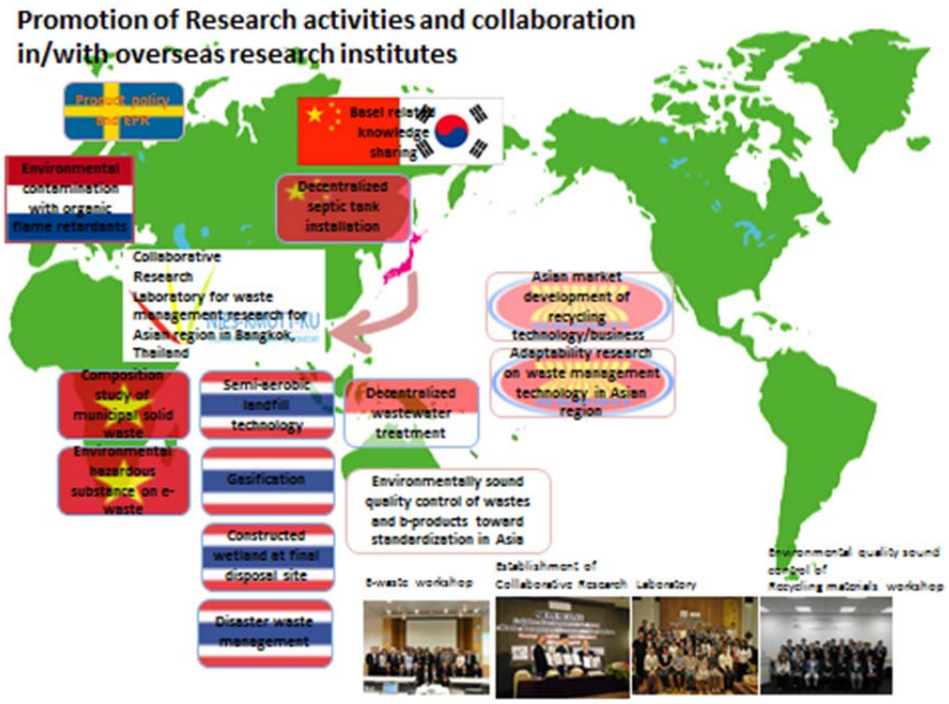


Fig. 2 Promotion of research activities in and collaboration with overseas research institutes

2 Research budget, human resources, and papers during the third NIES five-year plan

2.1 Research budget per each fiscal year

	FY2011	FY2012	FY2013	FY2014	FY2015
Grant For Operating Costs	290	467	576	880	785
Other External Research Funding	398	577	763	129	110
Total	688	1,044	1,304	1,009	885

(Unit: million yen)

2.2 Human resources

Cumulative total number of staff during the third five-year plan: 415

2.3 Total number of papers and conference presentations during the third five-year plan

Papers		Books	Presentations		Patents
Peer review	Others		Domestic	International	
225	198	35	665	224	7

2.4 Major papers and patents (up to 5)

(1) Matsukami, H., Kose, T., Watanabe, M., Takigami, H. (2014) Pilot-scale incineration of wastes with high content of chlorinated and non-halogenated organophosphorus flame retardants used as alternatives for PBDEs. Sci. Total Environ. 493, 672-681.

Chlorinated and non-halogenated organophosphorus flame retardants (OPFRs) including tris(2-chloroisopropyl) phosphate (TCIPP), diethylene glycol bis(di(2-chloroisopropyl) phosphate) (DEG-BDCIPP), triphenyl phosphate (TPHP), and bisphenol A bis(diphenyl phosphate) (BPA-BDPP) have been used increasingly as alternatives to polybrominated diphenyl ethers and other brominated flame retardants. For this study, five batches of incineration experiments of wastes containing approximately 1% of TCIPP, DEG-BDCIPP, TPHP, and BPA-BDPP were conducted using a pilot-scale incinerator. Destruction and emission behaviors of OPFRs were investigated along with the effects on behaviors of unintentional persistent organic pollutants (POPs) such as polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), dioxin-like polychlorinated biphenyls (dl-PCBs), hexachlorobenzene (HCB), pentachlorobenzene (PeCB), and pentachlorophenol (PCP). Incineration conditions were chosen according to current regulations for waste incinerators in Japan and UNEP. The OPFRs in the input materials were mainly destroyed in the primary combustion with destruction efficiencies greater than 99.999%. Concentrations of the OPFRs in the exhaust gases and ash were, respectively, <0.01–0.048 μg m-3 and <0.5–68 μg kg-1. Almost all of the total phosphorus in the input materials was partitioned into the ash, but less into final exit gases, indicating negligible emissions of volatile phosphorus compounds during incineration. Inputs of chlorinated OPFRs did not affect the formation markedly. Destruction and emission behaviors of unintentional POPs were investigated. Emissions of such POPs in exhaust gases and the ash were lower than the Japanese and international standards. Results show that even in wastes with high contents of chlorinated and non-halogenated OPFRs, waste incineration by the current regulations for the waste incinerators can control environmental emissions of OPFRs and unintentional POPs. Incineration is regarded as a best available technology (BAT) for waste management systems.

(2) Oguchi M., Sakanakura H., Terazono A. (2013) Toxic metals in WEEE: Characterization and substance flow analysis in waste treatment processes. Science of the Total Environment. 463-464, 1124-1132.

Waste electrical and electronic equipment (WEEE) or E-waste has received extensive attention as a secondary source of metals. Because WEEE also contains toxic substances such as heavy metals, appropriate management of these substances is important in the recycling and treatment of WEEE. As a basis for discussion toward the better management of WEEE, this study characterizes various types of WEEE in terms of toxic metal content. The fate of various metals contained in WEEE, including toxic metals, was also investigated in the actual waste treatment processes.

(3) Tasaki T., Tojo N., Lindhqvist T. (2015) International Survey on Stakeholders' Perception of the Concept of Extended Producer Responsibility and Product Stewardship. English version, Report of Joint Research of IIIEE and NIES, May 2015, 171p.

Extended Producer Responsibility (EPR), as well as product stewardship (PS), has been one of the most important ideas for waste management policy worldwide for the last two decades. In order to identify how differently various stakeholders in different countries perceive the concept, the authors conducted an international survey on stakeholders' perception of EPR/PS in 2013. This report showed that there was a variety of perceptions of EPR/PS among the 426 responses obtained.

(4) Kobayashi T., Wu Y.-P., Lu Z.-J., Xu K.-Q. (2015) Characterization of Anaerobic Degradability and Kinetics of Harvested Submerged Aquatic Weeds Used for Nutrient Phytoremediation. Energies 8:304-318.

In this study, eight different submerged aquatic species were screened using batch biochemical methane potential and anaerobic degradability tests to identify a promising/suitable feedstock. The kinetics of the best-screened substrates were studied in a mesophilic semi-continuous experiment. The aquatic species *Myriophyllum aquaticum*, *Egeria densa* and *Potamogeton perfoliatus* showed relatively higher methane yields of over 400 NmL/g-VS (volatile solids). Semi-continuous operation was carried out by feeding *E. densa* for over 400 days. The achieved results were 33%–53% chemical oxygen demand (COD) reduction and methane yield of 126–231 NmL/g-VS with a short hydraulic retention time (HRT). Additionally, the NH_4^+ and PO_4^{3-} releases from the biomass to water were found to be low (18%–27% and 2.5%–3.9%) throughout the experiment. Hydrolysis was the limiting step in the digestion of *E. densa*, regardless of changes in HRT (15–45 days). The acid-phase model indicated that the hydrolysis rate constant (kh) of *E. densa* was 0.058 one/day, which was one third lower than the kh value of food waste, but quite similar to that of cow manure.

(5) Kawai K., Tasaki T. (2015) Revisiting estimates of municipal solid waste generation per capita and their reliability. Journal of Material Cycles and Waste Management. Online

Firstly, per capita municipal solid waste (MSW) generation, a core indicator of environmental pressure, is a useful measure for evaluating the intensity of waste generation over time and comparing the level of intensity among cities or countries. We provide an overview of global data on MSW generation per capita at the national and local levels. Although the legal definition of MSW varies from country to country, we conceptualize MSW as simply the waste managed by or for municipalities as a public service. We note the current challenges in estimating MSW generation per capita in developing countries, including a lack of equipment (e.g., weighbridges), lower rates of MSW collection efficiency, and rural–urban migration, all of which may have negative effects on the reliability of the data. Incomplete data compilation systems at the national level also results in lower reliability and reduces the comparability of national data. We suggest technical solutions for estimating MSW generation per capita at the local and national levels to improve the reliability and comparability of data.

IV Center for Environmental Risk Research

Noriyuki SUZUKI, Director, Center for Environmental Risk Research

1 Overview of research outcomes

1.1 The third NIES five-year plan

To contribute towards the creation of a sustainable society, it is necessary to precausiouly respond to environmental risks, including hazards to both human health and the environment. To achieve the goal of the 2020 World Summit on Sustainable Development to "use and produce chemicals in ways that minimize significant adverse effects on human health and the environment," policies are being promoted to better grasp the risks associated with such chemicals to human health and the environment and to eliminate major sources of risk. To achieve success in these areas, we need to establish a scientific basis for risk assessment to support the management of as-yet unidentified risks from chemical substances as well as risks to vulnerable populations.

We are focusing on various ways of facilitating the advancement of assessment and management of environmental risks. This includes elucidating the routes and dynamics of chemical exposure and developing exposure evaluation methods; developing techniques for ascertaining the status and effects of exposure to chemicals in the environment; studying mechanisms and methods for evaluating ecological risks and adverse effects on human health; studying policies on and management of environmental risks; and gathering information on environmental risks.

In Japan, a focus on the impacts on living organisms in the environment has recently been incorporated into the management of chemical substances. However, the concept of ecosystem protection is not fully entrenched in risk assessment. Accordingly, we need to further develop techniques for evaluating ecological risk. Conventional techniques for hazard assessment may not be sufficient for a full evaluation of the effects of nanomaterials on human health and ecosystems. Strategic approaches to managing a variety of chemicals need to be established to enable more effective control of the risks these pose. To address these issues, since the adoption of the third NIES five-year plan we have implemented research as part of the 'Research Program on Risk Assessment and Control of Environmental Chemicals'.

To develop the infrastructure for assessing and managing the risks posed by chemical substances, we performed the major task of establishing a reference laboratory and developing databases to gather information related to environmental risk, as follows: (1) to develop chemical substance databases and better disseminate data, we have continuously updated and improved our chemical substance database, which users can access at our website (Webkis-Plus), and the website EnvMethod, which encompasses methods for analyzing various chemical substances in the environment, (2) to establish a reference laboratory for ecological hazard assessment**,** we have promoted techniques for eco-toxicity testing and improved the reliability and accuracy of toxicity data for environmental risk assessment. We have also developed an efficient system for maintaining and providing the organisms (including medaka [*Oryzias latipes*] and water fleas [*Daphnia* spp.]) which are used in tests in Japan and abroad.

In addition to the research summarized above, we have contributed to chemical substance risk assessment and management which have informed environmental standards and legislation (such as the Chemical Substances Control Law) as part of our activities in the Chemical Substances Examining Office.

1.2 Research, other outcomes, and self-assessment under the third NIES five-year plan

Reseach conducted at the Center for Environmental Risk Reseach can be classified into four categories. First is that conducted as part of the "Research Program on Risk Assessment and Control of Environmental Chemicals," which is a Priority Research Program at NIES that aims to study methodologies for the ecological risk assessment of chemicals, the safety assessment of nanomaterials, and strategies for the control of environmental chemicals (see section 1.2.1). A second category is activities related to the establishment of environmental research infrastructure (see section 1.2.2); this includes the maintenance of a chemical substance database and reference laboratory for ecotoxicological hazard assessment. The third category is fundamental research on topics that will inform environmental action plans; the aim of this research is to develop practical techniques for the assessment and management of the risks (see section 1.2.3). The final category inlcudes a wider range of scientific activities falling outside the above - from basic

research to applied sciences (see section 1.2.4); we have selected several examples, from small to larger scales, to illustrate the activities in this area.

The Center for Environmental Risk Research carries out integrated investigations and research on environmental risks—of chemical substances in particular—with the goal of ensuring the safety of human health and the protection of ecosystems by evaluating and managing environmental risks.

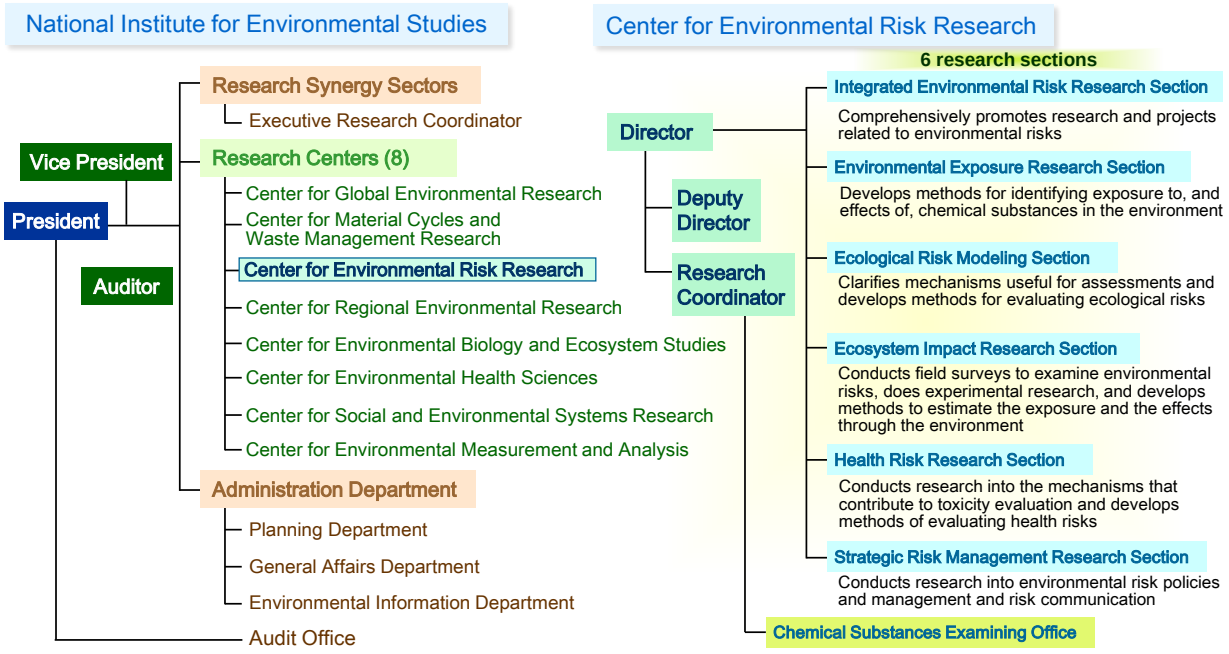


Fig. 1 Center for Environmental Risk Research

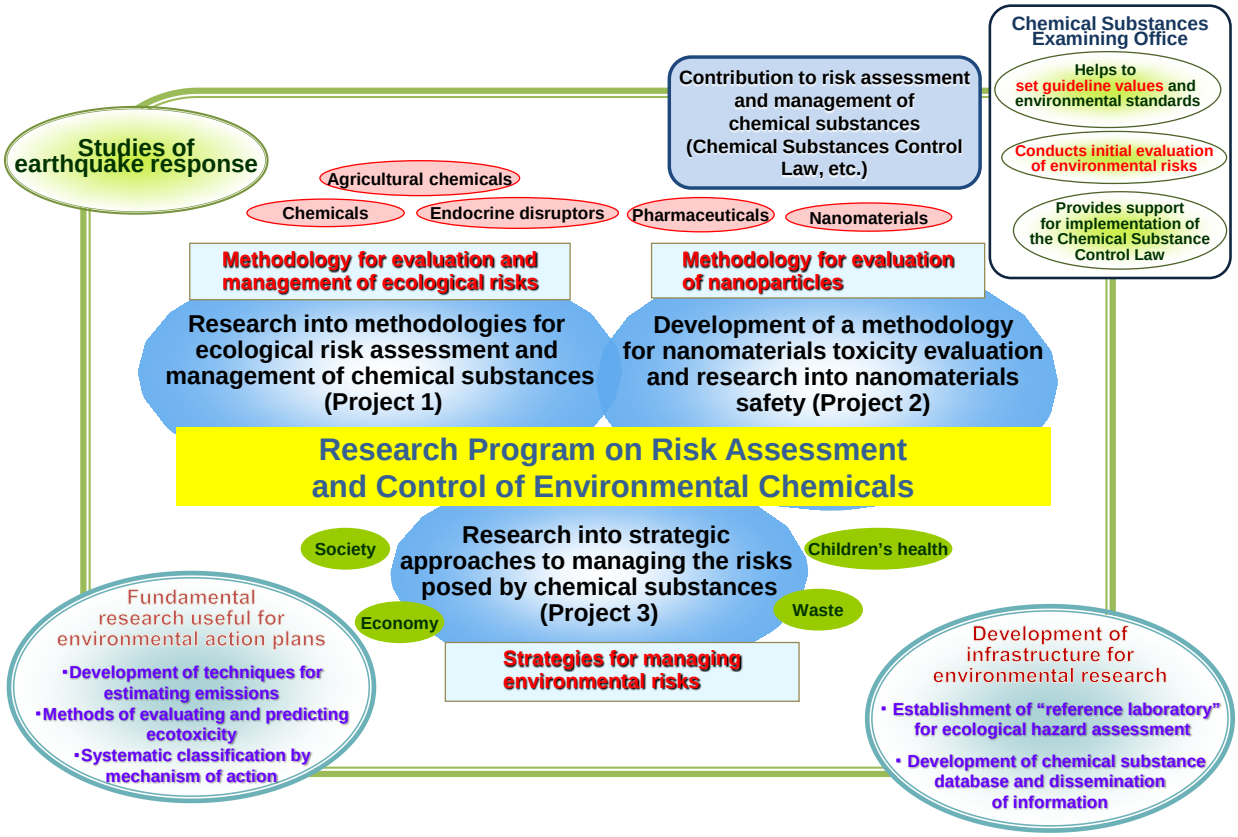


Fig. 2 Outline of Environmental Risk Field

1.2.1 Research Program on Risk Assessment and Control of Environmental Chemicals

The research program consists of three projects focusing on ecological risk assessment, nanomaterial toxicity and safety, and a strategic approach to managing chemical-related risks.

Research into methodologies for ecological risk assessment and management of chemical substances (Project 1) aims to develop ecological risk assessment methodologies for chemical substances from an ecological perspective. Two ecological models for ecotoxicology, the Aquatic Tri-Trophic Ecological Risk Assessment Model (A-TERAM) and the *Daphnia* population model are discussed. A-TERAM simulates population dynamics in an aquatic community with three trophic levels (the algae–zooplankton–fish system). It incorporates ecological aspects into the chemical risk assessment framework by including ecological interactions between trophic levels (prey–predator interactions) and temporal changes in chemical concentrations in the environment. The *Daphnia* model simulates the population dynamics of the water flea under toxicant stresses, with an emphasis on endocrine-disrupting chemicals (EDCs), which are known to change offspring sex in *Daphnia*. The ecological risk posed by EDCs was evaluated in the context of decreased growth rates in *Daphnia* populations. In addition to these models, we also explored an integrative method of database analysis, based on large-scale spatial bio-monitoring data for river benthos and concentrations of pesticides in the environment. Our analysis indicated that the best management scenario for reducing chemical use in a particular region, to enable the recovery of biodiversity, was dependant on achievement of the optimal management targets and the hydrological structure of the river systems which were included in the target region.

Development of a methodology for nanomaterials toxicity evaluation and research into nanomaterials safety (Project 2) was begun following the completion of our first nanotechnology project, conducted from FY 2006 to 2010. In that project, we used laboratory animals and cultured mammalian cells to investigate the health effects of nanoparticles, such as ultrafine particles in diesel exhaust, carbon nanotubes, and heat-treated asbestos. The current nanotoxicology project, begun in FY 2011, focuses on the mechanisms of toxicity of carbon nanotubes, the *in vivo* and *in vitro* toxicity of silver nanoparticles and dendrimers, and the use of embryos and the sac fry of fish in an ecotoxicological evaluation of titanium dioxide (TiO_2) nanoparticles. In addition, as part of this second project, we intend to develop an *in vitro* nanoparticle exposure system at the air–water interface for toxicity screening of various types of nanoparticles and nanomaterials. To this end, toxicity testing methods suitable for nano-sized particles need to be established, with a focus on the shape, dispersibility, and surface charge of nanomaterials. The overall goals of this project are to develop a health-risk-assessment framework and to help formulate international guidelines for the safety evaluation of nanomaterials.

The aim of Project 3 is to investigate strategic approaches to managing the risks posed by various chemical substances, as well as other risk factors. We have studied methods of assessing the environmental fates and spatiotemporal distributions of chemicals (Sub-themes 1-1 to 1-3) and control strategies for chemicals in society (Theme 2). Sub-theme 1-1 focuses on developing models for predicting spatiotemporal changes in the emissions and levels of pesticides (PeCHREM/G-CIEMS models), validating the models, and promoting the models as effective means of managing pesticides. Sub-theme 1-2 focuses on developing and studying emissions and exposure scenarios, particularly at the indoor product-use stage, by using both measurement and modeling approaches, with flame retardants and perfluoroalkyl substances as the target compounds. Sub-theme 1-3 focuses on the environmental fate of persistent organic pollutants (POPs) and development and validation of a new global multimedia model for POPs (the Finely Advanced Transboundary Environmental Model, or FATE). Theme 2 investigates strategies for managing chemicals across the different dimensions of risk posed by various sources, particularly in relation to the diversity and receptivity of social bodies.

These three research projects are successfully proceeding in line with the associated five-year research plan. Figure 3 is a general summary of the three projects and their integrated outcomes as part of the research program. Project 1 has produced ecological risk assessment methodologies through models and scenario study; Project 2 has investigated the mechanistic toxicology of carbon nanotubes and the ecotoxicology of titanium oxide; and Project 3 has produced emission and fate modeling on both a regional and a global scale and has demonstrated the implications of this modeling for management strategies. The research outcomes from these projects have provided a scientific basis, as well as modeling methodologies, to improve exposure assessment in implementation of the Chemical Substance Control Law in Japan. In addition, they have

contributed to several other management schemes of the Ministry of the Environment, including those involving air pollution by hazardous chemicals, control of water pollution by chemicals, and pesticide management, as well as governmental projects on combined exposures to chemicals. These achievements have also been the basis of contributions to international organizations, such as the Organisation for Economic Co-operation and Development (OECD) and United Nations Environment Programme (UNEP), in various task forces and meetings.

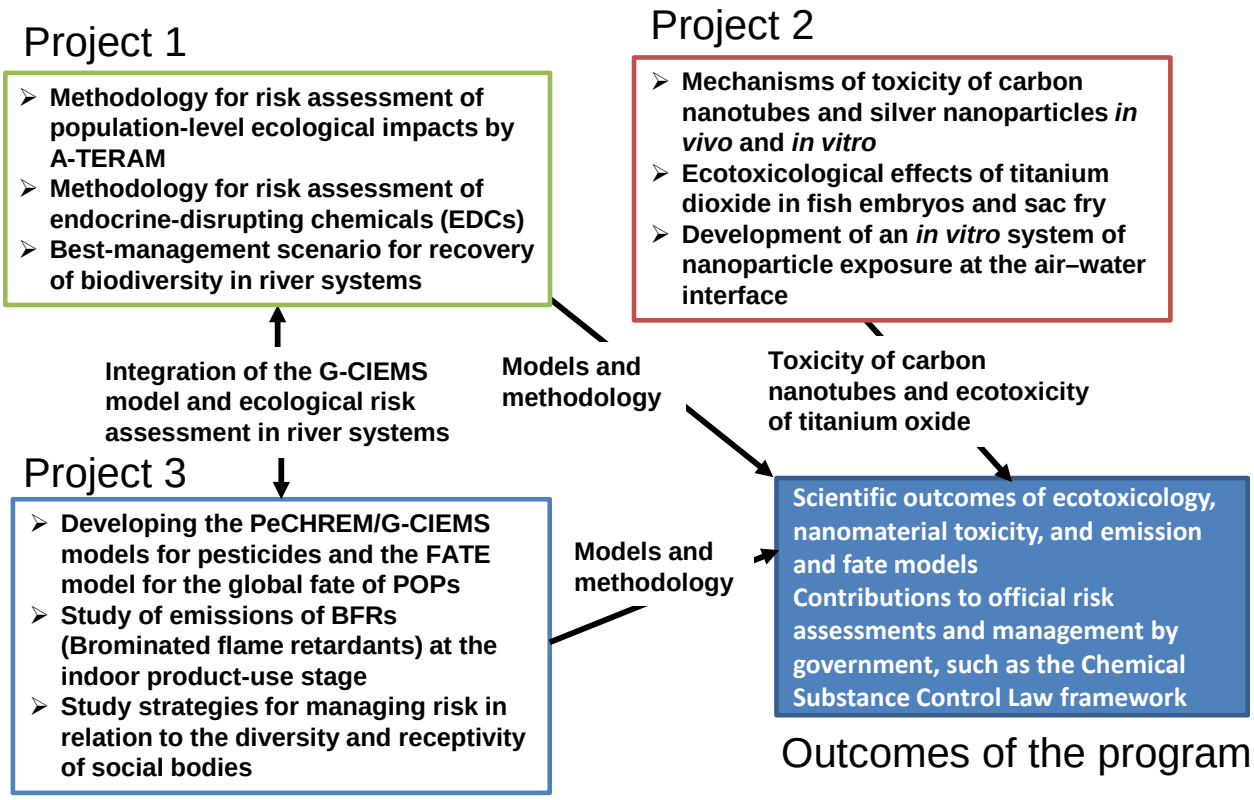


Fig. 3 Summary of the Research Program on Risk Assessment and Control of Environmental Chemicals

1.2.2 Environmental Research Infrastructure

Development of a chemical substance database and dissemination of relevant information is ongoing. This information is disseminated on our website Webkis-Plus, which is open to the public, as is another related database, EnvMethod. The Webkis-Plus database contains information on about 10,000 substances, including information on physicochemical properties, regulations, environmental concentrations, shipment volumes, PRTR (Pollutant Release and Transfer Register) emissions and transportation amounts, and the results of risk assessments. The EnvMethod database contains methods for analyzing various chemical substances in the environment. These two databases are linked by a chemical substance code and medium. These websites are publicly accesible and any interested party can thus easily obtain chemical information by inputting search words or searching by categorized lists. We are also developing a new database and a related website to highlight additional research outcomes.

We have established a reference laboratory for ecological hazard assessment with the aims of creating references for eco-toxicity testing to develop standardized eco-toxicity tests in Japan and abroad; promoting techniques for eco-toxicity testing; improving the reliability and accuracy of toxicity data for environmental risk assessment; and supporting the development of testing laboratories in Japan. As part of this effort, we have been working on the following three initiatives. (1) development of new testing methods for endocrine disruptors and effluent assessments in collaboration with relevant institutions in Japan and abroad; some of the test protocols have already been approved as OECD test guidelines, (2) hosting of practical training seminars to teach the elementary knowledge and techniques for eco-toxicity testing on zebrafish (*Danio rerio*), daphnids, and algae to participants from various organizations (companies, research institutes, and universities) to promote and improve eco-toxicity testing, (3) refurbishment of the systems for culture and supply of test organisms to develop and support infrastructure for eco-toxicity testing.

Figure 4 summarizes our activities on environmental research infrastructure. We have successfully expanded our databases and updated their functions. We also successfully conducted several training seminars throughout the year, and have been working to establish a whole-effluent toxicity (WET) program in Japan and establish new ecotoxicology test guidelines for the OECD.

