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ENVIRONMENT DIRECTORATE
JOINT MEETING OF THE CHEMICALS COMMITTEE AND THE WORKING PARTY ON CHEMICALS

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Series on Risk Management No. 10

PROCEEDINGS OF THE OECD WORKSHOP ON SUSTAINABLE CHEMISTRY PART1

Venice, 15 - 17 October, 1998

English text only

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OECD Environmental Health and Safety Publications

Series on Risk Management

No. 10

PROCEEDINGS OF THE OECD WORKSHOP ON SUSTAINABLE CHEMISTRY

Venice, 15-17 October 1998

IOMC

INTER-ORGANIZATION PROGRAMME FOR THE SOUND MANAGEMENT OF CHEMICALS

A cooperative agreement among

UNEP, ILO, FAO, WHO, UNIDO, UNITAR and OECD

Environment Directorate
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT
Paris 1999

INTERUNIVERSITY CONSORTIUM CHEMISTRY FOR THE ENVIRONMENT

Other Environmental Health and Safety publications related to risk management include:

Risk Reduction Monograph No. 1: Lead. Background and National Experience with Reducing Risk (1993)

Risk Reduction Monograph No. 2: Methylene Chloride. Background and National Experience with Reducing Risk (1994)

Risk Reduction Monograph No. 3: Selected Brominated Flame Retardants. Background and National Experience with Reducing Risk (1994)

Risk Reduction Monograph No. 4: Mercury. Background and National Experience with Reducing Risk (1994)

Risk Reduction Monograph No. 5: Cadmium. Background and National Experience with Reducing Risk (1994)

OECD Proceedings: Sources of Cadmium in the Environment (1996)

OECD Proceedings: Fertilizers as a Source of Cadmium (1996)

Risk Reduction Monograph No. 6: Methylene Chloride Information Exchange Programme: Survey Results (1996)

Risk Reduction Monograph No. 7: Proceedings of the OECD Workshop on Non-Regulatory Initiatives for Chemical Risk Management (1997)

Risk Reduction Monograph No. 8: Proceedings of the OECD Workshop on the Effective Recycling of Nickel-Cadmium Batteries, Lyon, France, 23-25 September 1997 (1999)

Risk Reduction Monograph No. 9: Proceedings of the OECD Workshop on the Integration of Socio-Economic Analysis in Chemical Risk Management Decision Making, London, 7-9 January 1998 (1999)

About the OECD

The Organisation for Economic Co-operation and Development (OECD) is an intergovernmental organisation in which representatives of 29 industrialised countries in North America, Europe and the Pacific, as well as the European Commission, meet to co-ordinate and harmonize policies, discuss issues of mutual concern, and work together to respond to international problems. Most of the OECD's work is carried out by more than 200 specialised Committees and subsidiary groups made up of Member country delegates. Observers from several countries with special status at the OECD, and from interested international organisations, attend many of the OECD's Workshops and other meetings. Committees and subsidiary groups are served by the OECD Secretariat, located in Paris, France, which is organised into Directorates and Divisions.

The Business and Industry Advisory Committee (BIAC) and the Trade Union Advisory Committee (TUAC) provide input as official consultative bodies of the OECD.

The work of the OECD related to risk management is carried out by the Workng Party on Risk Management, with Secretariat support from the Environmental Health and Safety Division of the Environment Directorate. As part of its work on risk management, the OECD has issued "status report" monographs on five substances that were, or continue to be, the subject of review: **lead, cadmium, mercury, selected brominated flame retardants** and **methylene chloride**. It has also published two volumes of the **proceedings of the OECD Cadmium Workshop** held in Saltsjöbaden, Sweden, in 1995 and a **survey report on methylene chloride**, supplementing the information presented in the monograph on methylene chloride (see list of publications on page 4). In 1996, OECD Environment Ministers endorsed a **Declaration on Risk Reduction for Lead** to advance national and co-operative efforts to reduce the risks from lead exposure.

The Environmental Health and Safety Division publishes documents in six different series: **Testing and Assessment**; **Good Laboratory Practice and Compliance Monitoring**; **Pesticides**; **Risk Management**; **Harmonization of Regulatory Oversight in Biotechnology**; and **Chemical Accidents**. More information about the Environmental Health and Safety Programme and EHS publications is available on the OECD's web site (see next page).

This publication was produced within the framework of the Inter-Organization Programme for the Sound Management of Chemicals (IOMC).

This publication is available electronically, at no charge.

For the complete text of this and many other Environmental Health and Safety publications, consult the OECD's web site (http://www.oecd.org/ehs/)

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The Inter-Organization Programme for the Sound Management of Chemicals (IOMC) was established in 1995 by UNEP, ILO, FAO, WHO, UNIDO, UNITAR and the OECD (the Participating Organizations), following recommendations made by the 1992 UN Conference on Environment and Development to strengthen co-operation and increase international co-ordination in the field of chemical safety. The purpose of the IOMC is to promote co-ordination of the policies and activities pursued by the Participating Organizations, jointly or separately, to achieve the sound management of chemicals in relation to human health and the environment.

FOREWORD

These Proceedings contain the presentations made at the OECD Workshop on Sustainable Chemistry held in Venice, Italy, on 15-17 October 1998. There is also a report of the Workshop, including participants' conclusions and recommendations. A description is given of the Risk Management Programme of the OECD, under which the Workshop was held; the development of methodologies to support OECD countries' efforts to manage risks posed by chemical substances; and the role of this Workshop in supporting such activities.

A survey conducted before the Workshop collected basic information on Sustainable Chemistry activities recently completed or ongoing in Member countries. A report summarising the survey results and identifying trends across countries is included in an annex.

ACKNOWLEDGMENT

The OECD gratefully acknowledges the financial assistance provided by *the International Consortium, Chemistry for the Environment* for the publication of this monograph.

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POSTERS DISPLAYED AT THE WORKSHOP:

EXECUTIVE SUMMARY

At the February 1998 Joint Meeting of OECD's Chemicals Group and Management Committee, Member