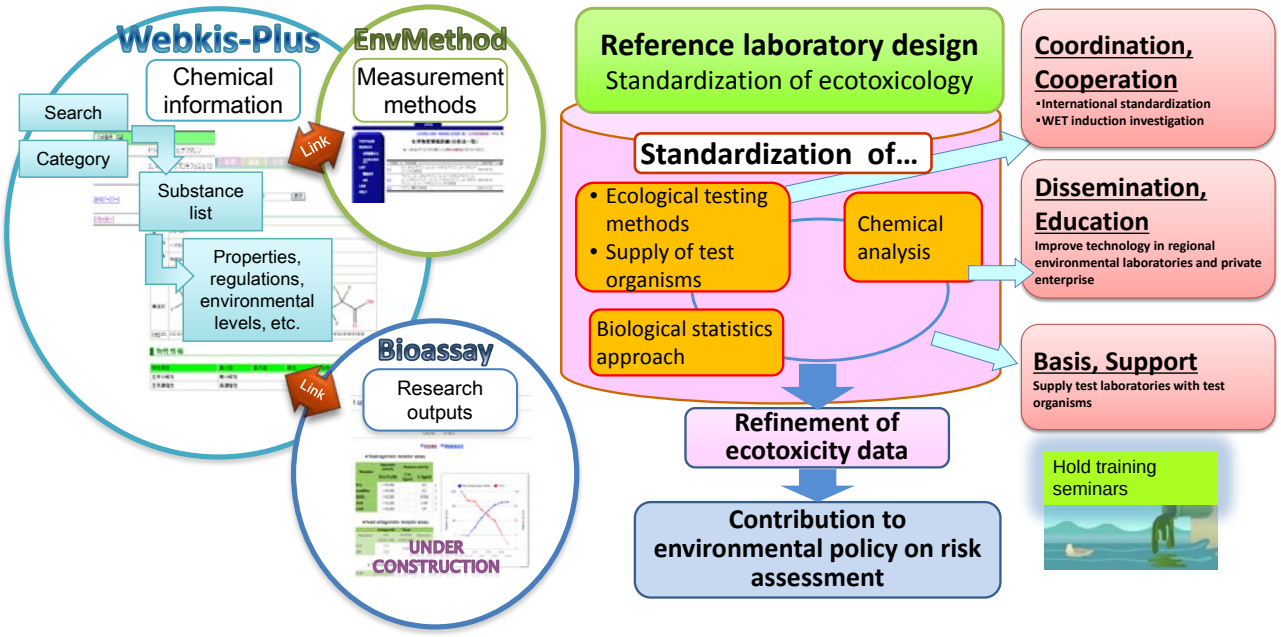


Fig. 4 Outline of "environmental research infrastructure" activities

1.2.3 Fundamental research useful for environmental action plans

One aim of this project is to develop new techniques for estimating the emissions of chemical substances into the environment by considering various factors that have not been sufficiently studied, such as emissions from various processes and changes in these emissions over time. We incorporated updated emission factors and detailed categories from Japan's amended Chemical Substances Control Law to revise our existing model system (MuSEM). We then examined how emission factors differed according to the physicochemical properties of chemicals' use-categories used in both screening and risk assessments under the amended substance control law framework. By using a dimensional analysis of emissions with regard to time, we also established general mathematical representations of chemical emissions from products in various processes during product life cycles. We then developed a tool that estimates emissions in processes such as product use by considering factors such as the time course of production volume, distribution of product life, and changes in emission factors.

Our research into the development and use of a method for predicting the toxicity of chemical substances aims to develop quantitative structure–activity relationship (QSAR) models useful in evaluating acute aquatic toxicities. First, we constructed QSARs for α,β-unsaturated carbonyl compounds by using Gasteiger's partial equalization of orbital electronegativity (PEOE) method. The QSARs based on the PEOE descriptor should be useful for predicting toxicity, especially in the case of compounds with an α-hydrogen. Combining a hydrophobicity descriptor with PEOE allowed for accurate prediction of fish toxicity. We then proposed simple interspecies quantitative structure–activity–activity relationships (QSAARs; i.e., QSARs with descriptors) to estimate species-specific acute aquatic toxicity. Although our simple QSAARs have limitations, they are defined sufficiently clearly as to be applicable to chemical screening. We also developed two statistical approaches to extrapolate chronic ecotoxicity from acute ecotoxicity data. The first approach uses regression models and provides a reasonable statistical background for predicting chronic ecotoxicity from the correlative relationships among ecotoxicity data. The second approach applies a simple Bayesian framework to predict the posterior probability that the chronic toxicity exceeds a threshold value for screening chemicals.

In developing biological testing techniques based on the mechanisms of action of chemical substances, we have focused on the application of bioassay data to risk assessment. To plan measures for reducing the risk of combined exposure, we have assessed the total impact of multiple chemicals in the environment by

using data from *in vivo* and *in vitro* bioassays. Our research projects are focused on evaluating the hazards of multiple chemical substances in the ambient air and aquatic environment. The projects include (1) anatomization of the mutagenic or carcinogenic potency of environmental chemicals (especially polycyclic aromatic hydrocarbons in ambient air), and (2) analysis of the endocrine-disrupting activities of chemical substances detected mainly in the aquatic environment, and establishment of a database of the endocrine-disrupting activities.

Our work in developing a new method of estimating emissions was successful in expanding the functions of the existing MuSEM tool for some processes, considering the time course of production and product life. The study of a method for predicting chemical substance toxicity by using QSARs to consider interspecies ecotoxicity differences is expected to be the basis of our existing toxicity prediction program development. Our study of biological testing techniques based on mechanisms of action added new insights into the mutagenic potency of polycyclic aromatic hydrocarbons (PAHs) and endocrine-disrupting activities. The results will form the basis of future risk evaluations of air quality guidelines and endocrine-disrupting chemicals.

1.2.4 Other research

Our work in developing testing methods for endocrine disrupting chemicals (EDCs) aims to develop and improve ecotoxicity tests using fish and invertebrates under the Ministry of the Environment's testing and assessment framework for EDCs (EXTEND 2010: Extended Tasks on Endocrine Disruption 2010). For fish testing, we have developed three types of tests using Japanese medaka: a fish short-term reproduction test (TG229), a fish sexual development test (TG234) for anti-androgen action, and a multi-generation test. Our proposal for amendment of the OECD test guideline for the fish short-term reproduction test using Medaka as a test species was approved in 2012. We also plan to propose a test guidance document with a modified TG229 to detect anti-androgen action. A medaka multi-generation test jointly developed with the US Environmental Protection Agency was also approved at an OECD expert meeting as the Medaka Extended One-Generation Reproduction Test (MEOGRT). For daphnid testing, we worked on the development of three types of tests using *Daphnia magna*, namely screening tests to detect juvenile hormone analogs and molting hormone analogs, and a multi-generation test.

Our ecological effect assessment of neonicotinoids and other systemic pesticides studied the potential impact of these pesticides in paddy fields in Japan. The main use of these pesticides is on rice paddy fields. There are about 25,000 km^2 of paddy fields in Japan, and these provide broad wetland-like habitats for rural biological communities. The use of systemic pesticides applied via nursery boxes for young rice plants has been increasing in Japan. However, the ecological risks posed by these pesticides—especially to the biological communities inhabiting paddy fields—have been the subject of only minimal assessments. Given the increased concern over the ecological risk of neonicotinoids, we started a project consisting of the following four sub-projects: (1) ecotoxicological research by using an experimental paddy-field mesocosm and laboratory exposure testing, (2) ecological field research in paddy fields treated with different systemic pesticides, (3) development of compartment fate and transport models of systemic pesticides in paddy fields, and (4) integration of effect and exposure assessment and development of management methods. In this project, we focused on four popular systemic pesticides (clothianidin, imidacloprid, fipronil, and chlorantraniliprole). Our results suggested that (1) there are strong effects of systemic pesticides on some dragonfly species, which are key species in the paddy field biological community, and (2) there are long-term residues of systemic pesticides in concentrations potentially harmful to some non-target species in Japanese paddy fields.

Our study of atmospheric nanoparticles and issues related to primary and secondary aerosols from vehicle emissions focused on emissions from vehicle exhaust. We measured the number and mass of particles emitted from gasoline direct ignition (GDI) vehicles and the latest type of diesel engine vehicles, as well as the secondary organic aerosols (SOAs) generated from the exhaust of these vehicles. In addition, to monitor the primary aerosols emitted from vehicles, particle number concentrations and size distributions have been monitored at roadside sites since 2004. The particle number emission rate per unit operating distance in GDI vehicles was more than 10 times that of gasoline port injection (GPI) vehicles. We found that emission of elemental carbon dominated emissions from GDI vehicle in GDI, GPI, and the latest type of diesel engine (equipped with oxidative catalyst and a diesel particulate filter) vehicles. Moreover, in GDI, GPI, and the latest type of diesel engine vehicles, the rate of generation of SOAs was comparable to the

emission rates of primary organic aerosols. To reduce the burden associated with atmospheric aerosols, emission controls for GDI vehicles and a reduction in the emissions of SOA precursors are needed. The particle number concentrations at the Ikegami-Shincho roadside test site were lower in 2006 than in 2004–2005, but levels have remained steady since 2006, despite stricter emission regulations.

A mechanistic approach to arsenic toxicity was used to study the affinity of arsenite for promyelocytic leukemia (PML) protein. Once arsenic is taken up by the cells, it is reduced by, and conjugated with, intracellular glutathione and generates arsenic triglutathione (ATG). In hepatic cells, ATG is further methylated by arsenic (+3) methyltransferase (AS3MT). We found that promyelocytic leukemia (PML) protein became less soluble in a common lysis buffer and was SUMOylated in the nuclear or peri-nuclear region in response to arsenite concentrations as low as 0.1 to 0.3 μM in HEK293 and CHO-K1 cells. PML has a cysteine-rich domain, and biochemical modification of PML is a sensitive indicator of exposure to arsenite.

We investigated the effects of severe hypoxia (dissolved oxygen <1 ml l^{-1}) on recruitment of mantis shrimp (*Oratosquilla oratoria*) in Tokyo Bay. Ten-year field surveys were conducted to examine the quantitative relationships between the annual mean densities of larvae and juveniles and between the spatial distribution of juveniles and severe hypoxia. There was no significant correlation between annual mean densities of larvae and juveniles, suggesting that mortality during the larval and juvenile stages varies across years, thus potentially regulating the abundance of young-of-the-year juveniles. Juvenile density was low in severely hypoxic areas, implying that hypoxia could affect the survival and spatial distribution of juveniles. There were yearly fluctuations in juvenile density in normoxic areas of both the northern and southern parts of the bay. This evidence suggests that the abundance of post-settled juveniles might be determined not only by the effects of hypoxia but also by other factors influencing mortality during the early life stages.

Multi-profiling analysis of chemical effects by using gene expression and toxicity information in the Health Effects Alert System (HEALS) highlighted the usefulness of integrated toxicological information approaches. The environmental health risk from exposure to chemicals in the environment has been analyzed by using various methods, and multilateral toxicological information has accumulated during the last decade. Integrated toxicological information approaches to toxicological hazard identification and chemical characterization are considered to be promising tools for guiding resource-efficient decision-making on chemical hazards and risk management. HEALS was developed to predict chemical effects and toxicities (http://project.nies.go.jp/heals/). It includes four subsystems: a retrieval system for chemical toxicity (ChemToxGen); a database assembling microarray data for chemicals (ChemArrayDB); the association of toxicity information and gene expression signatures (pCEC); and the networking of processes of toxic effects on the basis of gene expression data (MulCEH). These systems allow us to evaluate chemical effects by using a number of databases and algorithms. In the MulCEH system, the high-performance Bayesian network system RX-TAOGEN has been developed.

Each of these research projects has generated new information covering various aspects of environmental risk research. Although the projects are not necessarily directly linked to official chemical management at present, they have successfully reported on a variety of new scientific insights that could be a future basis for management applications.

The Chemical Substances Examining Office has provided important information for risk assessment and management, thus contributing to the environmental protection measures implemented by the Ministry of the Environment and to the risk assessment of chemical substances prioritized by the Chemical Substances Control Law. The Office has also helped establish guidelines on the health risk assessment of hazardous air pollutants, supporting the setup of environmental standards for water quality (e.g., disolved oxygen and chemical substances), introducing a whole effluent test system for water quality management, and improving pesticide management.

2 Research budget, human resources, and papers during the third NIES five-year plan

2.1 Research budget per each fiscal year

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
Grant for Operating Costs	257	269	285	403	274
Other External Research Funding	351	393	365	354	84
Total	608	662	650	757	358

(Unit: million yen)

2.2 Human resources

Cumulative total number of staff during the third five-year plan: 434

2.3 Total number of papers and conference presentations during the third five-year plan

Papers		Books	Presentations		Patents
Peer review	Others		Domestic	International	
196	58	14	496	116	1

2.4 Major papers and patents (up to 5)

(1) Abe R., Watanabe H., Yamamuro M., Iguchi T., Tatarazako N. (2015) Establishment of a short-term, in vivo screening method for detecting chemicals with juvenile hormone activity using adult *Daphnia magna*. J. Appl. Toxicol. 35(1):75–82.

(2) Arai Y., Miyayama T., Hirano S. (2015) Difference in the toxicity mechanism between ion and nanoparticle forms of silver in the mouse lung and in macrophages. Toxicology 328: 84–92.

(3) Fujitani Y., Kumar P., Tamura K., Fushimi A., Hasegawa S., Takahashi K., Tanabe K., Kobayashi S., Hirano S. (2012) Seasonal differences of the atmospheric particle size distribution in a metropolitan area in Japan. Science of the Total Environment, 437, 339–347.

(4) Kawai T., Jagiello K., Sosnowska A., Odziomek K., Gajewicz A., Handoh I.C., Puzyn T., Suzuki N. (2014) A new metric for long-range transport potential of chemicals. Environmental Science & Technology, 48 (6), 3245–3252.

(5) Kodama K., Tajima Y., Shimizu T., Ohata S., Shiraishi H., Horiguchi T. (2014) Disturbance of recruitment success of mantis shrimp in Tokyo Bay associated with effects of hypoxia on the early life history. Marine Pollution Bulletin, 85(2): 433–438.

V Center for Regional Environmental Research

Akio IMAI, Director, Center for Regional Environmental Research

1 Overview of research outcomes

1.1 The third NIES five-year plan

Mankind's activities have substantial impacts on both mankind itself and natural ecosystems through environmental media such as the atmosphere, water, and soil. The Center for Regional Environmental Research is investigating the mechanisms by which regional environmental issues develop on multiple scales (local, urban, and trans-boundary) in both Asia and Japan, through research approaches such as extensive monitoring, robust modeling, and laboratory experiments, in order to establish a sound scientific basis for minimizing anthropogenic environmental impact. Furthermore, by integrating many of the outcomes thus obtained, we are developing solutions to such regional environmental issues and investigating how these solutions are applied to the real world (Fig. 1).

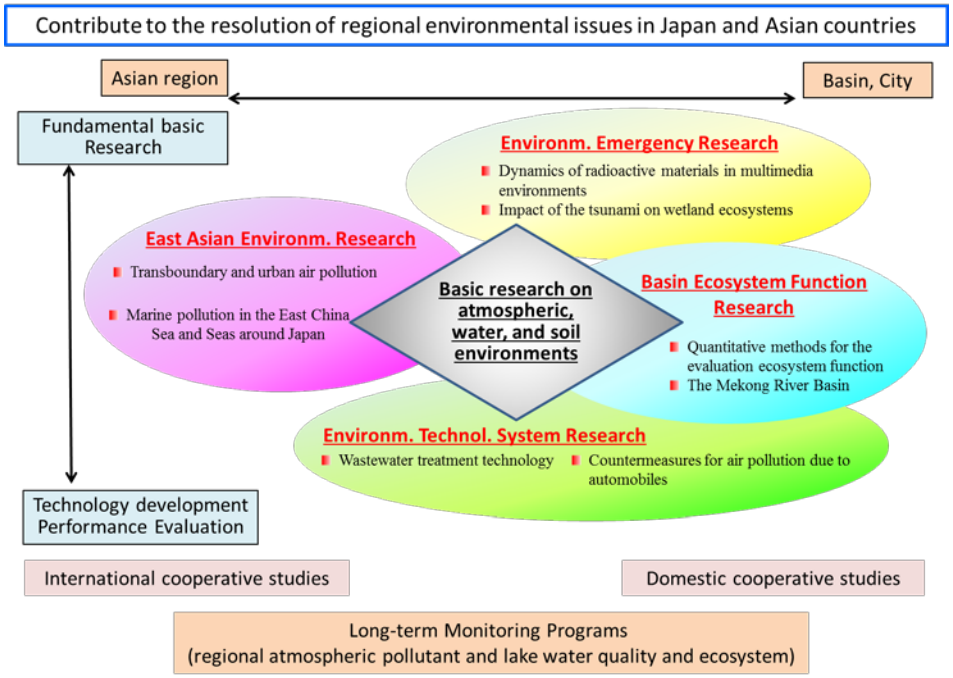


Fig. 1 A schematic framework of research activities at the Center for Regional Environmental Research.

The center comprises eight sections (Regional Atmospheric Modeling Section, Regional Atmospheric Environment Section, Urban Atmospheric Environment Section, Water Quality Management Section, Lake and river Environment Section, Marine Environment Section, Soil Environment Section, and Regional Environmental Systems Section) and has two Principal Researchers.

We have implemented many research projects covering a wide range of regional environmental issues. Our main research projects are as below:

1) Investigation of air quality issues ranging from local to hemispherical scales, with particular emphasis on trans-boundary transport of air pollutants, and their impact on human health and ecosystems in East Asia.
2) Development of integrated numerical models that can simulate the impact of human activity in China's Yangtze River basin on the environment in the ECS and the seas around Japan, in the context of concern regarding increasing anthropogenic pollutant loads from terrestrial East Asia and accompanying wide-scale degradation of marine environments, as exemplified by the occurrence of red tides on the continental shelf of the East China Sea.
3) Development of methodologies for the quantitative assessment of ecosystem function, focusing on the material and water cycles of basin ecosystems (e.g., forests, lakes and wetlands, rivers, and coastal regions), and subsequent assessment of the relationships between ecosystem function and various environmental factors.

4) Fundamental studies on conservation, enhancement, and creation in urban, regional, and basin environments, in collaboration with researchers affiliated with other centers within NIES as well as research institutes in prefectures nationwide.
5) Studies to elucidate, analyze, and predict the actual environmental conditions, dynamics, and future prospects of radioactive substances emitted from the Fukushima Daiichi Nuclear Power Plant. Most of these research projects have been undertaken in collaboration with other centers at NIES.
6) Studies on the development and demonstration of appropriate wastewater technology with consideration to regional characteristics in the current era characterized by sustainable development, as well as the prospects for application of energy-saving wastewater treatment systems for both developed and developing countries.
7) Two long-term monitoring programs: (1) Regional Atmospheric Pollutant Monitoring at Cape Hedo on Okinawa Island and Fukuejima in Nagasaki Prefecture, and (2) GEMS/Water (Global Environmental Monitoring System/Water Program) trend monitoring of water quality and the ecosystem in Lake Kasumigaura, Ibaraki Prefecture, a collaborative project with the Center for Environmental Biology and Ecosystem Studies.

1.2 Research and other outcomes, and self assessment under the third NIES five-year plan

We are implementing many research projects covering a wide range of regional environmental issues, e.g., one Priority Research Program (East Asian Environment Research Program), and one Advanced Research Program (Basin Ecosystem Functions Research Program), and several cross-discipline research projects. Furthermore, we have conducted research projects addressing multimedia modeling and long-term monitoring of radioactive substances emitted from the Fukushima Daiichi Nuclear Power Plant, and we have two ongoing long-term programs monitoring air pollution and water quality in a lake.

The aforementioned research projects have, as a general rule, been proceeding in a satisfactory manner, and research outcomes have been widely applied in policy making by the Japanese administration, local prefectural governments, and other Asian national and local governments. Public awareness regarding regional environments has been expanded by the results of our research and through associated proposals.

Research Program: East Asian Environment Research Program

Rapid economic growth in the East Asian region has brought with it severe environmental problems. As Japan is closely connected to East Asia, both geographically and economically, environmental issues in this region have considerable influence on the Japanese environment. As part of East Asia, Japan must adopt a long-term strategy to facilitate preservation of the East Asian environment; one which promotes multi-national environmental security and sustainable regional societies. However, further research is needed to obtain fundamental scientific knowledge concerning environmental issues and anthropogenic impacts on the environment. In this context, research in the East Asian Environment Program is undertaken on multi-scale air pollution in East Asia, and on the effects of wide-scale anthropogenic activities on marine ecosystems in the East China Sea and seas around Japan. Through field observations and model simulations, we aim to clarify both the current situation and the formation mechanisms of trans-boundary air pollution in East Asia to reveal the relationships between environmental burdens and their impacts, and to suggest solutions that will benefit marine ecosystems. In collaboration with the Center for Social and Environmental Systems Research, an integrated impact assessment of the future migration of anthropogenic pollutants on atmosphere–land–ocean environments in East Asia has also been conducted.

Research Program: Basin Ecosystem Functions Research Program

To develop methodologies for the quantitative assessment of ecosystem function, we focus on the material and water cycles of typical basin ecosystems such as forests, lakes, wetlands, dams, and coastal regions. We perform long-term strategic monitoring, and assess the relationships between ecosystem function and various environmental factors. Based on our assessments, we develop and evaluate scenarios for forest management, reduction of sediment release in lakes, and ecological engineering methods for green tide control in coastal seas. In addition, we evaluate the developed scenarios for proper water and nitrogen cycles using an integrated land–lake numerical simulation model for the Lake Kasumigaura basin.

The methodologies for the quantitative assessment have been applied to dams in the Mekong River basin, and the effects of the dams in the basin examined, specifically the balance between the losses of fishery production due to damming and the gains of production through aquaculture in the reservoirs.

Computer modeling was applied to assess the impact of damming on the diversity of fish species and biomass.

Other Research

(1) Investigation of $PM_{2.5}$ pollution mechanisms

We determined the mechanisms causing $PM_{2.5}$ pollution concentrations to exceed the short-term/long-term environmental standards. We improved a NIES-developed air pollution forecasting system (VENUS) for better accuracy and usability in order to address public concern regarding $PM_{2.5}$ pollution.

(2) A study of particulate matter (PM) in the urban atmosphere with regard to its reduction and an evaluation of its toxicity and health impact

To better understand the atmospheric behaviors and health effects of atmospheric aerosols ($PM_{2.5}$), we conducted field measurements, numerical simulations, toxicity assessments, and epidemiological studies of $PM_{2.5}$ throughout Japan. We assessed the toxicity of secondary organic aerosols (SOAs) and the health risks associated with $PM_{2.5}$. To reduce both the quantity of $PM_{2.5}$ emissions and their harmful effects on humans, it is also necessary to consider the emission sources, distribution of air pollutants, and population distribution.

(3) Estimation of fluxes of nutrients and global warming gases from sediments

We succeeded for the first time in obtaining the 3D structures of chironomid tubes in lake sediments via MRI analysis. Our study indicated that the inner-sediment-layer exchange of soluble substances might be enhanced at the depths where many tubes are found.

(4) Development and demonstration of appropriate wastewater treatment technologies

In the current era of sustainable development, it has been indicated that the prospect of application of technologies such as energy-saving wastewater treatment systems such as a methane fermentation process and aerobic trickling filter system are promising for both developed and developing countries. We develop appropriate wastewater technology and conduct demonstrations of that technology in cooperation with the local government in Thailand (Bangkok Metropolitan Administration). Such technology was proven to be effective in ensuring sufficient effluent quality with minimal electricity requirements.

(5) Research activities other than those mentioned above

A wide scope of additional research, both in terms of topics and funding sources have been undertaken. These include a consideration of the effects of antibiotics on the microbial arsenic cycle in the aquatic environment; a high-resolution study on air pollution using a global cloud-resolving model; and two long-term monitoring programs, one to observe atmospheric pollutants at two sites in Japan, and another a UNEP (United Nations Environment Programme) GEMS/Water trend monitoring of water quality and the ecosystem in Lake Kasumigaura. These research projects and the long-term monitoring programs have been proceeding in a satisfactory manner, and have yielded both the results and data expected.

1.2.1 Research Programs

1.2.1.1 East Asian Environment Research Program

Rapid economic growth in the East Asian region has given rise to severe environmental problems. As Japan is closely connected to East Asia both geographically and economically, environmental issues in this region have considerable influence on the Japanese environment. Research as part of the East Asian Environment Program is conducted on multi-scale air pollution in East Asia (Project 1), and on the effects of wide-scale anthropogenic activities on marine ecosystems in the East China Sea and seas around Japan (Project 2). The objective of Project 1 is to clarify the current situation and formation mechanisms of trans-boundary air pollution in East Asia by means of field observations and model simulations. Project 2 is intended to reveal the relationships between environmental burdens and their impacts, and to suggest solutions that will benefit marine ecosystems. An integrated impact assessment of future migration of anthropogenic pollutants on atmosphere–land–ocean environments in East Asia has also been conducted (PJ1 and PJ2 collaborative research), in collaboration with the Center for Social and Environmental Systems Research.

[1] Project 1: Analysis and evaluation of multi-scale air pollution by integration of observations and modeling

P1.1 A study of the variation of hemispheric-scale air pollution using large-scale monitoring

The amount of tropospheric ozone over East Asia has been observed to be increasing at a substantially greater rate than in Europe and North America. A model simulation of regional chemical transport, which incorporated a yearly regional emissions inventory, reproduced the ozone levels successfully but failed in the quantitative reproduction of the decadal growth. The model suggested that increasing Asian anthropogenic emissions accounted for about half the observed increase, and that there could be missing and/or underestimated emissions of ozone precursors in upwind regions of East Asia. We examined the emissions of ozone precursors in East Asia using field and satellite observations to fill the gap between the observations and the model. The emission factors for NOx and speciated volatile organic compounds (VOCs) from biomass burning emissions in Siberia and China were derived and compared with previous bottom-up and top-down studies. These results will be incorporated in model simulations to better reproduce past ozone trends and understand the controlling factors.

P1.2 Analysis of trans-boundary air pollution to Japan using integrated observational data

Based on a chemical analysis of particulate matter (PM), we examined the influence of trans-boundary air pollution on urban air quality in northern parts of Kyushu, Japan. Sulfate and oxygenated organic species were the major components, suggesting that trans-boundary air pollution has considerable influence on the air quality in Fukuoka. Furthermore, the effects of dust, PM mass, and chemical composition on health were analyzed and some relations found.

P1.3 Investigation of the structure and impact of air pollution in Asia based on multi-scale chemical transport model (CTM) simulations and the estimation of the effect of measures intended to control it

The spatiotemporal structures of atmospheric pollution by ozone and $PM_{2.5}$ in East Asia were examined based on multi-year simulations using a multi-scale chemical transport model (CTM). The simulations used the latest data on emissions of air pollutants, and the changes in East Asian air quality estimated based on a scenario of air pollutant emissions in the near future (2030). The effect of ozone on Japanese beech trees in mountainous regions of Japan was estimated using the output from the CTM simulations.

[2] Project 2: Study of effects of wide-scale anthropogenic activities on marine ecosystems in the East China Sea and seas around Japan

P2.1 Development of prediction method for pollutant loads to the East China Sea from the Yangtze River basin

The long-term changes of various nitrogen inputs to the Yangtze River basin have been analyzed using statistical data from the 1980s to the 2000s. To simulate the temporal variations in the freshwater and pollutant discharges within the Yangtze River basin, a catchment water and material circulation model was developed, which was validated using observational data of water quality indicators of the river. The total nitrogen input into the river basin increased dramatically in the 1990s and then stabilized at a high level in the 2000s. The amount of nitrate flowing through the lowest course of the Yangtze River to the East China Sea was about 3.6 times larger in the 2000s than in the 1980s.

P2.2 Study on mechanisms of degradation of marine ecosystem on the continental shelf in the East China Sea

Based on new findings obtained from cruise surveys in the East China Sea and related laboratory experiments, an ocean assessment model was developed. A series of sensitivity simulations was conducted using the model to elucidate the response of seawater quality to changes in pollutant loadings from the Yangtze River. These simulations indicated the extensive influence of the changes in the total amounts of nitrogen and phosphorous loadings and of their ratio (i.e., NP ratio) throughout the river on the phytoplankton biomass, spatial distribution, and dominant algal class (diatoms or flagellates) on the continental shelf of the East China Sea. They also suggested that the recent predominant tendency for dinoflagellates over diatoms on the central continental shelf of the East China Sea would be caused by the high NP ratio (≈ 100) of the nutrients in the discharged river water.

P2.3 Scenario-based prediction of near-future water pollution in China and assessment of its impact on inland water and marine environments for development of an integrated land–sea environmental management system

The spatiotemporal variations in water and pollutants from 2010–2030 were predicted by estimating reasonable unit values of the regional amounts of water and pollutant loads per unit industrial gross output, and using the Chinese provincial-scale economic growth forecast data, established by the Asia–Pacific Integrated Model/Computable General Equilibrium (AIM/CGE) model, based on the future scenario of "conventional society" for global climate change studies. The prediction results show that the annual water withdrawal throughout China will increase by 2.3 times from 2002 to 2030, while industrial gross output will increase by 5.3 times, i.e., the pollution load will increase dramatically in association with the increase in water discharge from manufacturing industries. The results suggest that the implementation of appropriate point source management is essential if future pollution loads in China are to be reduced.

P2.4 Integrated impact assessment of migration of anthropogenic pollutants on atmosphere–land–ocean environments in East Asia—PJ1 and PJ2 collaborative research

One of the goals of this research program is to predict the fate and impact of anthropogenic pollutants on the atmosphere, land, and ocean environments in East Asia. To achieve this goal, Projects 1 and 2 collaborated in the integration of field monitoring and modeling studies. They also established an assessment system with which to evaluate the responses of the aquatic environments in the Yangtze River basin and the East China Sea (ECS) to changes in atmospheric nitrogen deposition caused by various human activities (e.g., economic growth, urbanization, technological advances, policies) in East Asia from 2000–2010.

The atmospheric simulation showed that the magnitude of nitrogen deposition into the entire ECS increased by about 1.5 times between 2000 and 2010. The oceanic simulations indicated that such an increase in nitrogen deposition enhanced primary production significantly in the Yellow Sea and slightly on the central and eastern continental shelves of the ECS, especially in early summer.

1.2.1.2 Basin Ecosystem Functions Research Program

In order to minimize the loss of biodiversity in important ecosystems, it has been proposed to utilize the power of ecosystem functions by exploiting their effects on the soundness of the ecosystem. However, there have been few reports on quantitative methods for the evaluation of ecosystem functions in natural environments. In important ecosystems in the natural environment, the lineages and relationships between ecosystem functions and environmental factors have not been elucidated, which is why there has been no substantial progress in how best to protect, restore, and resurrect ecosystem functions.

Our objective was to develop methodologies for the quantitative assessment of ecosystem function and we are focusing on the material and water cycles of basin ecosystems (e.g., forests, lakes and wetlands, rivers, and coastal regions). We have also performed long-term strategic monitoring of typical basin ecosystems and assessed quantitatively the relationships between ecosystem function and various environmental factors. Based on these scientific findings and associated information, we have extended our project to a large basin (the Mekong River basin) and have assessed the relationship between the losses of fishery production due to damming and the gains of production through aquaculture in the reservoirs.

[1] Project 1: Quantitative evaluation of links between ecosystem functions and environmental factors in natural ecosystems

In three typical chronically loaded natural ecosystems (forest, lake, and coastal sea), we assessed the mechanisms of the relationships between ecosystem function and various environmental factors that directly affect the improvement of environmental problems. For example, nitrogen saturation in a forested area, eutrophication and the increase of recalcitrant dissolved organic matter in a lake, and green tide in coastal seas. Based on this assessment, we developed and evaluated a scenario for forest management, preventing reductions in lake sediments, and ecological engineering methods for green tide control in order to improve the environmental conditions within each of these systems. Finally, based on the assessed ecosystem functions, we evaluated the developed scenario for proper water and nitrogen cycles using an integrated numerical simulation model of the land and lake processes in the Lake Kasumigaura basin.

[2] Project 2: Development of strategic environmental assessment technology and its application to watershed restoration

We developed techniques and procedures to assess strategically the effects of dam development in the Mekong River basin, specifically regarding the balance between the losses of fishery production due to damming and the gains of production through aquaculture in the reservoirs. To achieve this objective, we monitored a variety of limnological parameters in multiple reservoirs and natural lakes in the basin including the nutrients, primary productivity, concentrations of harmful algae such as *Microcystis*, fish production, and the carbon sources and trophic levels of major food web components. We also investigated the migration behavior of commercially important fish species and assessed the potential impacts of damming on their fishery. Computer modeling was used to assess the effect of damming on fish species diversity, biomass, and the eco-hydrological properties of the Mekong River as an entity. We then implemented a strategic environmental assessment to develop effective, efficient, and science-based techniques for the restoration of mangrove and other wetland vegetation along the coasts of Vietnam and Tohoku in Japan.

1.2.2 Other research

1.2.2.1 Investigation of $PM_{2.5}$ pollution mechanisms causing the exceedance of long- and short-term air quality standards and development of an air pollution forecasting simulation

Initiatives such as the analysis of observational data, air sampling for research purposes, receptor analysis using componential data, and implementation of 3D numerical simulation calculations have been undertaken to elucidate the pollution mechanisms leading to the exceedance of short- and long-term environmental standards, as a type II joint research program on $PM_{2.5}$ in association with local governmental environment institutes. Furthermore, with funding from the Ministry of the Environment, improvements to the VENUS air pollution forecasting system were made to enhance the calculation accuracy and convenience of the user interface, and to add an overview page for the prediction results.

1.2.2.2 A study of PM in the urban atmosphere for its reduction and the evaluation of its toxicity and health effects based on chemical compositions

In order to understand better the atmospheric behaviors and health effects of atmospheric aerosols (in particular $PM_{2.5}$), we conducted a project which included field measurements, numerical simulations, toxicity assessments, and epidemiological studies of $PM_{2.5}$ across Japan. A CTM was improved with an enhanced emission inventory, yield measurement data from an atmospheric experiment chamber, and field observations. Toxicity and epidemiological studies were also performed based on the chemical compositions and mass concentrations of the PM.

To study the toxicity of SOAs, we developed a small reaction chamber system for the α-pinene/ozone reaction and the photo-oxidation of m-xylene, 1,3,5-trimethylbenzene, 1,3-butadiene, and isoprene in the presence of nitric oxide. The toxicities of the SOAs generated from the precursors, which were emitted from anthropogenic sources (m-xylene, 1,3,5-trimethylbenzene, and 1,3-butadiene) were higher than those generated from natural sources such as α-pinene and isoprene. Field measurements in the Kanto area in Japan were performed in summer 2012 and the chemical composition of the PM analyzed. The major species of PM were organic matter and sulfate and the fraction of organic matter was about 50%. Oxidative stress of airborne PM was found to be lower than the SOA of anthropogenic origin. Results of atmospheric simulations were evaluated using the observed chemical composition of the $PM_{2.5}$ from the Kanto area. The CTM overestimated the nitrate and underestimated the organic matter levels. The SOA model, which considers the aging reactions of semi-volatile organic compounds, was better able to reproduce the observed organic aerosol concentrations when compared with traditional SOA models. The epidemiological study revealed that sulfate was associated with respiratory mortality, while there were no significant associations of elemental and organic carbon with mortality.

Methods adopted to reduce PM should consider emission amount and source, distribution of air pollutants, and population distribution. It is also important to monitor the effects of reductions in emissions, which will require improvements in the emission inventory, CTM, lab and field experiments, and toxicity and epidemiological studies.

1.2.2.3 Flux estimation from sediment in nutrients and global warming gases based on MRI and stable isotope analysis

Outbreaks of blue-green algae and aquatic macrophytes have been a serious problem in eutrophic lakes worldwide. Nutrient return from the sediment surface to the water column has been suggested as a primary cause of this, as lake sediment is one of the most deteriorated parts of inland ecosystems. However, no reliable tools are available to analyze the physical structures within the sediment such as benthic tubes and methane bubbles.

In this study, we succeeded in obtaining 3D structures of chironomid tubes within the sediment using MRI analysis. A comparison of the MRI pictures of sediment cores and chloride ion concentrations in pore water suggested an enhancement of the inter-layer exchange of pore water at the depth where many tubes could be found.

We also analyzed the methane production processes in the sediment using measurements of the carbon isotope ratios ($\delta^{13}C$) of methane and dissolved inorganic carbon (DIC). Low values of $\delta^{13}C$ of methane (ca. -70‰) and high values of $\delta^{13}C$ of DIC (up to +6.9‰) suggested that reduction of carbon dioxide was the main methane production process within the sediment of Lake Kasumigaura. We found that methane production was enhanced at the depth where the $\delta^{13}C$ values of both methane and DIC were higher.

1.2.2.4 Development and demonstration of appropriate wastewater treatment technology

In the current era of sustainable development, energy-saving wastewater treatment systems (such as the methane fermentation process and aerobic trickling filter system) have been shown to be promising technologies for both developed and developing countries. Developing countries in Southeast Asia have problems with surface water pollution by organic wastewater. Furthermore, existing treatment systems (such as anaerobic ponds) cause the emission of greenhouse gases (e.g., methane). Therefore, based on regional characteristics, appropriate technology for sewage treatment was developed and a demonstration of that technology conducted in cooperation with local government (Bangkok Metropolitan Administration).

An evaluation of the process performance of an advanced aerobic trickling filter system for decentralized treatment revealed that it achieved sufficient effluent quality accompanied by minimal electricity requirements (85% reduction in electricity consumption). In addition, the development of advanced methane fermentation technologies (such as the psychrophilic treatment of low-strength wastewater, and treatment of high-strength recalcitrant wastewater, e.g., molasses-based bioethanol wastewater) was undertaken in cooperation with national and international industrial, academic, and governmental organizations.

These activities are expected to contribute to planned measures to be introduced for wastewater treatment technology appropriate for the conservation of regional environments (i.e., conservation of water environment and reduction of energy and greenhouse gases). Furthermore, in order to enable favorable conditions for technological development and realization, NIES held an international workshop on the development of sustainable wastewater treatment technology to share relevant knowledge and elucidate the issues associated with future developments.

1.2.2.5 Effects of antibiotics on the microbial arsenic cycle in aquatic environments

We investigated the effects of antibiotics on microbial arsenate (As(V)) reduction and arsenite (As(III)) oxidation in sediments collected from a small pond and a eutrophic lake. The As(V)-reducing activities were less susceptible to chloramphenicol in aerobic conditions than in anaerobic conditions. Aerobic As(V) reduction proceeded in the presence of diverse types of antibiotics. In contrast, some antibiotics strongly inhibited aerobic As(III) oxidation. These results indicate that the aerobic As(III) oxidizers in the sediment are more sensitive to certain types of antibiotics than the aerobic As(V) reducers. Our results suggest that antibiotic disturbance of environmental microbial communities affects the biogeochemical cycle of As.

1.2.2.6 Study of air pollution using high-resolution global cloud-resolving model

As part of the East Asian Environment Research Project, we developed an atmospheric air pollution model coupled with a global nonhydrostatic model (NICAM-Chem) with 10-km spatial resolution, in order to better simulate air pollution over East Asia. To investigate the performance of the model in simulating one of the major air pollutants (i.e., aerosols), we first applied a stretched-grid system to NICAM-Chem to run as

a regional aerosol-transport model. We executed the “Stretched-NICAM-Chem” for the target of Tokyo (Japan) with a maximum horizontal resolution of approximately 10 km. We obtained fields of primary and secondary aerosols and of short-lived gases compared with in situ measurements and of more general accuracy than other aerosol-transport models. Secondly, we integrated NICAM-Chem on a global scale with 14-km spatial resolution. The “Global-NICAM-Chem” simulation of aerosol optical depth was generally approximate with values obtained using measurements derived from satellite. These results will be useful for further investigations of aerosol–cloud interactions and detailed estimations of the effects on human health.

1.2.2.7 Long-term monitoring at CHAAMS and Fukuejima Station to investigate the changes of atmospheric emissions and their chemical composition in East Asia

Long-term monitoring of atmospheric pollutants including aerosols and gaseous species has been conducted since 2004 at Cape Hedo Atmosphere and Aerosol Monitoring Station (CHAAMS) on Okinawa Island and since 2008 at Fukuejima Observatory on an island in Nagasaki Prefecture, Kyushu, in order to observe changes in the atmospheric environment of the East Asian region. Although trans-boundary pollution events have been observed repeatedly at CHAAMS throughout the period, the peaks of $PM_{2.5}$ mass and aerosol optical thickness of spherical particles appear to have occurred around 2006–2007.

1.2.2.8 Long-term monitoring in Lake Kasumigaura

We have been conducting monthly monitoring at Lake Kasumigaura, the second-largest lake in Japan, for nearly four decades. We have monitored many environmental variables including water quality, nutrients, heavy metals, plankton (e.g., bacteria, heterotrophic nanoflagellates, ciliates, picoplankton, phytoplankton, zooplankton, and mysids), primary production, benthos (chironomids and oligochaetes), and fish.

2 Research budget, human resources, and papers during the third NIES five-year plan

2.1 Research budget per each fiscal year

	FY2011	FY2012	FY2013	FY2014	FY2015
Grant for Operating Costs	268	311	305	458	316
Other External Research Funding	264	213	91	214	137
Total	532	524	396	707	453

(Unit: million yen)

2.2 Human resources

Cumulative total number of staff during the third five-year plan: 510

2.3 Total number of papers and conference presentations during the third five-year plan

Papers		Books	Presentations		Patents
Peer Review	Others		Domestic	International	
432	115	22	753	192	5

2.4 Major papers and patents (up to 5)

(1) Kudo S. Tanimoto H., Inomata S., Saito S., Pan X., Kanaya Y., Tsaketani F., Wang Z., Chen H., Dong H., Zhang M., Yamaji K. (2014): Emissions of nonmethane volatile organic compounds from open crop residue burning in the Yangtze River Delta region, China. J. Geophys. Res. atomos., 119, doi:10.1002/2013JD021044.

Open crop residue burning is one of the major sources of air pollutants including the precursors of photooxidants like ozone and secondary organic aerosol. We made measurements of trace gases including nonmethane volatile organic compounds (NMVOCs) in a rural area in central East China in June 2010. During the campaign, we identified six biomass burning events in total through the simultaneous enhancement of carbon monoxide and acetonitrile. Four cases represented fresh plumes (<2 h after emission), and two cases represented aged plumes (>3 h after emission), as determined by photochemical age. While we were not able to quantify formic acid, we identified an enhancement of major oxygenated volatile organic compounds (OVOCs) as well as low molecular alkanes and alkenes, and aromatic hydrocarbons in these plumes. The observed normalized excess mixing ratios (NEMRs) of OVOCs and alkenes showed dependence on air mass age, even in fresh smoke plumes, supporting the view that these species are rapidly produced and destructed, respectively, during plume evolution. Based on the NEMR data in the fresh plumes, we calculated the emission factors (EFs) of individual NMVOC. The comparison to previous reports suggests that the EFs of formaldehyde and acetic acid have been overestimated, while those of alkenes have been underestimated. Finally, we suggest that open burning of wheat residue in China releases about 0.34 Tg NMVOCs annually. If we applied the same EFs to all crops, the annual NMVOC emissions would be 2.33 Tg. The EFs of speciated NMVOCs can be used to improve the existing inventories.

(2) Koshikawa H., Higashi H., Hasegawa T., Nishiuchi K., Sasaki H., Kawachi M., Kiyomoto Y., Tkayanagi K., Kohata K., Murakami S. (2015): Assessing depth-integrated phytoplankton biomass in the East China Sea using a unique empirical protocol to estimate euphotic depth. Estuarine, Coastal and Shelf Science 153, 74-85.

The Changjiang (Yangtze) River plume has a direct impact on phytoplankton biomass in the East China Sea (ECS). The present study aimed to analyze the spatial distribution of depth-integrated chlorophyll a (Chl-a) concentrations from the surface to the euphotic depth (Z_e; $\sum Chl_{Ze}$) using samples collected at 50 stations in the ECS during a cruise in June 2007. However, spatial coverage was limited because the Z_e, obtained from radiometric measurement of the vertical diffuse attenuation of solar irradiance, was only available at the 20 daytime stations. To address this limitation, it was determined that Z_e could be expressed empirically using the vertical means of Chl-a concentration, turbidity, and salinity in the euphotic zone. Using this relationship, the potential value of Z_e at night-time or low-light stations was calculated, and a dataset of ($\sum Chl_{Ze}$) for the entire research area was obtained. A low salinity surface water mass (LSSW) was identified on the eastern continental shelf (125.0° - 126.5° E, 30.0° - 31.0°N), probably part of the Yellow Sea Mixed Water, but clearly influenced by Changjiang Diluted Water (CDW) extending from the west. The Taiwan CurrentWarmWater mass (TCWW) was

located to the south of the LSSW. Other oceanic water masses, including Kuroshio Surface Water, were located to the east of the LSSW. The means of the Z_e and $\sum Chl_{Ze}$ in the LSSW were significantly shallower and higher, respectively, compared with the TCWW and other oceanic water masses ($p < 0.01$). The present study suggests that the extension of the Changjiang River plume beyond the CDW affects the phytoplankton biomass on the eastern continental shelf of the ECS, more than 300 km from the river mouth.

(3) Shinohara R., Imai A., Kawasaki N., Komatsu K., Kohzu A., Miura S., Sano T., Satou T., Tomioka N. (2012): Biogenic phosphorus compounds in sediment and suspended particles in a shallow eutrophic lake: A ^{31}P-nuclear magnetic resonance (^{31}P NMR) study. Environ. Sci. Technol. 46, 10572-10578.

Differences in biogenic phosphorus (P) compounds between sediment and suspended particles in aquatic environments are important for understanding the mechanisms of internal P loading, but these differences are still unknown. We used solution-state ^{31}P-nuclear magnetic resonance spectroscopy (^{31}P NMR) with NaOH-ethylenediaminetetraacetic extraction to detect the multiple P compounds in suspended particles and sediment in the eutrophic Lake Kasumigaura, including orthophosphate monoesters, orthophosphate diesters, pyrophosphate, and polyphosphate. We tested the hypothesis that there is a significant difference between these groups in suspended particles and sediment. Biogenic P other than orthophosphate was found in significantly higher proportions in suspended particles (74.3% of total P) than in sediment (25.6%). Orthophosphate monoesters were comparatively more abundant in suspended particles, as indicated by the ratio of orthophosphate diesters to monoesters (average, 0.31 for suspended particles; 1.05 for sediment). The compounds identified as orthophosphate monoesters by ^{31}P NMR spectroscopy originated mainly from phospholipids (α-glycerophosphate and β-glycerophosphate) and ribonucleic acid (RNA-P), whereas the orthophosphate diesters included mostly DNA (DNA-P). These results suggest that the dynamics of orthophosphate diesters, the production of DNA-P, or the degradation of phospholipids, play an important role in P cycling in Lake Kasumigaura.

(4) Fukushima M., Jutagate T., Grudpan C., Phomikong P., Nohara S. (2014): Potential effects of hydroelectric dam development in the Mekong River Basin on the migration of Siamese Mud Carp (*Henicorhynchus siamensis* and *H. lobatus*) elucidated by Otolith microchemistry. PLOS One 9(8), e103722.

The migration of Siamese mud carp (*Henicorhynchus siamensis* and *H. lobatus*), two of the most economically important fish species in the Mekong River, was studied using an otolith microchemistry technique. Fish and river water samples were collected in seven regions throughout the whole basin in Thailand, Laos and Cambodia over a 4 year study period. There was coherence between the elements in the ambient water and on the surface of the otoliths, with strontium (Sr) and barium (Ba) showing the strongest correlation. The partition coefficients were 0.409–0.496 for Sr and 0.055 for Ba. Otolith Sr-Ba profiles indicated extensive synchronized migrations with similar natal origins among individuals within the same region. *H. siamensis* movement has been severely suppressed in a tributary system where a series of irrigation dams has blocked their migration. *H. lobatus* collected both below and above the Khone Falls in the mainstream Mekong exhibited statistically different otolith surface elemental signatures but similar core elemental signatures. This result suggests a population originating from a single natal origin but bypassing the waterfalls through a passable side channel where a major hydroelectric dam is planned. The potential effects of damming in the Mekong River are discussed.

(5) Syutsubo K., Onodera T., Choeisai P., Khodphuvieng J., Prammanee P., Yoochatchaval W., Kaewpradit W., Kubota K. (2013): Development of appropriate technology for treatment of molasses-based wastewater. Journal of Environmental Science and Health, Part A 48, 1114-1121.

In this study, the performance of a proposed treatment system consisting of an anaerobic process (acidification, methane fermentation) and an aerobic process (trickling filter)was evaluated for treating high concentrations of molasses-based wastewater (43–120 gCOD/L) by a continuous flow experiment. An anaerobic up-flow staged sludge bed (USSB) reactor, equipped with multiple gas solid separators, was used as the main treatment/methane recovery process. The USSB showed good efficiency of both COD removal (80–87%) and methane recovery (70–80%) at an organic loading rate of 11–43 kgCOD/m^3 day. As the influent COD concentration was increased, the organic loading rate for stable operation of the USSB was reduced due to cation inhibition. However, the COD removal efficiency of the whole treatment system (including the aerobic post-treatment process) was 96% even at an influent COD concentration of 120 gCOD/L. Use of the treated wastewater as a fertilizer and/or irrigation-water for sugarcane was evaluated by a field cultivation test. Both growth of sugarcane and emission of greenhouse gases from the field soil were measured. A relatively high methane flux (352 μgCH_4/m^2 h) was observed when the treated wastewater from day 0 was used. By day 3, however, this value was reduced to the same level as the control. In addition, growth of sugarcane was satisfactory when the treated wastewater was used.

The treated wastewater was found to be useful for cultivation of sugarcane in terms of both a low risk of greenhouse gas emission from the field soil and effectiveness for growth of sugarcane.

VI Center for Environmental Biology and Ecosystem Studies

Hiroya YAMANO, Director, Environmental Biology and Ecosystem Studies

1 Overview of research outcomes

1.1 The third NIES five-year plan

The Center for Environmental Biology and Ecosystem Studies (CEBES) was established as one of the eight research centers of the National Institute for Environmental Studies (NIES) on April 1, 2011, to assume a leading role in the nation's basic and applied research in the areas of environmental biology and ecosystems. CEBES collaborates with national, prefectural, and local agencies, nongovernmental organizations (NGOs), and universities to contribute to the accumulation of the scientific knowledge and data necessary for the conservation of biodiversity and ecological services (Fig. 1).

The Biodiversity Research Program aims to clarify the current status of biodiversity, to predict its future, and to propose reliable and effective methods for its conservation on a scientific basis. Our tasks are to develop methods and protocols for monitoring the status of biodiversity at the genetic and landscape levels (Project 1); to assess the state of biodiversity on a broad scale and to analyze scenarios for future predictions (Project 2); and to clarify the effects of anthropogenic disturbances on biodiversity and to determine ways to manage these effects (Project 3).

The Basin Ecosystem Functions Research Program, which is led by the Center for Regional Environmental Research, aims to understand the current status of biodiversity, predict its future, and propose reliable and effective methods for its conservation based on scientific principles.

Young scientists at CEBES are encouraged to apply for internal funding from the Basic Research on Biodiversity and Ecosystems. The topics include: 1) clarification of the mechanisms underlying biodiversity and ecosystems to provide scientific evidence upon which to establish conservation practices; 2) assessment of the impacts of anthropogenic threats to biodiversity and ecosystems; and 3) integration of natural sciences and human/social sciences to investigate the relationships between society and the conservation of biodiversity and ecosystems.

CEBES provides knowledge on biodiversity and ecosystems for Environmental Emergency Research, contributing both to our understanding of the effects of the disaster at the Fukushima Daiichi Nuclear Plant, and support towards recovery and restoration from this disaster.

For Environmental Research Infrastructure, CEBES conducts long-term monitoring programs (of lakes, vulnerable ecosystems in terrestrial Asia, and the distribution of herbicide-resistant oilseed rape plants at roadside sites) and bioresource programs (collection, preservation, and distribution of microbes and endangered algae, and banking genetic resources for threatened species). These can be used as the basic resources and data for various research undertakings.

Finally, CEBES contributes to various international platforms, including the Convention on Biological Diversity (CBD) and the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), and addresses regional/local environmental issues in Asia, including impacts from the compound disasters accompanying the Great East Japan Earthquake (GEJE) of March 2011.

1.2 Research and other outcomes, and self-assessment under the third NIES five-year plan

1.2.1 Research program: "The Biodiversity Research Program" (Fig. 2)

Methods and protocols with which to monitor the status of biodiversity at the genetic and landscape levels have been developed as part of PJ1 in the above diagram. Remote sensing methods have been used to analyze landscape metrics, including habitats and topography. For example, we introduced the Structure from Motion technology to generate digital surface models and orthorectified images. We have prepared land-use and land-cover data that can be used to estimate the spatial distributions of biodiversity and ecosystem services based on vegetation maps. DNA barcoding has been instituted for microalgae, insects, and fish, and these data have been used to analyze environmental DNA collected from lakes. Databases for land use/cover and DNA barcoding are publicly accessible and are frequently utilized by persons affiliated with external institutions, etc.

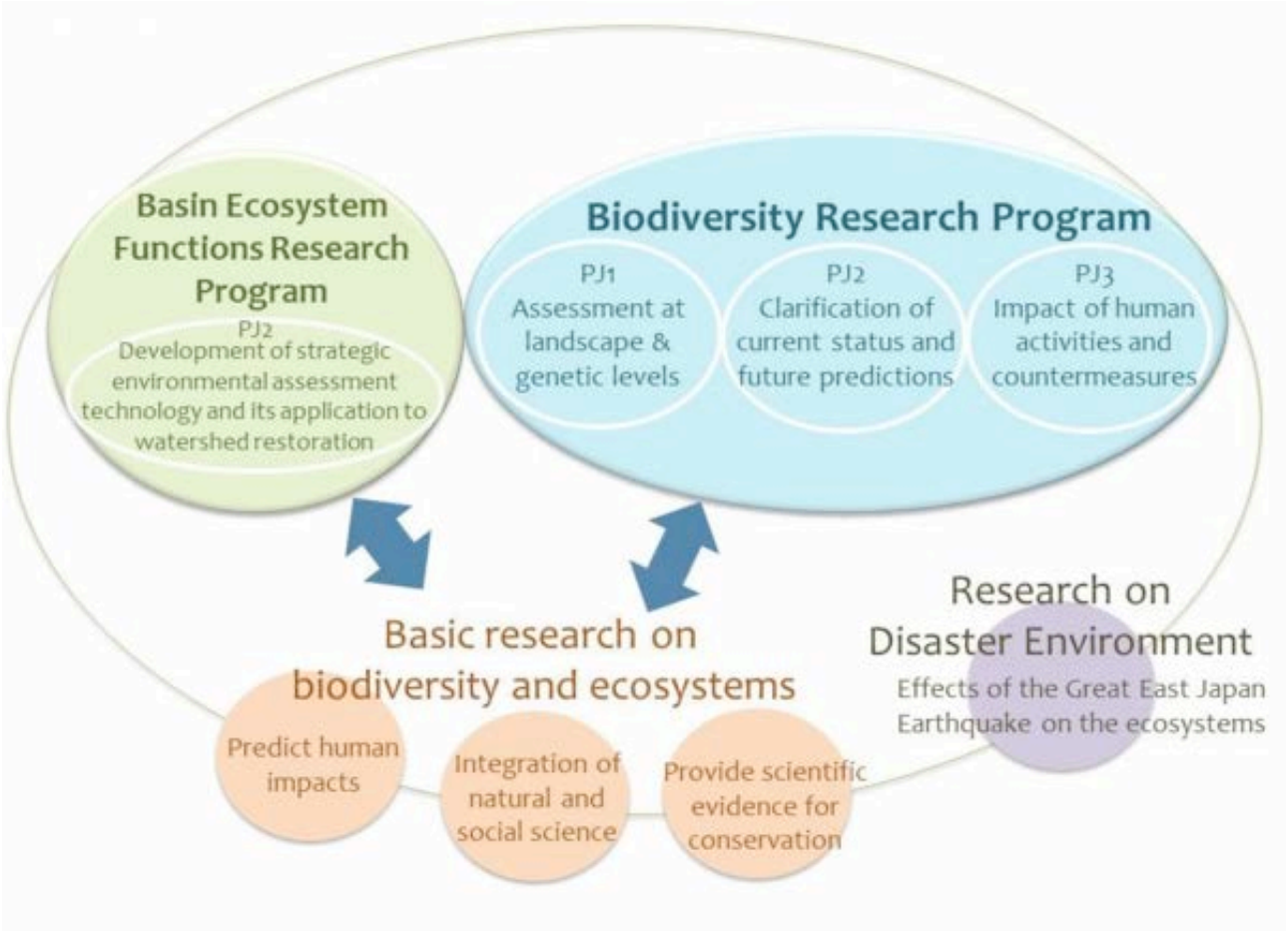


Fig. 1 Programs conducted by CEBES. For information on the Basin Ecosystem Functions Research Program and Environmental Emergency Research, see the data provided by the Center for Regional Environmental Research and the Fukushima Project Office.

Methods to evaluate the current status of biodiversity based on large-scale spatial data, to analyze extinction risks and to establish protected areas have been developed a part of PJ2. We estimated the projected plant species loss at the national level with stochastic simulations based on an extensive population census dataset. We predicted that between 370 and 561 plant species will become extinct in Japan in the next 100 years. Using time-series data, we have shown that the existing national protected areas (PAs), covering ca. 7% of Japan, will not adequately prevent the decline of populations. We have developed a calculation tool for PA prioritization based on the principle of reducing extinction risks. The tool provides more efficient criteria to identify potential PAs when compared with other methodologies, especially when the total areas of the PAs are limited. The biodiversity data generally available is largely inadequate for this purpose. Therefore, we analyzed the effectiveness of conservation area prioritization using limited data. We found that areas of high priority for the preservation of rare species also include common species, but not vice versa. In recent years, the habitat range of deer has been expanding in Japan. Therefore, we reevaluated the spatial priorities for deer management to facilitate the conservation of endangered plants by investigating and projecting their spatial distributions today and into the future. We demonstrated that the sites to be managed will extend to the northern part of Japan as the distribution of the deer population expands.

Emerging issues are investigated as part of PJ3. We have undertaken intensive research into the control and eradication of alien species that have serious ecological and environmental consequences. We assess the effectiveness of eradication methods, and design efficient eradication strategies for each target species. Eradication methods used in Japan have been improved by creating an eradication network. We have developed chemical eradication methods for two invasive alien arthropods, the Argentine ant, *Linepithema humile*, and the European bumblebee, *Bombus terrestris*. Using these methods, we have successfully eradicated the Argentine ant populations in Tokyo. We have also estimated the eradication probability for the mongoose *Herpestes auropunctatus* on Amami Island. A simulation study indicated that the eradication feasibility in 2023 would exceed 90% if the annual capture effort afforded in 2010 is maintained.

Emerging infectious diseases are reducing biodiversity on a global scale. Our research has focused on two infectious diseases, avian influenza and amphibian chytrid fungi. We have created a potential risk map, based on ecological variables, for the avian influenza A virus' infiltration into Japan and estimated that western Japan and the Pacific coast were high-risk areas. We have studied the origin and expansion process of the amphibian chytrid fungus. This pathogen probably originated in and has coexisted for millions of years with a clade of salamander hosts in Asia. Climate change is affecting the functions and distribution of many organisms, and we investigated two sensitive ecosystems, coral reefs and alpine ecosystems.

Japan represents an ideal setting in which to examine the changes in coral reef ecosystems because its coral covers a wide latitudinal range, from subtropical to temperate areas, and the Japanese islands occur within the latitudinal limits of coral reefs and coral distributions. Therefore, it is possible to examine the range expansion of corals in Japan. We selected the Qinghai–Tibetan Plateau, China, to study alpine ecosystems, at altitudes up to 5500 m. The results of monitoring and future projections show that these ecosystems respond dramatically to climate change.

We have encountered no significant delays and/or problems in conducting our researches. Our results have been cited in the CBD National Report (Japan), Global Biodiversity Outlook 4, and the IPCC 5th Assessment Report. Three CEBES researchers have been selected as experts by IPBES. We have also established an agreement with the International Union for Conservation of Nature - Japan Committee (IUCN-J) to apply our results to conservation activities. Although these negotiations are still in progress, we believe that forthcoming collaboration with NGOs will prove important.

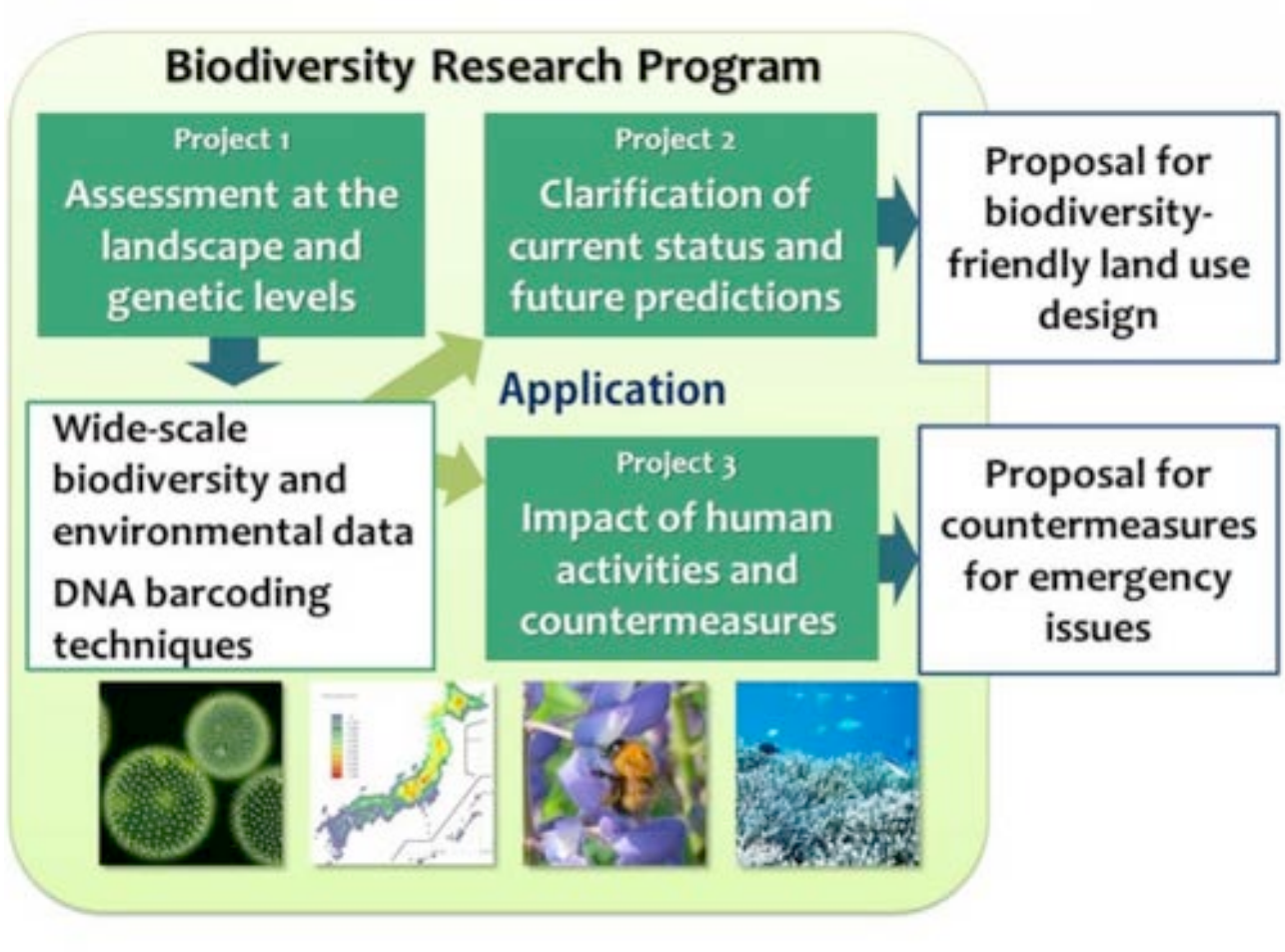


Fig. 2 Overall structure of the Biodiversity Research Program.

1.2.2 Environmental Research Infrastructure

1.2.2.1 Collection, preservation, and distribution of microbes and endangered algae

The Microbial Culture Collection at the National Institute for Environmental Studies (MCC-NIES) has three major functions: the collection of important microbial strains for life science and environmental studies; the stable maintenance of these strains; and the dissemination of these strains in response to users'

requests. During the third NIES five-year plan (2011–2015), MCC-NIES has:

1) accepted the deposition of 419 strains from researchers and has made 2,473 strains (including endangered macroalgal species) available on its website for distribution;
2) consistently distributed more than 1,000 strains per year, resulting in 257 English publications (average impact factor, 2.93);
3) efficiently maintained strains, optimizing the cryopreservation methods for barely cryopreservable species, facilitating the successful cryopreservation of ca. 500 strains;
4) developed a risk management strategy for the collection, in collaboration with two other facilities, facilitating the back up and maintenance of 1,586 cryopreserved strains in Kobe University's macroalgal collection and 436 subcultured strains at Hokkaido University;
5) undertaken more than 10 research projects related to the MCC-NIES, most of which have informed the collection of important strains and provided complementary additional information.

1.2.2.2 Genetic resource banking for threatened species

The cryopreservation of genetic resources, such as germ cells, somatic cells, and tissues, in genetic resource banks is one option in strategies for *ex situ* conservation. NIES has maintained genetic resource banks for endangered species since their establishment in 2002. Approximately 2,500 specimens were accepted in the period between April 2002 and September 2014, and 45,000 tubes containing genetic resources had been cryopreserved as of September 2014. Cultured cells from the last Japanese crested ibis (*Nipponia nippon*), which was previously distributed in Japan, are included in our collection. In addition to genetic resource cryopreservation for domestic endangered species, NIES has been introducing their genetic resource banking system to other Asian countries since 2011, given that the many biodiversity hotspots in Asia currently have no cryopreservation facilities.

1.2.2.3 Long-term monitoring

Lake monitoring: We conduct three monitoring projects (GEMS/Water (Global Environmental Monitoring System/Water Program) National Focal Point, monitoring Lake Kasumigaura, monitoring Lake Mashu), in cooperation with the Center for Regional Environmental Research and the Center for Environmental Measurement and Analysis. To increase data availability and data users, during the period of the current five-year plan, we redesigned our web databases and strengthened our relationships with international observation networks by providing them with our data. We have also developed effective monitoring methods and genetic analyses. Using long-term monitoring data, we have examined the effects of exotic fish species on native fish community structures and fisheries. We began to monitor radioactive cesium concentrations in the freshwater biota of Lake Kasumigaura soon after the accident at the Fukushima Daiichi Nuclear Power Plant.

Vulnerable ecosystems in terrestrial Asia: We have established a long-term monitoring system to observe the physical environments, plant biodiversity, and ecosystem functions of five vulnerable ecosystems in terrestrial Asia. The monitoring sites include a steppe grassland in Mongolia, an alpine meadow and wetland on the Qinghai–Tibetan Plateau, tropical forests in Malaysia, and alpine meadows in Japan. We have identified large differences in the phenological responses and population sizes of different alpine species on the Qinghai–Tibetan Plateau. We have also optimized several approaches to the scaling-up of observational results for these sites to regional assessments using satellite data.

Distribution of herbicide-resistant oilseed rape at roadside sites: The expanding population sizes of escaped genetically modified (GM) oilseed rape plants have raised concerns about their harmful effects on domestic species and the introgression of transgenes into the genomes of wild plant populations. Therefore, we have focused on this escape phenomenon to evaluate the environmental impacts of GM oilseed rape. We conducted a census of the oilseed rape plants growing along Route 23 of Mie Prefecture, Japan; recording the number of oilseed rape plants in five predetermined sectors every 2 weeks for 3 years (from October 2009 to October 2012). Plants grew throughout the year during the period of our survey, and flowering plants were recorded in winter. Plant numbers were highest in March and April, decreased dramatically in June following road cleaning, and were lowest in August. Although the plants never disappeared completely, their numbers gradually recovered from September. These observations suggest that the seeds of oilseed rape were dropped from vehicles used in their transportation.

1.2.2.4 Databases for biodiversity and ecosystems

We maintain 12 databases, including those pertaining to invasive alien species; the occurrence records of particular organisms; agricultural ponds; land use/cover; and DNA barcoding. We also contribute data to the Global Biodiversity Information Facility (GBIF) and the Ocean Biogeographic Information System (OBIS).

1.2.3 Other Research

We conduct a variety of research projects to facilitate the conservation of biodiversity, many of which involve significant contributions and have been initiated by young researchers. These studies include those which aim to:

- identify the mechanisms underlying highly productive mangrove ecosystems;
- establish a Bayesian isotope mixing model for the dietary analysis of whole food webs;
- estimate the population decline of an endangered shrub species;
- assess the conservation value of remnant forests used by indigenous communities in Borneo;
- produce a simulation using a new ecosystem model for the Ogasawara Islands, Japan;
- perform an ecological risk assessment of neonicotinoid insecticides;
- examine the natural adaptation of terrestrial plants to water deficiency.

Socioeconomic issues must be considered if we are to successfully conserve biodiversity. Land use change is a major example of such issues. Three examples of studies initiated on topics related to land use are: 1) a consideration of catchment-to-reef continua and agricultural factors when establishing appropriate land-based management plans for the conservation of island environments; 2) an examination of the effects of historic land use on present-day mammal distributions in Japan; and 3) development of an index for the assessment of biodiversity in agricultural landscapes based on land-cover heterogeneity.

Twenty-four projects proposed by young researchers have been approved and 12 peer-reviewed papers published. Some of these projects were developed with the aim of receiving external funding. We believe that this is a strong indication of the success of our efforts to incubate research by young scientists.

2 Research budget, human resources, and papers during the third NIES five-year plan

2.1 Research budget per each fiscal year

	FY2011	FY2012	FY2013	FY2014	FY2015
Grant for Operating Costs	242	244	253	341	295
Other External Research Funding	274	332	279	285	TBD
Total	516	576	532	626	295

(Unit: million yen)

2.2 Human resources

Cumulative total number of staff during the third five-year plan: 567

2.3 Total number of papers and conference presentations during the third five-year plan

Papers		Books	Presentations		Patents
Peer Review	Others		Domestic	International	
275	45	48	553	81	2

2.4 Major papers and patents (up to 5)

(1) Fukasawa K., Miyashita T., Hashimoto T., Tatara M., Abe S. (2013) Differential population responses of native and alien rodents to an invasive predator, habitat alteration and plant masting. Proceedings of the Royal Society B: Biological Sciences, 280:20132075. doi:10.1098/rspb.2013.2075.

(2) Kadoya T., Takenaka A., Ishihama F., Fujita T., Ogawa M., Katsuyama T., Kadono Y., Kawakubo N., Serizawa S., Takahashi H., Takamiya M., Fujii S., Matsuda H., Muneda K., Yokota M., Yonekura K., Yahara T. (2014) Crisis of Japanese Vascular Flora Shown By Quantifying Extinction Risks for 1618 Taxa. PLOS ONE, 9 (6), e98954. doi: 10.1371/journal.pone.0098954

(3) Martel A., Blooi M., Adriaensen C., Van Rooij P., Beukema W., Fisher M.C., Farrer R.A., Schmidt B.R., Tobler U., Goka K., Lips K.R., Muletz C., Zamudio K.R., Bosch J., Lötters S., Wombwell E., Garner T.W.J., Cunningham A.A., Spitzen-van der Sluijs A., Salvidio S., Ducatelle R., Nishikawa K., Nguyen T.T., Kolby J.E., Van Bocxlaer I., Bossuyt F., Pasmans F. (2014) Recent introduction of a chytrid fungus endangers Western Palearctic salamanders. Science, 346 (6209), 630-631. doi:10.1126/science.1258268

(4) Matsuzaki SS., Kadoya T. (in press) Trends and stability of inland fishery resources in Japanese lakes: introduction of exotic piscivores as a driver. Ecological Applications. doi:10.1890/13-2182.1

(5) Yara Y., Vogt M., Fujii M., Yamano H., Hauri C., Steinacher M., Gruber N., Yamanaka Y. (2012) Ocean acidification limits temperature-induced poleward expansion of coral habitats around Japan. Biogeosciences, 9 (12), 4955-4968. doi:10.5194/bg-9-4955-2012

VII Center for Environmental Health Sciences

Keiko NOHARA, Director, Center for Environmental Health Sciences

1 Overview of Research Outcomes

1.1 The third NIES five-year plan

1.1.1 Aim of the research:

To reduce or prevent adverse health effects caused by environmental factors, better understanding of any effects and their underlying mechanisms are pivotal. In the Center for Environmental Health Sciences, we perform **experimental toxicology studies** to find, confirm, and assess various health effects of environmental factors and explore the modes of action/the molecular mechanisms, and perform **epidemiological studies** to find and assess the effects of environment on human health and any causal factors.

In our experimental studies, we also develop effective methods to experimentally detect health effects, such as those on immune function, allergy augmentation and neurotoxicity, caused by environmental factors. Regarding the mechanisms, our particular focus is on epigenetics. In our epidemiological studies, we also develop improved epidemiological methods and applications for estimating and assessing the health effects of harmful environmental exposure. We conduct exposure studies, including human biomonitoring and exposure factors research.

The Ministry of the Environment (MOE) established a nation-wide, long-term birth cohort study **"The Japan Environment and Children's Study (JECS)"**, aimed at elucidation of environmental factors that affect children's health and development, and started recruitment of expectant mothers in 2011. In the same year, **the National Center for JECS** was established in our center. It promotes the project by planning and coordinating the study, managing the work of participating institutions, organizing and managing data, and analyzing and preserving materials.

1.1.2 Organizational structure:

The Center for Environmental Health Sciences consists of four **basic research sections**: Molecular Toxicology Section, Biological Impact Research Section, Environmental Epidemiology Section, and Integrated Health Risk Assessment Section. In the **Molecular Toxicology** and **Biological Impact Research Sections**, experimental studies are the main topic of research. The **Environmental Epidemiology Section** focuses on atmospheric pollutant epidemiology. The **Integrated Health Risk Assessment Section** performs exposure science and integration of exposure and effects analysis.

The Environmental Epidemiology Section and the Integrated Health Risk Assessment Section concurrently manages **the National Center for JECS,** in cooperation with administrative staff.

1.1.3 Research activities: (Fig. 1)

We lead one of **the NIES Advanced Research Programs**, the "Research Program on Environmental Health for Children and Future Generations".

There is great concern about the effects of environmental chemical exposure on fetuses and children, since they are known to be vulnerable to a variety of environmental chemicals. In this program, we study issues that should be solved by epidemiological studies and experimental studies, with the main focus on such chemical exposure.

In Project 1, we perform studies for the improvement of epidemiological studies and exposure studies on the health effects caused by environmental pollutants. In Project 2, we perform 1) experimental toxicology studies on the effects of chemical exosure on allergic inflammation focusing on juvenile exposure, and 2) experimental studies on the late-onset effects of gestational arsenic exposure on tumor augmentation and energy metabolism. Regarding the mechanisms, we focus on epigenetics. (see 1.2.1)

In March 2014, **JECS** achieved the enrollment of over 103,000 pregnant women. Exposure measurements started in 2015. (see 1.2.2)

Researchers affiliated with our center also carry out many **other studies,** including research on a variety of environmental chemicals, metals, atmospheric pollutants, $PM_{2.5}$, and nanomaterials, funded internally, by MOE, or organizations, such as the Ministry of Health, Labour and Welfare (MHLW) and the Ministry of Education, Culture, Sports, Science and Technology (MEXT). **International cooperative studies** with Asian countries are also one of our research activities. We provide expertise to the **Environmental Emergency Research** group who investigate impacts of the Great East Japan Earthquake and the Fukushima Daiichi Nuclear Power Plant accident of March 2011. (see 1.2.3)

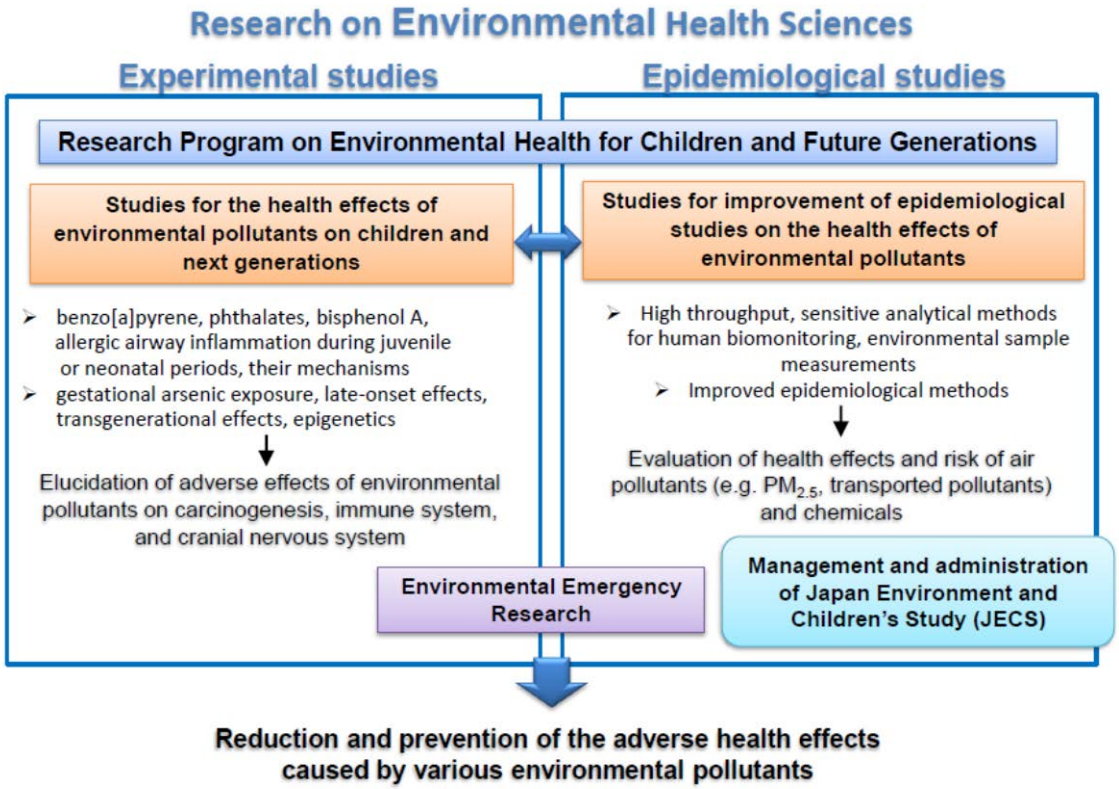


Fig. 1 Research activities at the Center for Environmental Health Sciences

1.2 Research and other outcomes, and self assessment under the third NIES five-year plan

1.2.1 NIES Advanced Research Program "Research Program on Environmental Health for Children and Future Generations"

1.2.1.1 Project 1: Studies for improvement of epidemiological studies on the health effects of environmental pollutants

In Project 1, we developed high-throughput and sensitive analytical methods for human biomonitoring and environmental sample measurements. A food frequency questionnaire specific to children that aims to measure not only nutrients but also exposure sources, was also developed. A new statistical method was explored to evaluate temporal variables of dependent, independent, and confounding factors. The combination of the advancement of exposure measurements and statistical models contributes to large-scale epidemiological studies such as JECS.

Recently, a new research paradigm "exposomics" is at the forefront of our research, in cooperation with international collaborators. Major achievements are described in section VII. 2 of the Detailed Report.

1.2.1.2 Project 2: Mechanism and evaluation studies on the effects caused by environmental pollutants on the health of children and the next generations

In Project 2, we performed intensive experimental studies assesing the effects of the chemicals that ubqiutusly exist in our daily environment (benzo[a]pyrene (BaP) etc.) on the immune system, focusing on inflammation, and assesing the effects of arsenic on tumor augmentation and the nervous system. We focused on gestational exposure and juvenile exposure. These studies demonstrated important novel findings.

In Subtheme 1 of Project 2, we investigated the effects of exposure to the environmental chemicals, BaP, di(2-ethylhexyl)phthalate (DEHP), diisononyl phthalate (DINP), and bisphenol A (BPA), throughout juvenility until adulthood or during neonatal periods, on allergic airway inflammation, and their mechanisms. Major results were the aggravation enhancement of allergic airway inflammation by intratracheal exposure to BaP and BPA throughout juvenility until adulthood. We clarified that exposure to environmental chemicals may aggravate allergic airway inflammation by stimulating the differentiation/activation of immune cells and enhancing Th2 responses. The results are described in section VII. 3 of the Detailed Report.

In Subtheme 2 of Project 2, we investigated the late-onset effects of gestational arsenic exposure, mainly focusing on tumor augmentation and the central nervous system. We also investigated the transgenerational effects of arsenic in the F2 generation.

Previous studies reported that gestational arsenite exposure of pregnant C3H mice, whose males are predisposed to spontaneously develop hepatic tumors later in life, increases hepatic tumors in the F1 male offspring. Using the same experiment model, we showed a variety of tumor augmenting changes, and epigenetic changes. We further demonstrated the multigenerational/transgenerational effects of gestational arsenic exposure on tumor augmentation. The results are described in section VII. 4 of the Detailed Report.

We performed experiments to assess whether the gestational exposure to arsenic impairs the development of the central nervous system in mouse models *in vivo* and *in vitro*. In our *in vivo* model, we developed an evaluation task for detecting behavioral flexibility in mice in an IntelliCage (NewBehavior AG, Zurich, Switzerland), and revealed that behavioral flexibility is impaired in the mice exposed gestationally to arsenic. We also found using histological methods that neurite outgrowth in the mouse cerebral cortex is suppressed by the exposure to arsenic. In addition, we established primary cultures of neurons and astrocytes taken from perinatal mouse brains and evaluated the effects of arsenic on cellular function. We demonstrated that arsenic blocks neurite outgrowth by suppressing the expression of the glutamate receptor GluA1 in primary culture of neurons. In primary culture of astrocytes, we detected that the cell cycle of astrocytes is dysregulated by exposure to arsenic. These results suggest that arsenic has an adverse impact on both neurons and astrocytes in the brain during development. The results of those studies are described in section VII. 5 of the Detailed Report.

1.2.2 Environmental Research Infrastructure "JECS Core Center (National Center for The Japan Environment and Children's Study)"

NIES hosts the Program Office (Core Center) for the JECS study. It organizes the Steering Committee, Advisory Committees, and Liaison Conferences with local study partners. The Program Office runs a data management center that maintains all personal data and measurement results of JECS. Communication materials are published by the Program Office (Kawamoto et al., BMC Public Health, 2014). A summary of the activities is given in section VII. 6 of the Detailed Report.

1.2.3 Other research

Studies supported by NIES, MOE, MEXT, MHLW etc.

1.2.3.1 Epidemiological studies of health effects of air pollutants: Supported by MOE and MEXT

In this field, the focus included the adverse health effects of long-range-transported air pollutants such as Asian dust, local air pollution such as traffic related air pollution, and short-term exposure to air pollution/ meteorological factors such as particulate matter (PM)/ extreme temperature. Major results were described in section VII. 1 of the Detailed Report.

The projects in which we have been involved show that Asian dust was associated with incidence of cardiovascular diseases; traffic-related air pollution was associated with development of asthma in school children; exposure to extreme temperatures increases human mortality; exposure to $PM_{2.5}$ was associated with emergency ambulance dispatches in general. However, there was no clear association between long-term exposure to PM and mortality/incidence of lung cancer, there was also no clear association between long-term exposure to PM and mortality/incidence of coronary heart disease.

Results of these studies have contributed to the discussion on revision of air quality standards, and many epidemiologists in our center have been invited to join committees to draft revised air quality standards by

the Ministry of the Environment, Japan.

1.2.3.2 Experimental studies: Supported by NIES, MOE, MEXT, MHLW etc.

We conducted research on a variety of environmental factors, including chemicals (phthalates, BPA, polycyclic aromatic hydrocarbons (PAHs), brominated flame retardants (BFRs), etc.), arsenic, nano particles, $PM_{2.5}$, Diesel exhaust origin secondary organic aeroso (DE-SOA), and Asian dust. We assessed their effects on immune function/allergy/inflamation, brain function, energy metabolism and tumorigenesis, mainly in mice. We also investigated their mechanism *in vivo* and *in vitro*. We applied state-of-the-art analytical methods, such as RRBS (Reduced representative bisulfite sequencing) analysis for DNA methylation status, and Exome analysis for genome-wide mutation analysis.

The major results are given below:

Environmental chemicals (phthalates, BPA, PAHs, BFRs, etc.)

- We clarified that BFRs can disrupt the expression of proinflammatory proteins in bronchial epithelial cells, possibly via the modulation of intracellular signaling pathways.
- We revealed that exposure to hexabromocyclododecane, a brominated flame retardant, contributes to metabolic dysfunction via an interaction with diet, resulting in accelerated progression of obesity.
- We clarified that some PAHs and PAH derivatives can induce cytotoxicity and activation in bronchial epithelial cells and immune cells. The toxicological effects may be related to the chemical structures and modulation of intracellular signaling pathways.
- We clarified that environmental chemicals (benzo[a]pyrene or phthalates) can activate T-cells mediated by promotion of antigen-presenting cell signals, which can be responsible for the aggravation of allergies.
- We analyzed the developmental toxicity of phthalate esters by using mouse induced pluripotent stem (iPS) cells. This *in vitro* system will be a useful tool for assessing the embryonic toxicity of various environmental pollutants.

Arsenic

- We revealed the involvement of impaired glutamate receptor expression in the mechanism of arsenic disturbance of the neurite outgrowth in primary culture of neurons.
- We revealed that histone modification is associated with the decreased expression of the tumor suppressor $p16^{INK4a}$ by arsenic in human urothelial cell lines. Our results contributed to elucidation of the mechanisms of arsenic-induced carcinogenesis.
- We revealed that the DNA methylation of oncogene *Fosb* is changed by arsenic, and that change is involved in *Fosb* expression by arsenic in Hepa1c1c7 cells. Our results contribute to elucidation of the expression regulation of *Fosb* and the mechanism of arsenic-induced carcinogenesis.
- We investigated that distribution and excretion of arsenic in non- or antibody-treated rats orally administered with dimethylarsinic acid (DMA^V). The results suggest that DMA^V was metabolized to sulfur-containing dimethylarsinic compounds by intestinal bacteria. The metabolite should be the focus of future investigations of the health risks of arsenicals.
- The results of other studies on the health effects of arsenic were described in section VII. 4 of the Detailed Report.

Air-pollutants

- Developmental exposure to diesel engine exhaust origin SOA (Secondary Organic Aerosol) may affect olfactory-based spatial learning behavior in preweaning mice by modulating c-AMP signaling pathway genes and the inflammatory markers in the olfactory bulb.
- We showed that gestational and lactational exposure (GD13 to PND 21) to DE-SOA) affects the immune system and central nervous system in offspring.
- We showed that PM2.5 and Asian dust from China causes inflammatory responses in lung cells mainly through endotoxin, suggesting the involvement of respiratory diseases in materials adsorbed on the particles.
- We clarified that Asian dust can activate bronchial epithelial cells and immune cells. These effects were associated with chemical and microbiological factors absorbed to Asian dust.

Nanoparticles

- Nanoparticle-rich diesel exhaust exposure affects spatial and non-spatial learning ability by modulating the glutamate metabolism –related gene expression in the hippocampus of mice.

Others

- Polyamidoamine (PAMAM) dendrimers may reach the brain via the systemic circulation or an olfactory nerve route after intranasal instillation, and may lead to neuronal effects by modulating the gene expression of brain-derived neurotrophic factor signaling pathways.
- Exposure to radio frequency electromagnetic fields (RF-EMF) from mobile phones showed transient changes of memory function-related genes and neuro-immune markers in the hippocampus of adult mice.
- Retrotransposon LINE-1, a biomarker of exposure to environmental chemicals, is found to be sex-dependently expressed in the mouse brain.
- It has been demonstrated that the composition of sex chromosomes in the brain affects sexual differentiation in the chicken brain, at least in part.
- We studied the differentiation of mouse iPS cells into lung component cells, such as epithelial cells and macrophages. This experiment will lead to novel alternative experiments to animal experiments for evaluating the toxicities of ambient pollutants.
- We found that the DNA methylation status is strictly controlled by the balance between the DNA methylation /active demethylation pathways, despite the upregulation of the active DNA demethylation pathways by a methyl-deficient diet.

We have clarified a variety of unique and novel findings on the health/biological effects of environmental chemicals and other pollutants, using sophisticated methods which we have established. These findings will help in the understanding of the hazardous effects of the pollutants, and lead to the implementation of preventative measures. They also provide evidence to support validity of epidemiological studies, such as JECS, and provide evidence for assessing the health risk of the pollutants.

1.2.3.3 NIES Environmental Emergency Research

The Integrated Health Risk Assessment Section is one of the leading groups involved in the Environmental Emergency Research initiated in the immediate aftermath of the composite disasters of March 2011. The section provides the research group with public health expertise: exposure modelling for excessive dose caused by crippled nuclear plants in Fukushima; exposure assessment for chemical and biological agents after environmental emergencies; and cell line based reporter gene assays for identifying acute and chronic ecological and human health effects of the emergency. The research supports improved government planning and implementation of emergency response strategies. It has also contributed to other countries' emergency response research such as in the United States, Korea and China.

1.2.3.4 Leading hub for international collaboration: Supported by NIES

We contribute to international research collaborations as a hub for research on: 1) arsenic pollution in Asia and 2) integrated exposure and effects analysis. In order to illustrate arsenic pollution and its health impact in Asia, e.g. Bangladesh and Myanmar, we invited researchers to hold workshops and seminars as well as technology transfer for a DNA methylation measurement. To respond to an international movement to assess exposure and its biological effects simultaneously, we funded and organized the first international workshop on the Integrated Exposure and Effects Analysis (IEEA) in 2012. The workshop was well attended by Asian, North American, and European researchers. The second workshop was organized in the U.S. by the U.S. Environmental Protection Agency in 2013. Asian workshops were held in 2014 and 2015.

2 Research budget, human resources, and papers during the third NIES five-year plan

2.1 Research budget per each fiscal year

	FY2011	FY2012	FY2013	FY2014	FY2015
Grant for Operating Costs	132	146	133	223	187
The National Center for JECS	4,445	2,398	2,830	3,439	1,983
Other External Research Funding	69	67	40	29	33
Total	4,646	2,611	3,003	3,691	2,203

(Unit: million yen)

2.2 Human resources

Cumulative total number of staff during the third five-year plan: 267

2.3 Total number of papers and conference presentations during the third five-year plan

Papers		Books	Presentations		Patents
Peer Review	Others		Domestic	International	
110	30	4	246	55	4

2.4 Major papers and patents (up to 5)

(1) Maekawa, F., Tsuboi, T., Oya, M., Aung, K.H., Tsukahara, S., Pellerin, L., Nohara, K. (2013) Effects of sodium arsenite on neurite outgrowth and glutamate AMPA receptor expression in mouse cortical neurons. Neurotoxicology 37, 197-206.

(2) Win-Shwe TT, Yanagisawa R, Koike E, Nitta H, Takano H. (2013) Expression levels of neuroimmune biomarkers in hypothalamus of allergic mice after phthalate exposure. J Appl Toxicol. 33(10):1070-8.

(3) Yanagisawa R, Koike E, Win-Shwe TT, Yamamot M, Takano H. (2014) Impaired lipid and glucose homeostasis in hexabromocyclododecane-exposed mice fed a high-fat diet. Environ Health Perspect. 122(3):277-83.

(4) Michikawa et al. (2015) Impact of short-term exposure to fine particulate matter on emergency ambulance dispatches in Japan. J Epidemiol Community Health 69:86-91.

(5) Nohara, K., Okamura, K., Suzuki, T., Murai, H., Ito, T., Shinjo, K., Takumi, S., Michikawa, T., Kondo, Y., Hata, K. (in press) Augmenting effects of gestational arsenite exposure of C3H mice on the hepatic tumors of the F2 male offspring via the F1 male offspring. J Appl. Toxicol.

VIII Center for Social and Environmental Systems Research

Tsuyoshi FUJITA, Director, Center for Social and Environmental Systems Research

1 Overview of research outcomes

1.1 The third NIES five-year plan

The Center for Social and Environmental Systems Research focuses on links between human activities and the natural environment to identify the relationships between socioeconomic systems and environmental issues. Covering broad areas, from global environmental issues, such as global warming mitigation and adaptation, to local issues such as recycling and lifestyles, we aim to contribute to the realization of a sustainable society. Under the third NIES five-year plan, investigations and research are conducted on the aforementioned issues from a broad perspective, and once these have been clarified we endeavor to propose appropriate measures and policies for their implementation.

Specifically, we develop theories and methodologies towards the realization of sustainability in both Japanese and international societies; construct scenarios and visions and examine desirable forms of sustainable production and consumption. Models are developed for environmental, societal, and economic application, to issues affecting both Japan and other countries. These are used to analyze current circumstances and status in relation to these factors as well as related policies.

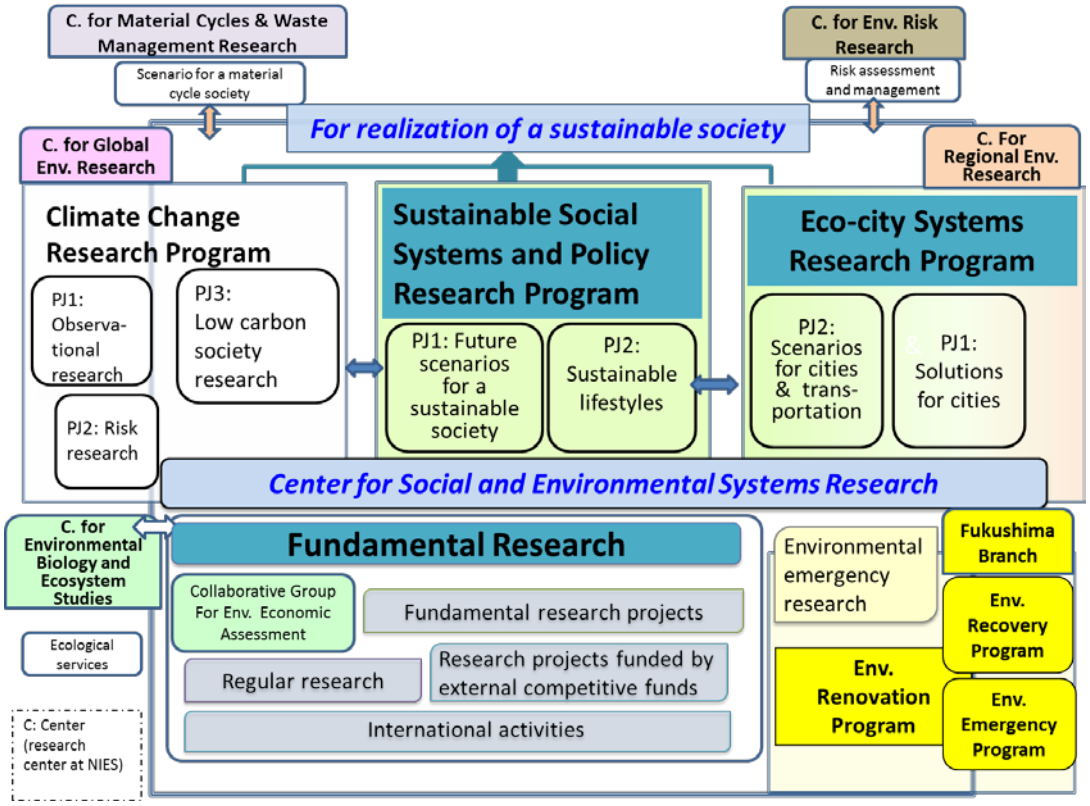


Fig. 1 Structure of research at Center for Social and Environmental Systems Research

The studies focus on aspects such as the following (a) construction of sustainable societies; and roadmaps and measures towards their realization, (b) examination of desirable forms of sustainable cities, and (c) design of systems for co-beneficial, environmentally friendly cities and for model related pilot experiments. Fundamental research for these studies includes surveys on environmental consciousness; social- and science-based communication; economic evaluation and verification of the effects of environmental policies and system design.

The following perspectives are maintained in the course of the research described above:

1) Analysis of social and economic visions as the driving force behind and the basis for future scenarios for sustainable societies. Such analyses adopt a scenario-based approach and qualitatively and quantitatively present measures and desirable forms of society and economy, as well as consumption and the lifestyles

required to realize a sustainable society, taking possible future environmental issues into consideration.

2) Development and provision of environmental solutions comprising co-beneficial technologies and measures to reduce anthropogenic impacts and improve socioeconomic systems, including planning approaches and evaluation methods. This is achieved on the basis of environmental simulations to analyze the effects of the anthropogenic environmental load on environmental resources and urban activities. To contribute to the planning of sustainable cities and regions, we are also elucidating the spatial structure of these areas and presenting scenarios for their realization via roadmaps.

3) Development and application of integrated assessment models and environmental-economic models to the activities described in 1) and 2) above, as well as to domestic and international issues in an effort to understand current circumstances and relevant policies. We implement research to verify the effects of, and economically evaluate, environmental policies and system design.

1.2 Research and other outcomes, and self assessment under the third NIES five-year plan

1.2.1 Research programs

1.2.1.1 Sustainable Social Systems and Policy Research Program

Toward the achievement of a sustainable society, our tasks are to develop medium- and long-term visions for Japan, formulate scenarios to achieve these goals, and create policy roadmaps, as well as elucidate specific strategies to promote the transformation of society. From the perspective of future scenarios for a sustainable society, descriptive socioeconomic scenarios based on sustainable development goals are being developed with an emphasis on the driving forces underlying environmental issues as well as the concepts and trends of indicators of sustainability. In addition, as transformation strategies, sustainable development indicators and a comprehensive plan within a municipality are provided and the attendant issues clarified. The consistency of the models for socioeconomic activities in nine subregions of Japan has been verified based on quantitative evaluations for the scenarios.

From the perspective of sustainable lifestyles and consumption patterns, the “sustainable lifestyle scenario 2030” has been developed in this research and it has been verified that this scenario is consistent with everyday lifestyles. This has been achieved by means of focus group interviews, a questionnaire survey, and workshops. Moreover, we have published a series of interviews with experts in the fields of social design, labor economics, social welfare, and family sociology which relate to our scenario in an online magazine with a young readership having a high awareness of environmental issues.

The aim of these activities is to realize a vision for actions by individuals and households to construct a sustainable society from the viewpoint of consumption. Our scenarios, indicators, and models for the advancement of sustainability and the achievement of sustainable development are expected to contribute to policies for both basic and comprehensive environmental plans, as well as to the establishment of new research fields.

[1] Project 1: Development of future scenarios for a sustainable society

1) Through comprehensively classifying the themes and contents of 10 fields related to the achievement of sustainability, key aspects for maintaining sustainability have been identified.
2) This research has both identified the desire of Japanese people today to sustain the country’s medical and health care systems and bequeath these to future generations, and their significant concerns regarding evaluation criteria such as efficiency and security.
3) For the verification of transformation strategies to achieve a sustainable society based on previously developed sustainable development goals, the following needs have been identified: a) to increase the ratios of environmental goals in the comprehensive plan of the municipality being studied, b) to promote the quantification and coordination of social goals, and c) to advance the integration of goals and targets through weighting. We are promoting research collaboration to facilitate the adoption of our outcomes by the municipality.
4) Based on previously developed multiple area models for Japan, data on air pollution, water pollution, chemical substances, and potential renewable energy sources have been organized and models have been extended to obtain a future outlook and realize quantification. Henceforth, the quantification of sustainability scenarios will be undertaken.

[2] Project 2: Social transformation toward sustainable lifestyles and consumption patterns

1) For the purpose of disseminating and verifying the scenarios developed under this project, a website in both Japanese and English versions has been created and Japanese and English language leaflets have been published.
2) For verification of our sustainable lifestyle scenario 2030, focus group interviews and an online survey were conducted to obtain evaluations by ordinary people. The results of these activities showed that the "eight basic trends" of our scenario were accepted by the respondents in the focus groups, but the "four future lifetyle scenarios" received some negative responses. In addition to these activities, we also organized a workshop and conducted interviews of socially active people by experts.
3) Based on the sustainable lifetyle scenarios we developed here, we organized a group of people from companies in the fields of toiletry products, food, beverages, housing, and robotics, as well as experts in the areas of work-life balance, robotics, and information technology, and discussed and developed the "2025 everyday life scenarios."

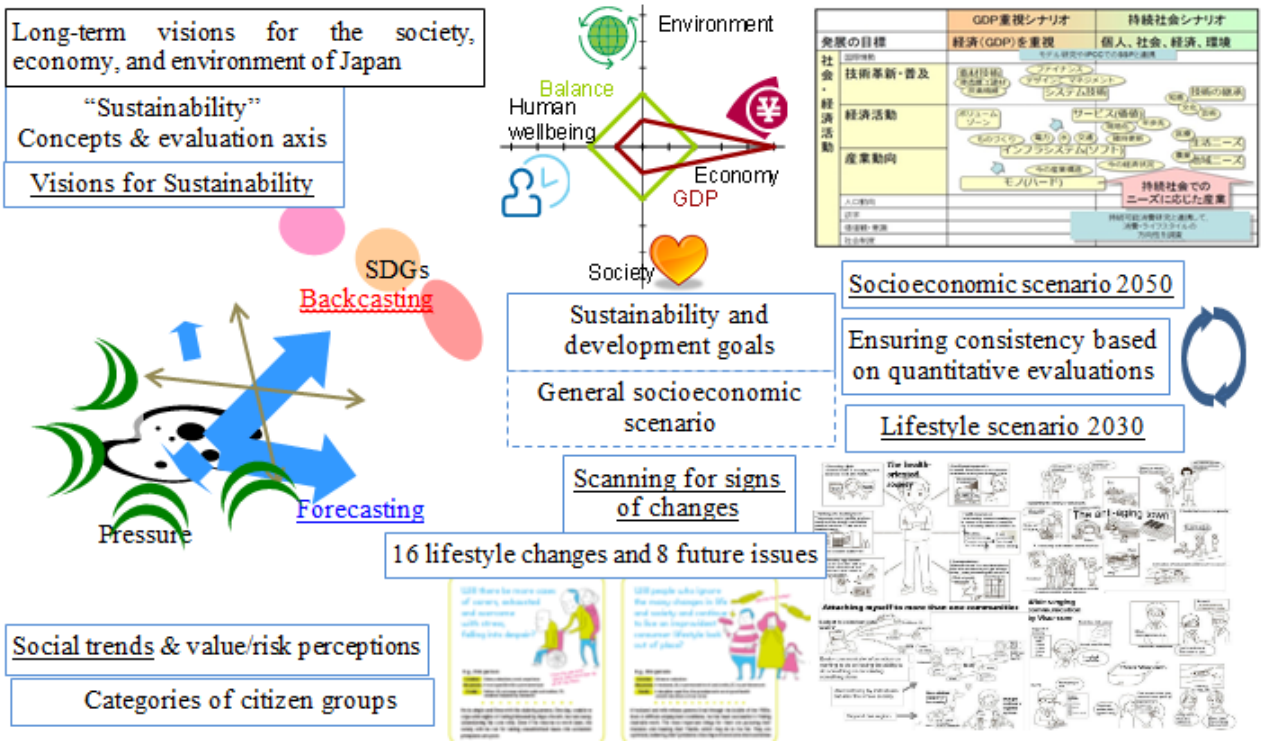


Fig. 2 Future scenarios for a sustainable society (PJ1) and lifestyle scenarios (PJ2)

1.2.1.2 Eco-city Systems Research Program

In the Eco-city Systems Research Program, methods of planning and evaluation to realize effective environmental technologies and policies at the regional and city levels are being developed. These methods will reveal pathways to achieve future targets for significant reductions in environmental loads and prevention of further deterioration of the natural environment. The program consists of two projects.

Project 1 aims to develop a system for the planning and evaluation of co-benefit type alternative technologies that can simultaneously improve the environment, ecosystems, and the economy. Through this research, a solution system based on a package of technologies and policies will be provided to promote the implementation of such technologies in cities in Japan and other Asian countries.

Project 2 has the objective of formulating a roadmap to determine the spatial structure of an eco-city based on factorial analysis of changes in the spatial population distribution of a region, followed by the development of a method to create feasible spatial scenarios. The optimal spatial structure will be elucidated by a comparison of the environmental load reduction effects and environmental impacts of different spatial scenarios.

These studies are being conducted in collaboration with domestic and international research institutions, governments, and companies.

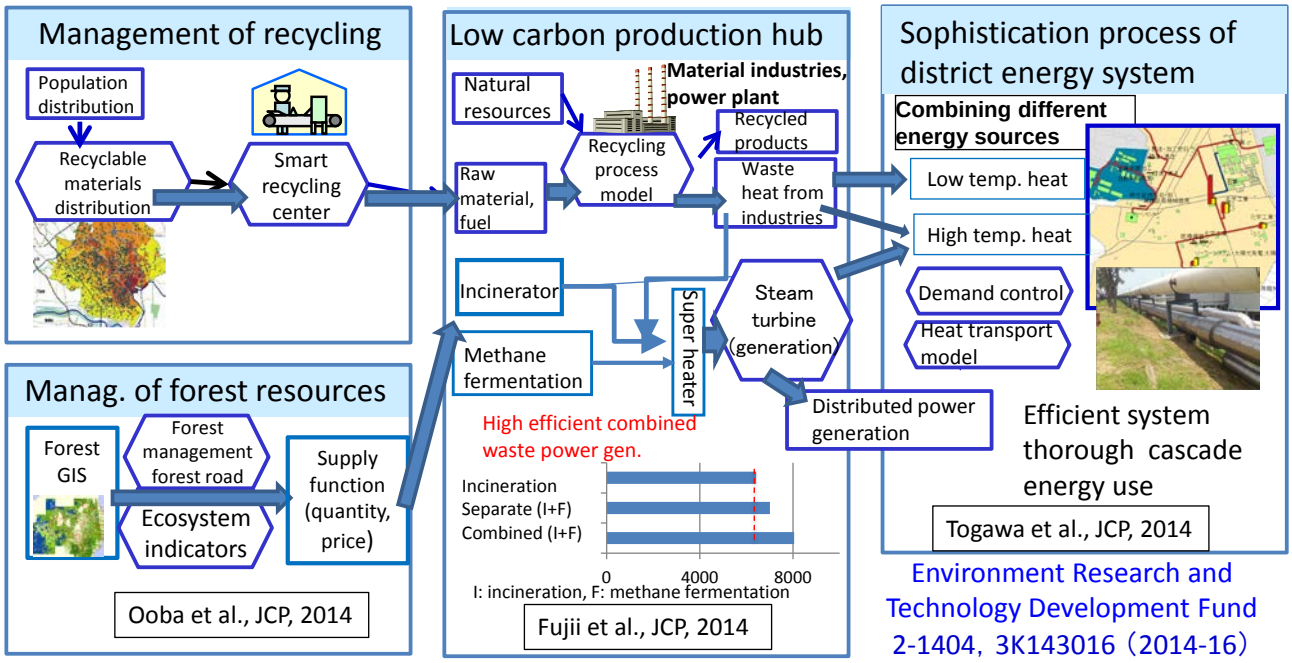


Fig. 3 Framework of a model for the planning and evaluation of co-benefit type alternative technologies

[1] Project 1: Development of evaluation methods for and social implementation of environmental technologies and policies for cities

To efficiently promote CO_2 reduction from spatially distributed emission sources, a prototype system is being developed which will facilitate planning for low carbon cities and verify the resulting CO_2 reduction effect based on the monitoring of energy consumption. This will clarify the optimal solution for each emission source as well as for the entire area. The system has been applied to Bogor City in Indonesia and Shinchi Town in Fukushima Prefecture, Japan. The accumulation of such monitoring data will cater to the need to gather information on energy consumption that tends to be lacking, especially in developing countries.

CO_2 reduction in the industrial sector comes with significant difficulties, particularly in the case of Japanese industries in which energy-saving technologies have already been installed since the oil crisis. To promote further CO_2 reductions one effective solution is the construction of hybrid industries that utilize to the extent currently possible, wastes, waste heat, and renewable resources as alternative raw materials and energy sources. The supply and demand potential for such alternative resources is being investigated and the feasibility of employing hybrid industries in cities in Japan and other Asian countries is being evaluated. The related research outcomes are reflected in the guidelines for local recycling zones formulated by the Ministry of the Environment, Japan.

An energy-saving sewage treatment system has been developed and the associated technology demonstrated in collaboration with the Bangkok Metropolitan Administration (BMA) and King Mongkut's University of Technology Thonburi (KMUTT) in Thailand. Experiments using an advanced trickling filter system fed with combined sewer water (low organic concentration) and separated sewer water (high organic concentration) showed satisfactory effluent quality (concentrations of organic carbon, nitrogen, and coliform bacteria). The demonstrated technology was also shown to reduce the attendant space requirements, electricity consumption (57 to 85%), and excess sludge (82 to 89%) when compared with the present treatment system (activated sludge process). These results may contribute to the planning of a sewage treatment system by BMA for decentralized treatment in densely populated areas. Based on surveys of sewage quality and treatment situations, this energy-saving sewage treatment technology will also be applicable to Indonesia and Malaysia.

[2] Project 2: Development of scenarios for the environmentally sustainable evolution of cities and regions

Based on factorial analysis of changes in the spatial distribution of population, focusing on a particular

region, a method to create feasible spatial distribution scenarios was developed. The results, in the form of a mesh revealed a trend toward further decreases in population in areas with previously low populations in Japan. The Gini coefficient for the population spatial distribution was then utilized to analyze and calculate the distribution within a municipality. The coefficient revealed that the population spatial distribution has become nonuniform in conjunction with the population decrease in recent years. Population spatial distribution scenarios with a high degree of feasibility of application were developed based on a simulation of the future distribution. The results were published online (Environmental GIS (Geographic Information Systems)) and have been utilized in research such as the Sustainable Social Systems and Policy Research Program, estimation of the number of heat stroke patients, and evaluation of a particular global warming impact.

To understand differences in the effects of reducing environmental loads and environmental impacts according to spatial structure, CO_2 emissions from automobiles, energy supply and demand, and mitigation and adaptation technologies for global warming were evaluated in different areas. A formula that expresses the relationships between CO_2 emissions from automobiles and populations in the form of a mesh was developed. This indicates, for example, the possibility that CO_2 emissions in future scenarios with different population spatial distributions will differ by around 10%. These results were also published on the Internet (Environmental GIS) and utilized in a model to elucidate transportation under different land use patterns developed by the Ministry of the Environment, Japan. In addition, outreach activities aimed at academic societies as well as to municipalities and the general public were implemented.

1.2.2 Other research

1.2.2.1 Fundamental research projects

To create new research themes and foster young researchers, the Center for Social and Environmental Systems Research conducted an open call for fundamental research projects at the Center (in principle of a two-year duration) with the results of the selected projects to be presented at the end of each fiscal year. During the period of the third five-year plan, nine projects were selected, and three of the nine ended halfway through the period concluded having been shifted to projects with external competitive funding. Fundamental research projects are also conducted as feasibility studies for research that will be put forward for external competitive funding. Because we cover a broad spectrum of research fields, these fundamental research projects relate to future desirable forms of the areas of research which are of a high priority for our center.

The following is a list of the projects conducted during the period:

1) Concept arrangement of risk approach for the climate change problem (ended in FY2011)
2) Economic analysis of flood risk and climate change–estimation of flood damage and construction of a flood risk model (FY2011–FY2012)
3) Study on policies to reduce fluorinated gas emissions at the international level (FY2011–FY2013)
4) Study of the institutional interaction between the Framework Convention on Climate Change and the Convention on Biological Diversity: Case study of REDD+ (FY2011–FY2012)
5) Collection and management of the latest research information on climate change impacts and sustainable development (FY2011–FY2012)
6) A time-series survey of environmental concern by the Japanese public (ended in FY2011)
7) Gaps in the implementation of the Ramsar Convention for the Conservation and Sustainable Utilization of Wetlands at National and Local Levels (FY2013–FY2014)
8) Behavior changes and CO_2 emissions caused by taking community efficiency measures considering social challenges (ended in FY2013)
9) Basic research on greenhouse gas emissions from municipal solid waste and wastewater in Asia (FY2013–FY2014).

1.2.2.2 Research projects conducted under external competitive funding

Research projects conducted under external competitive funds are classified into three research themes. The research results under each of these themes obtained as of the end of the period of the third five-year plan are summarized below.

1) Research on climate change impacts and adaptation (S-8 project funded by the Environment Research and Technology Development Fund (ERTDF), the Ministry of the Environment (MOE),

etc.)

Four and a half years have passed since a strategic research project funded by the ERTDF concerning climate change impacts and adaptation (S-8) began, and the project is now in its final year. To answer questions such as those relating to the risks of climate change impacts in Japan and the effectiveness of adaptation measures for risk reduction, NIES summarized and submitted the research results obtained in the four years of the S-8 project in cooperation with other participating institutes on March 17, 2014. These were widely disseminated and have been well-received by the national government, local governments, mass media, and other interested parties. The project will be concluded at the end of the fiscal year and is expected to contribute to adaptation measures by the government.

2) *Research on mitigation measures against climate change and on low-carbon societies (S-6-1, S-12-2, 2A-1103 and 2-1402 projects funded by ERTDF through MOE, the Science and Technology Research Partnership for Sustainable Development (SATREPS) of Japan Science and Technology Agency (JST) and Japan international Cooperation Agency (JICA), etc.)*

Research under this theme involves the development and application of the Asia-Pacific Integrated Model (AIM). AIM is an integrated assessment model to assess the climate mitigation and adaptation policies as shown in Figure 4. AIM is used for international and national research projects. Through projects including the S-12-2 and 2-1402 projects started in FY2014 and funded by ERTDF, AIM has been improved and expanded. In addition, studies that include those aimed at establishing a midterm target for greenhouse gas (GHG) emissions for the post-2020 period; offering opinions on the construction of a low carbon society; examining emission pathways of GHGs and short-lived climate pollutants (SLCPs); and proposing concrete measures to develop low carbon societies in Asian developing countries, have been continuously conducted. Through strengthening of cooperation with Asian partner countries, we have comprehensively promoted analysis, policy proposals, and verification.

3) *Research on systems for the planning and evaluation of eco-cities and other regions (ERTDF through MOE, international collaborations by the Japan Society for the Promotion of Science, funded by a contribution to the United Nations University made by MOE, etc.)*

The results of studies on venous industries, low carbon regions, and co-benefit cities will be published in high-level academic journals and developed into domestic and international political guidelines for the use of the Ministry of the Environment. A research project funded by ERTDF on green growth centers and spatial inventory started in FY2014 in cooperation with local governments, and we are now collecting data and making models.

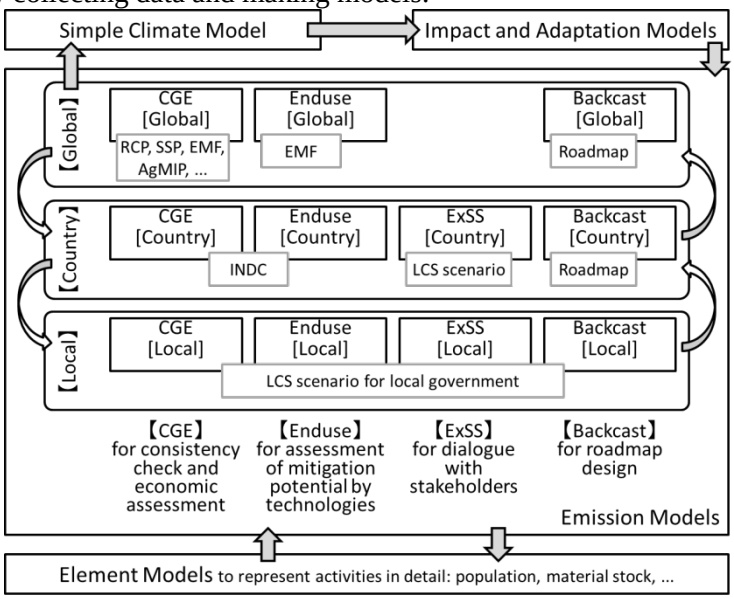


Fig. 4 Structure of AIM

1.2.2.3 Regular research

We have continued conducting regular research on the following topics, and the results obtained have been moved into the next stages as appropriate in cooperation with other research programs or other research projects funded by external competitive funds:

1) Study on the effectiveness of environmental policy and its design
2) Study on environmental planning and sustainable lifestyles
3) Collection of data and information to support the development of an integrated assessment model for assessing sustainable societies
4) Study on mitigation measures for the realization of a low carbon society.

1.2.2.4 International activities

[1] Contributions to environmental policies

We have participated as experts in international negotiations on the prevention of and adaptation to climate change, as well as the U.N. Minamata Convention on Mercury, and are aprised of the latest information about the negotiations. We are also working on future policies to contribute to the U.N. Framework Convention on Climate Change and post-Kyoto Protocol negotiations.

For discussions on targeted GHG emission reductions that will take place at COP21 in Paris in December 2015, nations had to present their targets for GHG emission reductions by March 2015. We provided the results of provisional calculations for such target setting for international research such as the Deep Decarbonization Pathways Project (DDPP).

We participated as a member of the evaluation committee for innovation in the field of low carbon technology managed by the Ministry of the Environment, Japan, and contributed to the appropriate technology selection. Moreover, in cooperation with the Ministry of the Environment, Japan, and the Ministry of Environment, Indonesia, we have established a research promotion system to perform energy consumption monitoring for the construction of low carbon societies using Japanese technologies and offered opinions on countermeasure technologies and environmental policies based on the monitoring results. We have also participated as international experts in networking for an environmental industry system for developing countries promoted by a network of National Cleaner Production Centres (NCPCs) set up by UNIDO, and promoted cooperation with Japan's Joint Crediting Mechanism (JCM) and a project to incubate firms in venous industries.

[2] Research activities

Four researchers affiliated with our center contributed to the publication of the Fifth Assessment Report of the United Nations Intergovernmental Panel on Climate Change (IPCC) (WGII: Chapter 19, LA; Chapter 20, LA; Chapter 24, CLA; and WGIII: Chapter 7, LA). We also played an active role in the development of an IPCC global socioeconomic scenario, which was published in the summer of 2014 under the title "Shared Socio-economic Pathways" (SSPs) by providing the results of computations using an integrated assessment model (IAM).

We participated in international comparison projects for IAMs such as the Integrated Assessment Modeling Consortium (IAMC); the Agricultural Model Intercomparison and Improvement Project (AgMIP); DDPP; and international networks for low carbon society in order to provide our research results to the international science community. Furthermore, we have been holding workshops on low carbon society scenarios and the use of IAMs and economic models for young researchers in Asian developing countries in order to transfer the technology of IAMs and develop low carbon society scenarios.

[3] Development of international research network

For the development of a low carbon society, we have continued to take part in the work of the International Research Network for Low Carbon Societies (LCS-RNet) and the Low Carbon Asia Research Network (LoCARNet, since April 2012) to promote research activities worldwide and in the Asian region, respectively. We have also carried out capacity building work for model and scenario development to realize low carbon societies in Asia by formulating a plan supporting the JCM.

As a result of joint research with Kyoto University, Universiti Teknologi Malaysia, and other research

institutes, we have been promoting SATREPS by JST and JICA in Malaysia.

To develop networking for international cooperation in the field of eco-cities, we have undertaken joint studies with major cities in Malaysia, Thailand, and China and networking with Asian cities through support for an international conference held in Kawasaki City.

In the sphere of industrial symbiosis, we have been conducting international joint research with the Korea Industrial Complex Corporation (KICOX) under mutual researcher exchanges.

With respect to media research, we have provided Japanese media data to the Media and Climate Change Observatory, chiefly administered by the University of Colorado at Boulderis. We have also joined a media research network in which EU, African, and Asian researchers are involved and conducted international comparative research on media related to COP and IPCC.

1.2.2.5 Environmental emergency research

Please see section VIII.1.2 of the Detailed Report.

2 Research budget, human resources, and papers during the third NIES five-year plan

2.1 Research budget per each fiscal year

	FY2011	FY2012	FY2013	FY2014	FY2015
Grant for Operating Costs	95	89	113	209	139
Other External Research Funding	404	384	407	777	580
Total	499	473	520	986	719

(Unit: million yen)

2.2 Human resources

Cumulative total number of staff during the third five-year plan: 402

2.3 Total number of papers and conference presentations during the third five-year plan

Papers		Books	Presentations		Patents
Peer Reviewed	Others		Domestic	International	
246	145	47	388	210	0

2.4 Major papers and patents (up to 5)

(1) Hanaoka, T., Akashi, O., Fujiwara, K., Motoki, Y., Hibino, G. (2014) "Potential for reducing air-pollutants while achieving 2°C global temperature change limit target," *Environmental Pollution,* 195:336–343, DOI: 10.1016/j.envpol.2014.06.022.

This study analyzes the potential for reducing air pollutants while achieving the target of a 2°C maximum global temperature change above pre-industrial levels, using the AIM/Enduse[Global] bottom-up optimization model. The focus of the study is on estimating mitigation potentials and costs of achieving 2°C, 2.5°C, and 3°C target scenarios. The co-benefits of reducing air pollutants such as NOx, SO_2, BC, and PM are also assessed.

(2) Kameyama, Y. (2014) "Environmental and Social Policies in Japan," in Tony Fitzpatrick ed., *International Handbook on Social Policy & the Environment*, UK: Edward Elgar Publishing, 228–248.

This book chapter aims at illustrating developments and common fundamentals between environmental and social policies in Japan. Pollution abatement policies in the 1950s and 60s had strong links to social policies such as poverty reduction and health care. With the increasing globalization of environmental problems, Japan's environmental policymaking shifted away from the domestic social policies of the time. Integration of environmental and social policies has become active again since the Great East Japan Earthquake in March 2011.

(3) Fujii, M., Fujita, T., Ohnishi, S., Yamaguchi, N., Geng, Y., Park, H. (2014) "Regional and temporal simulation of a smart recycling system for municipal organic solid wastes," *Journal of Cleaner Production,* Vol. 78, 208–215.

A cost-effective and robust waste treatment and recycling system is a requisite of a sustainable society. We propose a "smart recycling system" that utilizes existing industrial facilities with higher energy efficiency so that a cost-effective and robust recycling system for treating municipal wastes can be established. In order to test its applicability, we simulate the implementation of smart recycling in three satellite cities of Tokyo and evaluate its effects under three different scenarios.

(4) Chen, X., Fujita, T., Hayashi, Y., Kato, H., Geng, Y. (2014) "Determining optimal resource recycling boundary at regional level: A case study on Tokyo Metropolitan Area in Japan," *European Journal of Operational Research,* Vol. 233, No. 2, 337–348.

Theoretically, an appropriate facility scale and recycling boundary should be based upon a balanced consideration between economies of scale and transportation costs. This paper quantitatively seeks the determinants for recycling boundaries and the related mechanism; namely, the spatial density of separated wastes and the ratio of unit transportation cost to unit treatment cost.

(5) Masui, T., Matsumoto, K., Hijioka, Y., Kinoshita, T., Nozawa, T., Ishiwatari, S., Kato, E., Shukla, P. R., Yamagata, Y., Kainuma, M. (2011) "An emission pathway for stabilization at 6 Wm^{-2} radiative forcing,"

Climatic Change, 109, 59–76, DOI 10.1007/s10584-011-0150-5.

Representative Concentration Pathway 6.0 (RCP6) is a pathway that describes trends in long-term global emissions of greenhouse gases (GHGs), short-lived species, and land-use/land-cover change leading to a stabilization of radiative forcing at 6.0 watts per square meter (Wm^{-2}) in the year 2100 without exceeding that value in prior years, using the Asia-Pacific Integrated Model (AIM).

IX Center for Environmental Measurement and Analysis

Takashi IMAMURA, Director, Center for Environmental Measurement and Analysis

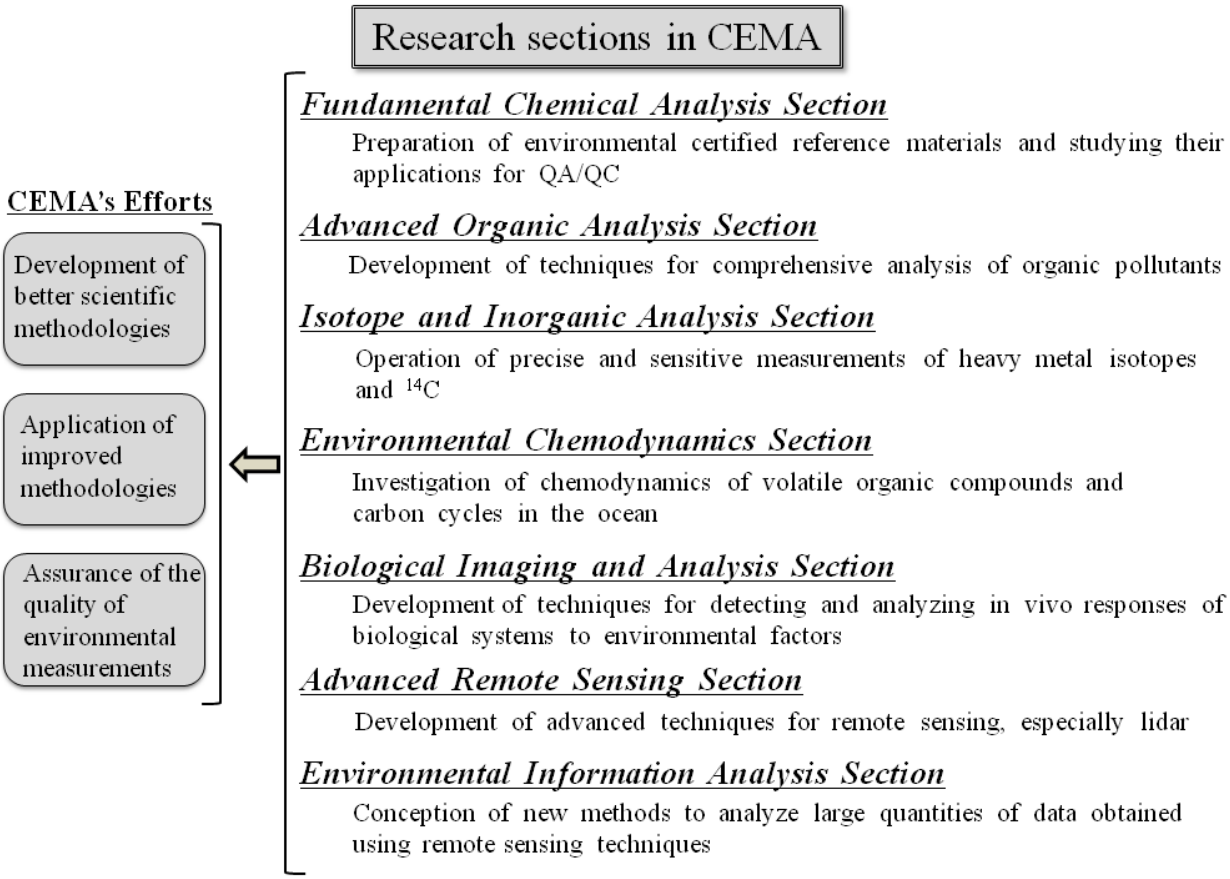
1 Overview of research outcomes

1.1 The third NIES five-year plan

The expansion of human activities has given rise to significant qualitative and quantitative increases in associated environmental loads for our planet. Environmental changes caused by such loading occur over different spatial and temporal scales, which range from time spans of minutes to centuries and from local to global scales. Impacts from these changes affect both human beings and all other forms of life. A comprehensive understanding of the mechanisms of environmental issues is required to mitigate environmental risks. It is also necessary to monitor environmental changes carefully to enable the early detection of environmental risks.

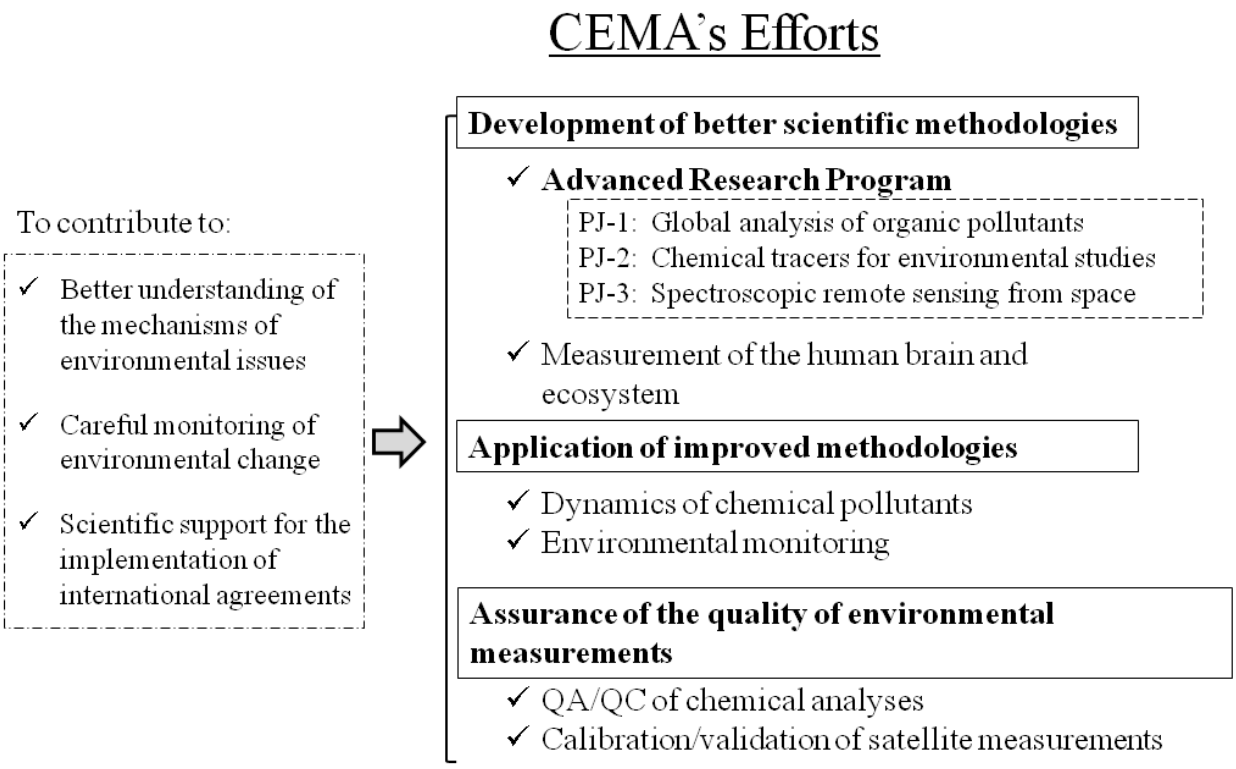
The mission of the Center for Environmental Measurement and Analysis (CEMA) is to contribute to the furtherance of environmental studies through research on scientific methodologies for environmental measurement and analysis.

CEMA consists of seven research sections. While each section focuses on a different type of research/approach, we make a combined effort to achieve common goals, i.e., developing improved scientific methodologies and demonstrating the effectiveness of these improved methodologies. We also aim to contribute to the quality assurance and quality control of environmental measurements.



During the period of the current five-year plan, CEMA has been conducting three advanced studies which have their focus in the development of new methodologies; global analysis methods for organic pollutants; novel application of chemical tracers for chemodynamics; and spectroscopic remote sensing techniques, as part of the NIES Advanced Research Program on Advanced Environmental Measurement and Analysis.

In addition to this research program, CEMA has also been conducting research concerning the development and optimization of methodologies; application of advanced/improved methods for the solution of environmental issues; and the quality assurance and quality control of environmental measurements and analyses.



The research activities and goals of CEMA during the research period covered by the current five-year plan are listed below.

1.1.1 Advanced Environmental Measurement and Analysis Research Program

This Research Program aims to develop new methodologies to contribute to the maintenance and future advancement of ongoing and forthcoming environmental studies.

The program consists of three Research Projects:

"Development of global analysis methods for organic pollutants" (Research Project 1)

Goals: To develop next-generation analytical methods for organic pollutants in the environment using comprehensive multi-dimensional gas chromatography (GC × GC), high-resolution time-of-flight mass spectrometry (HRTOFMS), and quadrupole-type tandem mass spectrometry (MS/MS).

"Novel application of chemical tracers for environmental chemodynamic studies" (Research Project 2)

Goals: To establish accurate measurement methodologies and technologies for chemical substances and isotopic ratios; detect possible changes in the emission of natural organic species as a response to environmental changes; and demonstrate novel applications using ^{14}C as an ideal tracer in environmental measurements.

"Development of advanced spectroscopic remote sensing techniques" (Research Project 3)

Goals: To develop algorithms to obtain necessary information using satellite observation data and design a spaceborne vegetation lidar.

1.1.2 Development of new measurement methodologies

"Development of methods for monitoring human brain response to environmental stress"

Goals: To develop non-invasive and non-destructive methods for monitoring the human brain using a magnetic resonance imaging (MRI) spectrometer.

"Monitoring ecosystems using digital cameras"

Goals: To develop methods for monitoring alpine ecosystems and coral using imaging sensors.

1.1.3 Contributions to the management of chemical pollutants

"Observation of persistent organic pollutants"

Goals: To observe the distribution of persistent organic pollutants (POPs) in Japan through cooperation with local environmental research institutes; demonstrate the effectiveness of dragonflies as perfluorooctane sulfonate (PFOS) biotracers; and prepare reference materials for PFOS analysis.

"Precise measurement of mercury isotopes"

Goals: To optimize the conditions of Hg isotopic analysis; determine the Hg isotopic composition of tuna fish; and determine the Hg isotopic composition of our Certified Reference Material (CRM No. 13: Human Hair).

"Groundwater pollution by diphenylarsinic acid (DPAA)"

Goals: To develop analytical methods for DPAA; analyze its behavioral effect on mice; and clarify its metabolism in the environment as well as experimental animals.

1.1.4 Environmental Monitoring

"Observation of aerosols in East Asia"

Goals: To monitor mineral dust and air pollutant aerosols using a ground-based lidar network.

"Observation of natural and anthropogenic halocarbons"

Goals: To demonstrate the role of tropical plants as a source and sink of halomethanes and monitor anthropogenic halocarbons at a remote station in Japan.

"Specimen banking (Time capsule program for environmental specimens)"

Goals: To complete the second round of bivalve sampling at sites located along coastal areas across Japan.

1.1.5 Quality assurance and quality control of chemical analyses and optical sensing data

"Certified Reference Materials (CRMs) for environmental studies"

Goals: To prepare more than three CRMs in demand for environmental chemical analyses.

"Calibration of onboard passive optical instruments for satellites"

Goals: To establish a methodology using lunar reflectance as a light source to calibrate optical instruments onboard earth observation satellites.

1.2 Outcomes and self-assessment of the third NIES five-year plan

1.2.1 Overview of CEMA's research activities

1.2.1.1 Advanced Environmental Measurement and Analysis Research Program

[1] Project 1: Development of global analysis methods for organic pollutants

We developed an automatic peak sentinel tool known as T-SEN for the comprehensive analysis of organic pollutants using a two-dimensional gas chromatograph coupled to a high-resolution time-of-flight mass spectrometer (GC × GC-HRTOFMS). T-SEN consists of a simple algorithm for peak detection and peak shape identification and allows for the rapid screening of target compounds. We analyzed and quantified 17 dioxin (PCDD/F) congeners and 24 poly chlorinated biphenyl (PCB) congeners in crude lake sediment extract by GC × GC-HRTOFMS with T-SEN, which provided the correct identification and accurate quantification of compounds without pre-treatment of the sample. The difference between the

values measured by GC × GC-HRTOFMS with T-SEN and the certified values for the certified reference materials ranged from 7.3% to 36.9% for compounds with concentrations above the limit of quantification. Using GC × GC-HRTOFMS in combination with T-SEN allows rapid and accurate screening and represents a powerful new approach for comprehensive analysis.

We also developed a method that selectively extracts a subset from GC × GC-HRTOFMS data to detect and identify the trace levels of organohalogens. The data were obtained by measuring several environmental and biological samples, i.e., fly ash, soil, sediment, atmosphere, and human urine. For global analysis, some samples were measured without purification. Using our software, the mass spectra of organochlorines or organobromines were then extracted in a data subset under high mass accuracy conditions that were approximately equivalent to a mass resolution of 6000 for some samples. Mass defect filtering as a pre-screening method for data extraction was effective in removing the mass spectra of hydrocarbons. This showed that data obtained using HRTOFMS were valuable for the global analysis of organohalogens and could most likely be applied to other compounds if specific data extraction methods were devised. (See section IX. 1 of the Detailed Report)

[2] Project 2: Novel application of chemical tracers for environmental chemodynamic studies (partial collaboration with the Center for Global Environmental Research)

Radiocarbon (^{14}C) is an ideal tracer to distinguish fossil fuels (^{14}C-dead) from modern biomass combustion sources of pyrogenic PAHs and BC in airborne particulate matter. Such an approach is enabled by combining the *state of the art* microscale ^{14}C analysis with sophisticated techniques to isolate PAHs and BC from complex environmental matrices. We applied our developed method to atmospheric pollutants in Kolkata, which is a heavily polluted Indian megacity. As a pilot study, surface sediments were collected from Kolkata city canals, and polycyclic aromatic hydrocarbons (PAHs) were isolated and analyzed for ^{14}C using accelerator mass spectrometry at NIES-TERRA (Tandem accelerator for Environmental Research and Radiocarbon). The ^{14}C abundance (percent of modern carbon, pM) of PAHs was 5–11 pM, indicating strong influence (i.e., >90%) from fossil fuel combustion. Combined with a molecular fingerprinting study, the relative contribution from coal combustion in brickyards to sedimentary PAHs was estimated to be >50%. As monsoon-driven runoff events flush canals every year, this result can illustrate the contribution of particle-borne pollution over the last few years. (See section IX. 2 of the Detailed Report)

Radiocarbon was also used to estimate the contribution of fossil fuel sources to secondary organic aerosol formation during summer in Tokyo; trace a bottom water renewal event in the Sea of Japan; and determine the distribution of bottom water within the Japan Basin.

We demonstrated that some volatile organic compounds (VOCs) function as indicators for global environmental changes. As such, we have performed global-scale observations of selected natural VOCs to detect possible changes in their emission from the ocean as a response to global environmental changes. We also examined long-term variations in atmospheric methyl iodide (CH_3I) at five remote sites covering 82.5°N–40.4°S and over the western and northern Pacific Ocean from the late 1990s to 2011. From this, we determined that its interannual variation pattern had good correlation with the Pacific Decadal Oscillation, suggesting that CH_3I emissions from the ocean are affected by global-scale sea surface temperature-related decadal anomalies. (See section IX. 5 of the Detailed Report)

[3] Project 3: Development of advanced spectroscopic remote sensing techniques (partial collaboration with the Center for Global Environmental Research and the Center for Regional Environmental Research)

We developed a unique aerosol retrieval algorithm to estimate the optical concentration of the main aerosol components in the atmosphere (e.g., mineral dust, sea salt, and black carbon) using lidar data. By expanding the application of this concept (i.e., singular algorithm using only lidar) to the synergistic use of both lidar and a multi-spectral radiometer, we designed an algorithm to retrieve the size distributions of

individual aerosol components as well as their optical concentrations. A 355-nm high spectral resolution atmospheric lidar (ATLID) and a multi-spectral imager (MSI) are to be placed aboard the Earth Clouds, Aerosols, and Radiation Explorer (EarthCARE) satellite.

We have improved our synergy algorithm to utilize both the ATLID and MSI data, which enable us to retrieve the optical concentrations of mineral dust, sea salt, black carbon, and water soluble aerosols and mode radii of water soluble and mineral dust aerosols. We also established an observation plan to validate this synergy algorithm and other algorithms developed for the EarthCARE mission using ground-based lidar networks (e.g., the Asian dust and aerosol lidar observation network (AD-Net)) and ground-based radiation observation networks (e.g., SKYNET). (See section IX. 3 of the Detailed Report)

We designed a new spaceborne lidar system to measure vegetation (e.g., tree height) and atmospheric particles (e.g., aerosols and clouds) in cooperation with the Tohoku Institute of Technology and National Institute of Information and Communications Technology. An imaging lidar technique was introduced for the measurement of ground surface inclination to accurately measure tree height. In addition, we adopted a dual wavelength lidar system to evaluate vegetation index. To realize the application of this lidar system, we developed basic techniques on an imaging lidar system with a dual wavelength (1064 and 1320 nm) YAG laser and transmitter system to produce a multi-beam laser.

We proposed a vegetation/atmosphere observation mission using this spaceborne lidar to Japan Aerospace Exploration Agency. This proposal was adopted as ISS (International Space Station) spaceborne lidar mission MOLI, and the technical investigations are ongoing. Unfortunately, the concept of vegetation index measurements using active remote sensing techniques was not adopted; however, the concept of imaging lidar remains as the multi-beam lidar.

1.2.1.2 Development of new measurement methodologies

[1] Development of methods for monitoring human brain response to environmental stress (partial collaboration with the Center for Environmental Health Science)

Images obtained at a high static magnetic field of 4.7 tesla (T) are advantageous as they have high sensitivity and good spatial resolution. However, at high fields, the inhomogeneous distribution of radiofrequency (RF) inside a dielectric sample, such as the human body, can yield images that are not uniform. To overcome this problem, we have developed a method for non-uniform image correction at 4.7 T. In this way, several uniform images of the human brain were obtained.

We also developed methods to measure *in vivo* metabolites and non-haemin iron in the human brain. A method to quantify the absolute concentrations of metabolites, such as glutamine and γ-aminobutyric acid, in the human brain was also developed using localized two-dimensional constant-time correlation spectroscopy. We also demonstrated that the transverse relaxation rate constants ($R_2^{\dagger}$) measured in six brain regions could be described as a function of the regional non-heme iron concentration, which suggests that $R_2^{\dagger}$ measurements can provide information on the brain iron concentration map.

We have also been investigating the possibility of utilizing measured MR images as *in vivo* biomarkers by comparing the data of healthy volunteers as baseline data with those of patients. (See section IX. 4 of the Detailed Report)

[2] Monitoring ecosystems using digital cameras (partial collaboration with the Center for Regional Environmental Research and the Center for Environmental Biology and Ecosystem Studies)

In collaboration with the Center for Global Environmental Research, alpine zone monitoring with digital cameras has been conducted in Japan since 2009. During this period, a new method for monitoring alpine zones using digital cameras was developed to detect yearly changes in snow-covered areas at high temporal and spatial resolutions. The snow-covered and snow-free pixels in the images were statistically

classified through the analysis of variance of gray level histograms. A flexible threshold was determined for each image to maximize the between-class variance. The distribution of the snowmelt dates showed site-specific characteristics and yearly variations.

We also developed the autonomous self-propelled mini boat-based stereoscopic imagery system for the three-dimensional observation of shallow water ecosystems. Our system was equipped with digital video cameras mounted just below the sea surface. The continuous capture of images with GPS data enabled the formulation of an orthographic projection mosaic image. We tested this system in tropical and warm temperature coral environments and successfully generated mosaic images. This system will provide efficient and detailed mapping and the monitoring of shallow water bottom features.

1.2.1.3 Contributions to the management of chemical pollutants

[1] Observation of persistent organic pollutants

We found that dragonflies were useful bioindicator organisms for monitoring environmental levels and identifying major emission sources of perfluoro surfactants, especially PFOS, in terrestrial environments. By examining PFOS levels in dragonflies after emergence, we found that mature males of several common species may have comparable accumulation capabilities and thus may be used together for terrestrial monitoring. We also analyzed bivalve samples collected at sites along coastal areas across Japan and obtained the distribution of PFOS and PFOA (perfluorooctanoic acid). Interestingly, the distribution of PFOS obtained from the analysis of dragonflies was different from that obtained from the analysis of bivalves.

[2] Precise measurement of mercury isotopes (partial collaboration with the Center for Environmental Risk Research)

Hg isotopic compositions of yellowfin tuna (*Thunnus albacares*) and bigeye tuna (*Thunnus obesus*) from the Northwest Pacific and Indian oceans, downwind and upwind regions of China and India, were measured to evaluate geographic variation in Hg sources and the associated chemical and biological reactions between the two marine ecosystems. Although δ^{202}Hg of muscle tissues did not indicate a significant discrepancy between the two species of tuna, the total Hg and Δ^{199}Hg values in yellowfin tuna were different from those in bigeye tuna. Since the magnitude of Δ^{199}Hg largely depends on the degree of photoreduced demethylation, combined with the fact that the habitat of yellowfin tuna is different from that of bigeye tuna, the observed results could be explained in terms of in situ production and destruction of methylmercury in different areas of the ocean.

We also measured Hg stable isotopic ratios in human hair to understand the exposure routes of methylmercury (MeHg)—a well-known toxic chemical. Since a common matrix between the sample and standard is required for highly precise isotopic measurement, we determined Hg isotopic compositions of our certified reference material (CRM No.13: Human Hair) using MC-ICP-MS.

[3] Groundwater pollution by diphenylarsinic acid (DPAA)

Evidence of groundwater pollution by man-made organoarsenic compound diphenylarsinic acid (DPAA) was found in 2003 in Kamisu, Ibaraki Prefecture, Japan. DPAA displays a characteristic neurotoxicity in exposed humans. As such, active research is being conducted on the development of analytical methods; identification of its source and polluted areas including depth profiling in groundwater; absorption, and distribution within the body of experimental animals; analysis of its behavioral effect on mice; and its metabolism in the environment and experimental animals.

In the environment, DPAA is degraded to phenylarsonic acid (PAA), methylated to phenylmethylarsinic acid (PMAA), phenyldimethylarsine oxide (PDMAO), etc., and further converted to thio-substituted analogues, such as diphenylthioarsinic and diphenyldithioarsinic acids. After repeated administration for 28 days, DPAA was found to accumulate in the highest levels in rat brains. Through microdialysis with LCMSMS, it was revealed that DPAA administered in drinking water to mice was rapidly absorbed and transported to the brain within 15 min.

In behavioral tests in mice, DPAA increased ambulatory activity and the response rate of the shuttle-type discrete conditioned avoidance response, reduced coordination ability on the fixed and rotating rods, and increased anti-anxiety-like effects in the elevated plus maze test, but it did not affect learning ability and/or memory, as evaluated using passive avoidance response. Long-term exposure to DPAA did not cause detectable degenerative changes in neurons or glial cells in mice, as revealed by the analysis of their specific marker proteins, i.e., TUJ-1 and GAFP.

1.2.1.4 Environmental Monitoring

[1] Observation of aerosols in East Asia (collaboration with the Center for Regional Environmental Research)

The Asian dust and aerosol lidar observation Network (AD-Net) was started in 2001 as a unique observation network in East Asia for continuous and automatic ground-based network observation using dual wavelength (532, 1064 nm) depolarization Mie scattering lidar. This lidar network observation contributed to the understanding of the occurrence and transport mechanisms of Asian dust, validation of chemical transport models, and data assimilation studies. In addition, the concentrations of Asian dust and air pollution aerosols evaluated from the AD-Net observation have been used in epidemiological studies (e.g., effect on the human body).

We introduced an in situ polarization optical particle counter, which can measure size distribution and non-sphericity of aerosols, to several observation sites of the AD-Net. This enabled us to evaluate the mixing state of Asian dusts from the lidar measurements. Furthermore, we wish to introduce a multi-wavelength Raman lidar and high-spectral resolution lidar to the AD-Net to estimate the concentration of further aerosol components; conduct data assimilation analyses using the retrieved concentration of individual aerosol components; and evaluate the emission of air pollutant aerosols in each region of East Asia. The AD-Net has 20 observation sites in East Asia and is recognized as one of the contributing networks of the Global Atmosphere Watch (GAW) program of World Meteorological Organization (WMO). The observed and analyzed data are open to the public in quasi real-time.

[2] Observation of natural and anthropogenic halocarbons (collaboration with the Center for Global Environmental Research)

Based on high-frequency atmospheric monitoring data, we found that halocarbon emissions dramatically increased shortly after the Great East Japan Earthquake (GEJE) of March 11, 2011. Annual emissions were significantly higher in 2011 than in other years, and the sum of earthquake-related emissions of six studied halocarbon species (CFC-11, HCFC-22, HCFC-141b, HFC-134, HFC-134, and SF6) were estimated to be 6.6 (5.2–8.0) Gg. These extraordinary halocarbon emissions were likely due to the destruction of building components containing halocarbons, such as air conditioners, foam insulation, and electrical equipment.

We studied the exchange of methyl chloride (CH_3Cl) and methyl bromide (CH_3Br), natural carriers of ozone-depleting halogens to the stratosphere, between tropical plants and the atmosphere. Most plant species examined showed production as well as consumption of CH_3Cl with a large net emission overall. In contrast, CH_3Br consumption was comparable to its production, resulting in low net emission. We also found that the consumption rates were faster in saplings whose leaves were generally covered by epiphytic microorganisms than in healthy looking leaves of mature trees. (See section IX. 5 of the Detailed Report)

[3] Specimen banking (Time capsule program for environmental specimens)

We started an environmental specimen banking (ESB) program in 2002 by reorganizing the former pilot phase ESB program initiated in 1979. The new ESB program—Environmental Time Capsule program—expanded sample collection activities, adopted the cryohomogenization of biological samples, and performed cryogenic sample preservation using liquid nitrogen vapor. Bivalve specimens were collected annually at four densely populated sites (i.e., Tokyo, Nagoya, Osaka, and Fukuoka) and six sites located in

background areas. Furthermore, we have completed the second round sampling of bivalves from almost 100 sites located along coastal areas across Japan during this research period. Bivalve specimens collected at various sampling sites were processed and cryogenically stored.

1.2.1.5 Quality assurance and quality control of chemical analyses and optical sensing data

[1] Certified reference materials (CRMs) for environmental studies

Our institute has been preparing and distributing environmental and biological CRMs since 1980. Over the past 30 years, we have provided 52 countries with thousands of bottles of CRMs. Our CRMs are unique as they are prepared with only natural substances. All CRMs are prepared to meet global standards (ISO guidelines) and registered with the international reference materials database (COde d'indexation des MAteriaux de Reference, COMAR).

During the current research period, we prepared four CRMs, i.e., rice flour (Cd and other elements), water hyacinth (elements), Gobi kosa (elements), and lake sediment (elements). These were developed for various applications, for example, the lake sediment CRM was developed for the determination of multi-elements in lake sediment and materials with similar matrices. In addition, its certified and reference values are given for the complete dissolution and $HCl/HNO_3/HClO_4$ extract determined according to "The Methods for Sediment Surveillance" of the Ministry of the Environment, Japan (August 2012). We are currently preparing a CRM of fish meat for PFOS and PFOA. (See section IX. 6 of the Detailed Report)

[2] Calibration of onboard passive optical instruments for satellites

Long-term relative calibration of passive optical instruments onboard earth observation satellites is essential for climate change monitoring. The reflectance of light by the Moon is fairly stable on a human timescale and is thus used as a calibration light source for these instruments. However, before the Moon can be used as a reliable long-term calibration light source, the characterization of the spectral reflectance of the Moon, including photometric correction, is required.

For this study, the Spectral Profiler (SP), a grating spectrometer covering 0.5–2.6 μm region onboard the Japanese lunar explorer, Kaguya, launched in 2007, was used to map the spectral reflectance and establish photometric correction procedures of the Moon. The results of radiometric calibration and photometric correction were validated, and the repeatability of SP photometrically corrected reflectance was confirmed to be approximately ±1% for 0.5–1.6 μm and a few percent for 1.6–2.1 μm. This lunar reflectance model is currently being applied to lunar calibration data acquired by Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) onboard the US Terra satellite and Cloud and Aerosol Imager (CAI) onboard the Greenhouse gases Observing SATellite (GOSAT) and will be applied to data from the Japanese hyperspectral imager, i.e., HISUI. In addition, discussions with the US and Japanese geostationary meteorological satellite operators, i.e., National Oceanic and Atmospheric Administration (NOAA) and Japan Meteorological Agency (JMA), are ongoing. (See section IX. 7 of the Detailed Report)

1.2.2 Self-assessment of CEMA's efforts and their contribution to environmental research

A research evaluation committee consisting of external experts suggested that the extensive interchange of ideas and collaborations among actors in the various research fields relevant to environmental studies should be of high priority. Based on this advice, many of our activities have been conducted in collaboration with other research centers in NIES, as described in this document. We have also been carrying out collaborations with research groups from other organizations.

The studies performed as part of CEMA's research program produced outcomes that have contributed to the furtherance of environmental studies as a whole. For example, we developed comprehensive analytical tools for the global analysis of organic pollutants, which will be a powerful tool for non-target monitoring and the assessment of organic species. We also demostrated in Project 2 that our state of the art microscale ^{14}C analysis enabled the development of a new approach for the source apportionment of atmospheric

pollutants. Our new synergy algorithm developed in Project 3 is expected to be used to retrieve aerosol information from the observations by ATLID and MSI installed on EarthCARE, which will be launched in 2018.

Careful environmetal monitoring with our improved methods produced new findings, for example, halocarbon monitoring made it possible to detect extraordinary emissions of man-made halocarbons associated with the GEJE and determine a link between CH_3I emission from the ocean and global environmental change.

Through our efforts on POP monitoring and Hg isotopic analyses, we are prepared to contribute to the necessary research for the implementation of the Stockholm Convention on POPs and Minamata Convention on mercury.

CEMA also contributes to international scientific communities. For example, CEMA's scientists contributed to or participated in international efforts for the preparation and review of scientific assessments/reviews, including the regional overview in the Northwest Pacific Action Plan (NOWPAP), part of the regional seas program of UNEP, and WMO/UNEP scientific assessment of ozone depletion 2014. Considerable effort was put into preparing the "Regional overview of persistent toxic substances (PTS) and POPs issues of ecological concern in the NOWPAP region."

CEMA activities also contributie to international programs. For example, AD-Net monitoring is registered as an important GAW Aerosol lidar Observations Network partner in the WMO/GAW program.

2 Research budget, human resources, and papers during the third NIES five-year plan

2.1 Research budget per each fiscal year

	FY2011	FY2012	FY2013	FY2014	FY2015
Grant for Operating Costs	270	313	238	411	413
Other External Research Funding	230	251	177	135	129
Total	500	564	415	546	542

(Unit: million yen)

2.2 Human resources

Cumulative total number of staff during the third five-year plan: 407

2.3 Total number of papers and conference presentations during the third five-year plan

Papers		Books	Presentations		Patents
Peer Review	Other		Domestic	International	
248	31	10	581	205	2

2.4 Major papers and patents (up to 5)

(1) Hashimoto S., Zushi Y., Takazawa Y., Fushimi A., Tanabe K., Shibata Y. (2013): Selective Extraction of Halogenated Compounds from Data Measured by Comprehensive Multidimensional Gas Chromatography/High Resolution Time-of-flight Mass Spectrometry for Non-Target Analysis of Environmental and Biological Samples, *J. Chromatogr. A*, 1282, 183–189.

(2) Nishizawa T., Sugimoto N., Matsui I., Shimizu A., Okamoto H. (2011): Algorithm to Retrieve Aerosol Optical Properties from Two-Wavelength Backscatter and One-Wavelength Polarization Lidar Considering Nonsphericity of Dust, *J. Quant. Spectr. Radiat.*, 112, 254–267.

(3) Mitsumori F., Watanabe H., Takaya N., Garwood M., Auerbach E. J., Michaeli S., Mangia S. (2012) Toward understanding transverse relaxation in human brain through its field dependence, *Magn. Reson. Med.*, 68, 947–953.

(4) Saito T., Fang X., Stohl A., Yokouchi Y., Zeng J., Fukuyama Y., Mukai H. (2015): Extraordinary Halocarbon Emissions Initiated by the 2011 Tohoku Earthquake, *Geophys. Res. Lett.*, 42, 2500–2507.

(5) Yamamoto S., Matsunaga T., Ogawa Y., Nakamura R., Yokota Y., Ohtake M., Haruyama J., Morota T., Honda C., Hiroi T., Kodama S. (2014): Calibration of NIR 2 of Spectral Profiler Onboard Kaguya/SELENE, *IEEE Trans*, *Geosci. Remote Sensing*, 52, 6882–6898.

X Environmental Emergency Research

Toshimasa OHARA, Principal Investigator, Fukushima Project Office

1 Overview of research outcomes

1.1 The third NIES five-year plan

There are many areas of disaster-related environmental research related to the Great East Japan Earthquake (GEJE) that require our urgent attention, including damage to the environment, contamination by radioactive substances released into the environment from the Fukushima Daiichi Nuclear Power Station (FDNPS), the impact of those substances on the health of human beings and other life forms, decontamination technologies, and reconstruction efforts to create new regional environments. We will accordingly seek both to contribute to reconstruction and environmental creation in areas affected by the GEJE through conducting integrated research in the four fields detailed below, and to apply research outcomes to the formulation of environmental policy and measures for remediation of damage suffered by people and the environment as a result of earthquakes and other calamities in general. We will work with Fukushima Prefecture and other local governments in affected areas as well as with other research organizations to carry out this research.

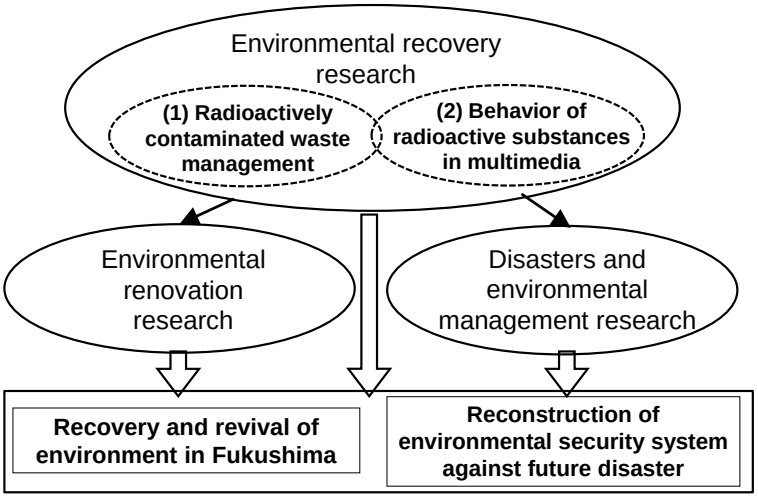


Fig. 1 Overall structure of Environmental Emergency Research

1.1.1 Environmental Recovery Research 1 "Establishment of technologies and systems for managing radioactively contaminated wastes"

With respect to waste materials and soil contaminated with radioactive substances, we will conduct field surveys, basic experiments, field tests, systems analysis and other research on the development, refinement and evaluation of disposal process control technologies and systems (storage, reduction, reuse, final disposal etc.), and on methodologies for the long-term management and eventual dismantling and removal of related treatment facilities based on the fundamental physical properties and behavior of radioactive substances. We will also conduct research on measurement, analysis and monitoring technologies, radioactive substance management strategies and system-wide flow/stock in waste disposal/resource recycling systems, and risk communication methods. We will contribute to the appropriate treatment and disposal of contaminated waste by collating and disseminating our research findings.

1.1.2 Environmental Recovery Research 2 "Study of the dynamics of radioactive materials in multimedia environments"

We will conduct research that combines multimedia environmental monitoring, environmental dynamics measurement and environmental data analysis to ascertain and predict future trends in the status of contamination and environmental dynamics for soil, forests, rivers, lakes and coasts undergoing various degrees of contamination with radioactive substances. We will also develop a method for the wide-area estimation of human radiation exposure and use it to ascertain actual exposure levels. While researching the impacts of radioactive substances on organisms and ecosystems, we will embark on research on changes in ecosystems resulting from human evacuation and decontamination, and on ecosystem management. Through these activities, we will endeavor to provide scientific outcomes that support ongoing and forthcoming

environmental recovery measures being implemented by the national and local governments.

1.1.3 Environmental Renovation Research "Promotion of surveys and research towards restoration and environmental creation for the post-disaster regional environment"

We will work with the Fukushima Prefecture municipalities of Shinchi and Minamisoma, where reconstruction is underway, to develop research theory and methods for supporting the process of restoration and environmental creation in post-disaster regional environments, and conduct research on supporting the policymaking of local governments using those methods. We will also consider such aspects as global warming countermeasures and resource recycling strategies tailored to the characteristics of affected areas, and conduct practical research aimed at building regional environmental resource and energy systems and formulating quantitative eco-city policy targets and roadmaps for achieving those targets.

1.1.4 Environmental Emergency Management Research “Studies on establishment of the environmental management system prepared for future disasters”

To prepare for earthquakes and other anticipated disasters, we will systematize and generalize the outcomes of research on the GEJE and other disaster-related environmental research, and conduct research to support environmental impact assessment and the creation of a disaster-resilient society, including more robust resource recycling and waste management for disaster debris and the establishment of environmental and health risk management strategies.

1.2 Research and other outcomes, and self assessment under the third NIES five-year plan

We have worked with the Ministry of the Environment, with Fukushima Prefecture and other regional governments in affected areas, and with other research institutes to conduct urgent, wide-ranging, integrated disaster-related environmental research on the damage to the environment caused by the GEJE; contamination by radioactive substances released into the environment; the impact of those substances on organisms and ecosystems; decontamination technologies and technologies for treating contaminated waste; and reconstruction efforts to create new regional environments. The resulting research outcomes have made a major contribution to reconstruction efforts and environmental creation in areas affected by the GEJE.

We have also embarked on disaster environmental management research to contribute to the formulation of environmental policy for environmental decontamination and recovery from damage caused to people and the environment by large-scale disasters, outcomes of which have already contributed to tangible results in disaster-related waste disposal and other areas.

We are now preparing to establish an environmental emergency research framework centered on our planned Fukushima branch to be located in the Environmental Creation Center, currently being advanced by Fukushima Prefecture.

As a result of the above efforts, we expect to achieve most if not all of the targets of our third five-year plan.

(1) Environmental Recovery Research 1 "Establishment of technologies and systems for managing radioactively contaminated wastes"

We conducted multifaceted research to tackle the issue of safe and appropriate treatment and disposal of disaster waste contaminated with radioactive substances, and made significant contributions in this area, serving also as a hub for coordinating academic and industry efforts with the core support of the Ministry of the Environment.

- Development and evaluation of waste treatment control technology systems
- Development, refinement and evaluation of treatment, disposal and recycling technologies
- Establishment of technologies for the long-term management of treatment facilities
- Construction of flow/stock model and establishment of measurement monitoring technologies

(2) Environmental Recovery Research 2 ”Study of the dynamics of radioactive materials in multimedia environments”

We conducted research in areas such as the quantitative evaluation of radioactive cesium (Cs) flow and stock in watersheds; development of a multimedia environment model; impacts on organisms and ecosystems, and radiation exposure evaluation, contributing to decontamination operations and other disaster zone environmental restoration processes by providing our research findings to the Ministry of the

Environment, Fukushima Prefecture and other parties.

- Environmental dynamics measurement
- Multimedia environmental modeling
- Impacts on organisms and ecosystems
- Evaluation of human exposure to radiation

(3) Environmental Renovation Research "Promotion of surveys and research towards restoration and environmental creation for the post-disaster regional environment"

We worked with the local administrations, residents, businesses and other parties in the town of Shinchi in Fukushima Prefecture to conduct research aimed at helping with reconstruction and community development, including expansion of local community information systems and data analysis, development of models for supporting reconstruction plans; development and application of a model for evaluating policies aimed at balancing reconstruction with environmental considerations; and the holding of workshops.

- Development of local information systems for regional environmental creation
- Development of models for analyzing regional environmental creation scenarios
- Development and implementation of participatory environmental creation methods

(4) Environmental Emergency Management Research "Studies on establishment of the environmental management system prepared for future disasters"

We embarked on research to bolster environmental disaster readiness and create support systems after systematically reorganizing our research structure. Research outcomes have been used by the Ministry of the Environment to prepare for the management of disaster waste arising from major earthquakes. We also conducted research on technologies for utilizing disaster waste as reconstruction materials.

- Establishing strategies for bolstering disaster waste management and resource recycling
- Research on strategies for managing environmental and health risks associated with disasters
- Construction of a disaster environment research network hub

1.2.1 Environmental Recovery Research 1 "Establishment of technologies and systems for managing radioactively contaminated wastes"

1.2.1.1 Research and Development of control technologies for waste management processes

(See section 2.4 (1) of this Report and section X.1 of the Detailed Report)

To provide a scientific basis for the appropriate disposal of radioactively contaminated off-site waste, thermodynamics, leaching and adsorption-desorption properties and behaviors of the radioactive contaminants in the treatment and the disposal processes were investigated.

Thermodynamics and other physical properties of radioactive substances were obtained. The vapor pressure of radioactive substances was measured. An equilibrium computation was applied to analyze the behaviors of radioactive substances and the effects of coexisting substances on them during the process of incinerating municipal solid waste. Calculated results of this incineration simulator were validated. The behaviors of radioactive substances contained within the biomass and the bottom ash during the process of incineration were identified. These results provided several possible options for appropriate solid waste incineration that can be applied by the Ministry of the Environment and by municipalities. They have been published in various journals as original articles and reviews.

To demonstrate the leachability of radiocesium during the humification of soil and vegetation, share of radiocesium in its water-soluble and ion-exchangeable state were estimated by performing serial-batch and serial-extraction tests. An index of higher leachability was proposed as the rate of distribution of each fraction. For vegetation, the amount of leaching was found to be increased in some species, and the effect of temperature was significant. These results indicate several possible options for storing decontaminated waste, and have also been published in journals as original articles.

Based on the adsorption-desorption properties of radiocesium in relation to soils, absorbents, incineration ashes and tsunami deposits were estimated by performing the batch-absorption test to yield expected adsorption of radiocesium in landfill sites. Because the concentration of salts, especially the potassium salts, was quite high in the leachate from incineration ash, the adsorption capacity in the leachate tended to be lower than that in the seawater. These absorption reactions also have significant rates of reaction, requiring 10 hours to achieve the absorption capacity, explained as a distribution coefficient. This rate of

reaction should be considered in the adsorption of radiocesium onto a thin layer absorption sheet. These results have been published in journals as original articles. They can contribute to the development of a design concept for the adsorption soil layer and its application to several new and existing landfill sites.

1.2.1.2 Development, upgrading and evaluation of waste treatment, recycling and disposal technologies

(See sections X.2 and X.3 of the Detailed Report)

Several control technologies using thermochemical and physical processes for separation, solidification, and isolation of radioactively contaminated off-site waste as part of the solid waste management (including storage, treatment, recycling and final disposal) were developed and improved. The applicability of these technologies was evaluated in the laboratory through demonstrations and in relation to the overall design of the whole system.

A fly ash washing technique was established using the bench-scale test set for a municipal solid waste incineration plant. Performance guidelines were compiled by organizing the study group working on fly ash washing technology. A summary of several notices for the dismantlement of the plant was also compiled. An alert system for a leachate treatment plant to monitor radiocesium at concentrations below the effluent standard was developed and tested at a landfill site. Preparations and responses to an alert were compared based on their efficacy and efficiency.

Decontamination methods and the recycling guidelines for massive quantities of radioactively contaminated concrete waste were summarized. The mechanism of cesium penetration into concrete was clarified through measurements of contaminated concretes and by a penetration experiment using radioisotopes. Insolubilizing technologies for radiocesium, including application of nickel ferrocyanide, and their performances, were summarized. These technologies can also be applied to on-site radioactive waste from nuclear power plants.

Information was compiled on concrete technologies for the construction of the designated waste landfill. This material will be used as inputs for actual construction and management operations for the intermediate storage facility. The interaction between fly ash containing a larger quantity of soluble salts and the concrete was experimentally investigated and several countermeasures were developed. A plan to acquire data for long-term maintenance of concrete products using disposal facilities was also prepared.

The permeability of aquiclude final covers for land disposal of the specified waste was tested at a demonstration site. The safety of stored decontamination and putrefactive waste that was compressed and volume-reduced was also tested at a demonstration site. The long-term stability of the cement solidified radioactively contaminated waste was investigated by performing a repetitive dry-wet test. Rates of leaching obtained through the batch leaching test were reproduced in penetration processes of the column leaching test. A model representing the suppression effect of solidified waste size on leaching was established. These results were reflected in the standard specification of facilities.

1.2.1.3 Development of technologies for long-term maintenance of waste management facilities

Methods for the long-term maintenance, dismantling and closing of thermal treatment and land disposal facilities for radioactively contaminated off-site waste were investigated. These are based on data acquired on the accumulation and movement of radioactive substances within facilities and an understanding of the nature and mechanisms of those phenomena.

The presence and movement of the radiocesium within the heat resistance material component of thermal treatment facilities for radioactively contaminated waste and decontamination waste were examined. Leachability and the effect of thermal cleaning of radiocesium within the heat resistance material were also examined. These results will support the long-term maintenance of facilities and the safer disposal of the heat resistance material.

The method for analyzing the behavior of radiocesium within landfills containing the specified general and industrial waste and the designated waste was standardized and incorporated within software available online. This method has been applied in relation to landfilling of radioactively contaminated waste in several municipalities. We have also supported the inspection of landfills and the training of engineers for

appropriate and long-term management of landfills containing specified wastes.

1.2.1.4 Establishment of technologies for measuring and monitoring radioactively contaminated off-site waste

Several methods for measuring and analyzing the dose rate and/or the radioactive concentration in waste related samples were evaluated. Knowledge relating to standardization and systematization of proper measurement, analysis and monitoring methods, including sampling methods for specific purpose were summarized.

Various measuring devices, including new products such as the scintillation fibers and the flexible container monitors were applied at several sites. The precisions of analysis methods related to sampling, preparation, and measurement of radiocesium and other nuclides were assessed. These results were incorporated in manuals on measurement methods compiled by the Japan Society of Material Cycles and Waste Management and the Ministry of the Environment.

1.2.1.5 Establishment of a control framework for flows and stocks of radioactively contaminated off-site waste

(See section X.4 of the Detailed Report)

The flows and stocks of radioactively contaminated off-site waste and the component radioactive substances during waste recycling and disposal processes were estimated. A framework of measures required for the comprehensive management of off-site radioactive substances was developed.

The rates at which radiocesium migrated to the collected municipal solid waste and sewage sludge, and their interannual and seasonal variation after the FDNPS accident were analyzed. Data on transactional flows of waste and by-product around Fukushima Prefecture were compiled and recorded in the physical input-output table (PIOT) that described interchanges of material between sectors. The relationship between the radioactive concentration of waste and the air dose rate at the point of its generation was analyzed and used to calculate the quantity of radiocesium from the weight in the PIOT. A flow-stock analysis model was constructed and integrated with the radiation dose estimation tool for waste management for application within case studies.

1.2.1.6 Establishment of method for risk communication

To establish risk communication between communities and the wider society, basic factors including inhibitors and accelerators were considered and technical information relating to risk communication was provided.

To establish the credibility of an information source, their provision of equitable, useful, and meaningful information to citizens was important. Means for increasing the utilization were required for the use of information provided by academic institutions, which have are at an advantage in their ability to issue information to a high degree of accuracy and expertise. Know-how and expertise regarding procedures for future disaster waste management was achieved through an understanding of the temporal transition of social circumstances in Fukushima Prefecture and through an investigation into procedures for implementing risk governance related to the radiation.

1.2.2 Environmental Recovery Research 2 ”Study of the dynamics of radioactive materials in multimedia environments”

We conducted research in areas such as the quantitative evaluation of radioactive Cs flow and stock in watersheds, development of a multimedia environment model; impacts on organisms and ecosystems; and radiation exposure evaluation - contributing to decontamination operations and other disaster zone environmental restoration processes by providing our research findings to the Ministry of the Environment, to Fukushima Prefecture, and to other parties.

1.2.2.1 Environmental dynamics measurement

(See section 2.4 (2) of this Report, and sections X.5 and X.6 of the Detailed Report)

We investigated the environmental dynamics of radioactive substances in forests, rivers, lakes, marine and other environments in order to ascertain their distribution, movement and accumulation and obtain measurement data to develop a multimedia environmental model.

We investigated the behavior of radioactive Cs in forests, and confirmed that regardless of the level of contamination, Cs outflow rate is very limited (less than 1% per year) compared with the amount deposited. We also determined Cs outflow characteristics according to the chemical form of Cs, and quantitatively evaluated the contribution of organic materials (plant detritus) in soil to Cs outflow.

We investigated the dynamics of radioactive Cs in inflow waters, and established by means of a quantitative evaluation of Cs deposition history in bottom sediment that direct fallout and initial inflow accounted for a much larger part of total Cs deposition from the nuclear power plant accident than the contribution of post-accident sediment inflow. We also demonstrated the role that dam reservoirs can play in preventing the spread of radioactive Cs to downstream inhabited regions.

We investigated the migration and accumulation of radioactive Cs at watershed level by analyzing stock and flow in the Utagawa and Kasumigaura watersheds, and clarified the current status and long-term trends of Cs movement and accumulation.

1.2.2.2 Multimedia environmental modeling

(See section 2.4 (3) this Report, and seX.7 and section X.8 of the Detailed Report)

We have been developing a multimedia fate model for radioactive substances by combining models for atmospheric, oceanic, and terrestrial environments. The atmospheric and the oceanic models have been developed based on a regional atmospheric transport and deposition model for air pollution and a coastal sea model for water pollution, respectively. The terrestrial model has been developed based on the multimedia fate model G-CIEMS (Grid-Catchment Integrated Environmental Modeling System), which was originally developed for risk assessment of organic pollutants. We aimed to simulate the multimedia fate of radioactive substances by coupling the three models with appropriate grid-based and geographic resolutions.

In the immediate aftermath of the accident, we simulated the atmospheric transport and deposition of ^{137}Cs and ^{131}I emitted from the FDNPS. The model approximately reproduced the observed temporal and spatial variations of deposition rates in eastern Japan. This was a first finding of atmospheric behavior of radioactive substances on a regional scale, and consequently gave rise to significant public concern following a press related release. The simulated data were used for decision making with regards to measures for radioactive contamination of water and land.

We revised several model parameters related to ^{137}Cs fates for G-CIEMS based on observation results and published related reports; set up the physicochemical properties of ^{137}Cs; and input data on deposited ^{137}Cs based on simulation by atmospheric model. Simulation was performed for a period covering 9 years following the accident for predicting the annual average of ^{137}Cs remaining in land area, surface water, and surface-water sediment. The results showed that 70% of the total deposited ^{137}Cs on the land surface was in forest area.

The objective of the ocean modeling study was to evaluate and predict the oceanic ^{137}Cs behavior and its impacts on marine ecosystem in the coastal shelf from the nuclear power plant accident into the future. We have developed a comprehensive numerical model of the oceanic ^{137}Cs behavior focusing on its dynamics including advection-diffusion transport caused by water currents, adsorption/desorption to/from particulate matter, and sedimentation/suspension interconnected with vertical activity profile in the sediment.

1.2.2.3 Impacts on organisms and ecosystems

(See section X.9 of the Detailed Report)

We conducted field surveys and experiments on plants and mammals to detect genetic and other impacts of radioactive material released into the environment on organisms and ecosystems. We also conducted research on predicting changes in ecosystems and damage caused by wildlife in districts from which human inhabitants have been evacuated so as to propose management strategies.

We created genetically modified plants that enable evaluation of repair of damage to DNA caused by radiation, and demonstrated that plant DNA damage due to radioactive substances in soil is quickly repaired. We are now in the process of establishing an experimental system capable of DNA damage evaluation in the field.

We found oxidation of sperm DNA in the large Japanese field mouse (*Apodemus speciosus*) captured in the wild in high-dose areas, but the sperm showed no morphological abnormalities. To investigate whether this oxidation was inducing genetic mutations, we completed a draft sequence of the large Japanese field mouse genome, and are evaluating the genetic diversity of individuals trapped in the radioactively contaminated zone of Fukushima Prefecture.

Our monitoring activities for aquatic organisms revealed that radioactive Cs accumulation varies by species and functional group, and that metabolic rate is an important factor affecting accumulation. We will determine the mechanisms whereby radioactive Cs accumulates in fish and other aquatic organisms inhabiting both marine and freshwater environments.

We are developing a means for collecting and promptly releasing monitoring data on mammals, birds, amphibians and insects. We will also develop a mathematical model of the ecosystems of Fukushima Prefecture to enable prediction of changes in ecosystems resulting from the evacuation of human inhabitants.

1.2.2.4 Evaluation of human exposure to radiation

(See sections X.8 and X.10 of the Detailed Report)

To evaluate human exposure to radioactive substances released into the environment, we measured environmental radiation levels including those of residential environments, and built a radiation dose estimation model that we used to carry out long-term, wide-area analysis of radiation doses. We also worked on the development of methods for measuring radioactive substances in the environment.

To provide scientific data that will help with long-term human radiation exposure prediction and reduction of radiation sources, we integrated modeling with monitoring to build a model for evaluating human radiation dose estimates, and analyzed radiation dose in detail.

Using our radiation dose estimation model, we estimated the distribution of radiation dose to inhabitants of eastern Japan for the first year after the nuclear power plant accident. We compared our model estimates with publicly available radiation dose data, and found that for external exposure, our estimates were consistent with actual measurements. While reviewing our data and fine-tuning parameters, we will also integrate this model with our multimedia environmental model to estimate radiation distribution and long-term radiation doses.

For monitoring, we measured actual radioactive Cs in indoor dust to set model parameters, and evaluated radiation doses and sources in Fukushima Prefecture and hotspots in the Kanto region (Tokyo and surrounding prefectures).

1.2.3 Environmental Renovation Research “Promotion of surveys and research towards restoration and environmental creation for the post-disaster regional environment”

The Environmental Renovation Research Program aims to promote surveys and research relating to projected future scenarios that focus on the restoration and reconstruction of the post-disaster regional environment. Accordingly, the project will investigate systems for developing regional socioeconomic and technological models, and for restoring social capital damaged by the disaster, as well as produce the design of a recovery center considering landuse planning in municipalities within Fukushima Prefecture. The scenarios developed within the project will be examined jointly with policymakers from the collaborating municipality (Shinchi Town in Fukushima Prefecture). They will be assessed based on local needs, while ensuring compatibility with existing regional plans and low-carbon technology scenarios.

1.2.3.1 Development of local information systems for environmental creation

(See section X.11 of the Detailed Report)

From the perspective of efficient use of limited resources and energy, much attention has been focused on distributed regional energy systems. These systems enable the efficient use of both electricity and heat by facilitating the practical application of regional resources and by taking advantage of the geographical proximity between supply and demand locations. Compared with a large-scale centralized system, the planning and operation of a region-specific system, based on conditions within a district, assumes importance within a distributed system. However, most systems to date have been primarily designed and operated based on individual experiences, therefore hindering the production of general knowledge. For this

study, we established a framework to support the design of a distributed energy system using a quantitative methodology. We confirmed its effectiveness through a case study of an actual district renovation project conducted within a municipality recovering from the GEJE. We further proposed expansion of the core project through an urban development plan based on a long-term perspective. One of the available options would be to expand the project to encompass overall planning of the entire town, including the industrial park.

For a distributed energy system installed at recovering areas, potential supply of various types of biomass were assessed in the eastern region of Japan. Promoting of biomass use may result in degradation of ecosystems and biodiversity. We also assessed effects of biomass use on ecosystems by using proxy variables for ecosystem services mapped for Japan's eastern region. These indices were analyzed using a multivariate statistical technique to identify specific key factors relating to the use of biomass and ecosystem services. Priority areas for the supply of biomass energy and ecosystem services were indicated and used to analyze potential conflicts between the two.

1.2.3.2 Development of models for analyzing regional environmental creation scenarios

(See section 2.4(4) of this Report,sections X.12 and X.13 of the Detailed Report)

From the perspective of local governments of areas devastated by the tsunami disaster, the process of recovery also provides an opportunity to establish a new energy system that is more efficient and self-sufficient; create new local businesses; and facilitate the lowering of emission levels of greenhouse gases (GHGs). Another important issue is to curb the trend towards depopulation already in evidence before the disasters.

To support the development of plans aimed at achieving the above targets, we developed a quantitative methodology that considered population, employment, industry, energy demand and supply, and energy technologies in a consistent and integrated manner. Applying the methodology to the town of Shinchi in Fukushima Prefecture,we developed scenarios for the town by 2050. In the "business as usual" scenario, the population would ultimately decline to almost half of the current level. The declining trend could be reversed in a scenario entailing the strategic location of industries based on industrial symbiosis. This would lead to efficient use of energy and more local energy-related industries, including smart network operators, co-generation facilities, and renewable energy producers.

For the analysis of optimal energy systems based on local characteristics, a bottom-up technology selection energy system model was developed for the town. In the baseline case, CO_2 emission would remain at around 50 kt-CO_2/y in 2050. CO_2 emission could be reduced by 80% through the installation of regional energy facilities such as solar photovoltaics and combined heat and power plants.

1.2.3.3 Development and implementation of participatory environmental creation methods

Shinchi is implementing a program aimed at creating a "Smart Hybrid Town" based on environmental, economical, and social values associated with a "Future City." In close collaboration with Shinchi, we developed the "Shinchi Life Assist Tab System" that includes two assist functions: "Local energy assist" and "Life assist." For this study, we programmed tablet computers to display energy consumption information for residential houses and public facilities and established a regional ICT system to share information on town development during the reconstruction process. Our main objectives were as follows: 1) to promote eco-friendly action through the use of local information, 2) to streamline the use of local on-demand transit, 3) to support reconstruction efforts by victims of the earthquake, and 4) to share information interactively among regional stakeholders. To promote energy conservation activities among residents, we conducted experiments in the form of campaigns in September 2014, November 2014, and March 2015. The maximum average power saving rate was 7% of the September rate. In parallel, we carried out several questionnaire surveys and interviews. Their results suggested that the behavior and consciousness of the residents regarding an eco-friendly lifestyle were influenced by regional characteristics.

1.2.4 Environmental Emergency Management Research "Studies on establishment of the environmental management system prepared for future disasters"

The GEJE caused extensive damage, including societal and environmental impacts, to Japan. Mitigation of the extent of the disaster's impact on society, and facilitation of expedited recovery from this damage are contingent on the resilience potential of Japan's social and technological systems. Accumulated knowledge and lessons, based on experiences of previous disasters including the GEJE, can contribute to strengthening

the resilience potential of these systems.

For the Environmental Emergency Management Research Program, we conducted three research projects as outlined below.

1.2.4.1 Implementation strategy for resilience in material cycle and waste management

(See section 3.1 (5) of this Report, and sections X.14 and X.15 of the Detailed Report)

Appropriate quantitative and qualitative estimation of disaster waste generation is essential for formulating a disaster waste management plan. We obtained a unit factor for disaster waste generation based on our study of the consequences of the GEJE. Applying this to future disaster scenarios such as earthquakes in the Nankai Trough and in the Tokyo Metropolitan Area, we developed a new methodology for estimating the disaster waste which could be generated by projected future disasters.

Regarding appropriate disaster waste management technologies, we performed a pilot investigation of mechanical and manual segregation of disaster waste. We established a methodology for optimizing processes according to the type of disaster waste as well as the purpose of respective processes, for example, incineration and recycling. Regarding the management of hazardous material, including disaster waste, we focused on waste containing asbestos. We developed a rapid screening method for this kind of waste and investigated asbestos material dispersion during crushing and segregation processes, including improved control measures to prevent the dispersion of asbestos into the environment. Based on our results, we proposed appropriate measures for controlling the environmental impact of asbestos-containing material in disaster waste management. Regarding the recycling of disaster waste, we carried out a cost–benefit analysis for the use of disaster waste as recycled material to restore damaged infrastructure, and compiled data through a field investigation of a pilot embankment site.

In addition to these studies, we developed guidelines on the use of disaster waste. For the proper treatment of domestic wastewater, including human nightsoil, in the context of disaster management, we proposed a countermeasure against liquefaction caused by the earthquake's impact on a *Jokasou* system which is a uniquely Japanese domestic wastewater treatment system. We further formulated an estimation scheme for assessing the earthquake-resistant capacity of a *Jokasou* system.

Concerning management of organizational and human resources within local governments for disaster waste management, we outlined the necessary disaster waste management operations, to be conducted within a set time frame, and systematized several different operations within an organizational function. We further proposed a number of basic principles that should be considered when establishing a disaster waste management plan.

The abovementioned research outputs were reflected in relevant technical documents pertaining to national and regional level guidelines on disaster waste management.

1.2.4.2 Health and environmental risk management strategies in environmental emergency

We discussed and proposed an environmental survey system to be applied in an emergency situation following the occurrence of a disaster. A particular discussion focus was on how to select and analyze target substances at the time of an emergency. We also collected relevant information from the US Environmental Protection Agency and the German and Canadian environmental ministries.

Moreover, we conducted several environmental monitoring surveys that focused, for example, on airborne particulates, long-term changes in a tidal flat ecosystem, and marine sediment contaminated with residual oil in the area affected by the tsunami disaster.

1.2.4.3 Development of exchange and networking for disasters and environment

We held a workshop to identify and outline necessary capacities of local government personnel for disaster waste management in the event of an emergency. Personnel who had previous experience of actual disaster waste management following the GEJE participated in the workshop. As a result of the discussions at the workshop, we were able to systematically organize the required capacity elements. Based on our research findings, we designed and proposed a comprehensive training program. We further developed and conducted a training workshop as the central component of the proposed program. The impact of the training

methodology was evaluated and subsequently improved.

Last, we established and disseminated outcomes and other information through a website serving as an information platform for disaster waste management. The website is expected to serve several purposes in facilitating preparion for future disasters. For example, it could support the development of disaster waste management plans by local authorities.

2 Research budget, human resources, and papers during the third NIES five-year plan

2.1 Research budget per each fiscal year

	FY2013	FY2014	FY2015
Grant for Operating Costs	274	833	804
Other External Research Funding	820	58	-
Total	1094	891	804

(Unit: million yen)

2.2 Human resources

Cumulative total number of staff during the third five-year plan: 327

2.3 Total number of papers and conference presentations during the third five-year plan

Papers		Books	Presentations		Patents
Peer review	Others		Domestic	International	
59	122	13	453	70	4

2.4 Major papers and patents

(1) Environmental Recovery Research 1: Thermal treatment of radioactively contaminated waste

Kuramochi H. (2014) Thermal treatment of waste contaminated with radioactive chemicals due to the accident at Fukushima nuclear power stations: A review of recent research findings and introduction of some key literatures. Journal of Society for Remediation of Radioactive Contamination in Environment, 2, 71-84. (in Japanese)

This study investigated the distribution of radioactive cesium (r-Cs) between fly ash and bottom ash discharged during the incineration of r-Cs-contaminated municipal solid waste (MSW). To understand the behavior of r-Cs during the incineration of MSW, the stoker-type incinerator was simulated using a multi-zonal equilibrium calculation. This reasonably represented r-Cs distribution between the two forms of ash. The r-Cs accumulated within refractory bricks collected from MSW incineration facilities was examined by measuring r-Cs activity extending from the surface to the bulk of the bricks. Differences were found in the chemical forms of the accumulated r-Cs within portions of the bricks.

(2) Environmental Recovery Research 2: Environmental dynamics measurement

Nishikiori T., Watanabe M., Koshikawa M.K., Takamatsu T., Ishii Y., Ito S., Takenaka A., Watanabe K., Hayashi S. (2015) Uptake and translocation of radiocesium in cedar leaves following the Fukushima nuclear accident. Science of the Total Environment, 502, 611-616.

To understand the migration and accumulation of radioactive Cs in environments, we conducted field measurement studies in a forest and water body. In a forest, ^{137}Cs was absorbed through the surface of cedar tree leaves soon after the FDNPS accident. A further finding was that ^{137}Cs in new leaves that sprouted after the accident mainly resulted through a process of translocation from the old leaves.

(3) Environmental Recovery Research 2: Atmospheric measurement and modeling

Morino Y., Ohara T., Nishizawa M. (2011) Atmospheric behavior, deposition, and budget of radioactive materials from the Fukushima Daiichi nuclear power plant in March 2011. Geophysical Research Letter, 38, L00G11.

To understand the atmospheric behaviors and impact of radionuclides, we conducted atmospheric modeling of radioactive materials immediately after the nuclear accident at the FDNPS. Regional transport modeling played key roles in understanding the atmospheric behaviors and deposition patterns of radioactive materials. The model roughly reproduced the observed temporal and spatial variations of deposition rates of ^{137}Cs and ^{131}I in eastern Japan. This is a first publication of atmospheric simulations on a regional scale.

(4) Environmental Renovation Research: Feasibility assessment of regional energy system

Togawa T., Fujita T., Dong L., Fujii M., Ooba M. (2014) Feasibility assessment of power plant source waste heat to plant factory considering spatial configuration, Journal of Cleaner Production, 81, 60-69.

Japan has faced with multiple challenges of energy system transformation and social decarbonization in the post-Fukushima era. In revitalization area from the GEJE, it is a crucial argument to develop sustainable and low-carbon regional systems. For this sake, an urban energy model was constructed and combined with spatial analysis. The findings of the study indicated that the waste heat system provided more environmental benefits compared with the individual boiler system. Cost-effective areas regarding the heat supply were identified based on cost–benefit analysis and geographic information system techniques.

(5)Environmental Emergency Management Research : Disaster waste management

Tajima R., Hirayama N., Osako M. (2014) Identifying emergency support functions for disaster waste management - Structuring the practical tasks undertaken in the case of Great East Japan Earthquake-, Journal of Japan Society for Natural Disaster Science, 33, special issue, 153-163. (in Japanese)

To enhance smooth and appropriate disaster waste management (DWM), this paper aimed to identify fundamental emergency support functions necessary for DWM by structuralizing actual DWM tasks observed in the case of GEJE. The analysis revealed 22 sub-functions organized under 5 basic functions (namely, operations, command, logistics, finance/administration, and planning), which could be used as a basis of preparedness actions including planning response actions and designing functional organizations for effective DWM.

XI. NIES Forthcoming Mid-term Plan

1. Administrative positioning of National Institute for Environmental Studies

The National Institute for Environmental Studies (NIES) falls under the category of a National Research and Development Agency as an Incorporated Administrative Agency under the jurisdiction of the Ministry of the Environment, Japan. Incorporated Administrative Agencies implement activities which, while not requiring direct government action, may not be completed if entrusted to private-sector corporations. Among these, National Research and Development Agencies have as their purpose the maximization of research development and outcomes. "Maximization of research development and outcomes" can be defined as the "maximization" of development in both the research process and outcomes thus generated on a national, unified level, and which contributes to sound progress for public livelihoods, economy, culture, as well as other aspects in the public interest.

The duties with which NIES is specifically tasked are:

a) Research to establish environmental circumstances; research relating to impacts of human activities on the environment; research on health impacts of environmental changes with their origin in human activities; research on strategies to lessen environmental burdens; and research and surveys on the conservation of the environment (excluding comprehensive surveys and research on Minamata Disease which is implemented by National Institute for Minamata Disease).
b) Collation and management of domestic and international information on the conservation of the environment (excluding Minamata Disease), and subsequent provision of such information.

2. Role of NIES in environmental research

NIES, as a leading research institution, is expected to endeavor to further research and technologies, while:

a) Pioneering comprehensive research with actual potential to contribute to the resolution of economic and social issues,
b) Endeavoring to provide scientific know-how which contributes to the administrative policy-making,
c) Strengthening ties with universities, regional environmental authorities and the private-sector, and
d) Furthering international ties

3. Issues as part of our next mid-term plan

Based on the contents and objectives of the current mid-term plan, NIES is currently considering how to engage with the following issues as part of our next mid-term plan

a) Implementation of research which will have real social applications
b) Actual capacity to contribute to the resolution of specific issues
c) Resolution of environmental issues with the various stakeholders
d) Introduction of a system designed to facilitate outstanding human resources and encourage the exchange of personnel
e) Improve internal systems for research evaluation

4. Research strategy for the next mid-term plan based on factors outlined in 1-3 above

a) Implementation of issue-oriented research programs: We will undertake interdisciplinary, issue-oriented research programs with a focus on research which has actual potential for application, and which efficiently contributes to the resolution of problems, as well as active social implementation, over the duration of the fourth mid-term plan.

b) Implementation of the Environmental Emergency Research Program centered on the Fukushima Prefectural Center for Environmental Creation: We will establish our Fukushima Headquarters, to facilitate social implementation for the assured and sustained recovery of the disaster zone and renewed environmental renovation.

c) Promotion of fundamental research: One of NIES' core strengths is the ability to seamlessly implement fundamental research which integrates basic and applied research in diverse fields, and we will continue to pursue this under the fourth mid-term plan.

d) Expansion of long-term research projects: We will maximized research development and outcomes on a national level, by identifying research which should be developed on an organizational level

and a long-term basis, ensuring continuity and external ties; and establish a department for research projects which have as their aim the promotion of data exploitation and application by external bodies.

e) Domestic and overseas ties: We will seek to further strengthen research ties towards maximized research development and outcomes on national and international levels, in our role as a leading institute for environmental research.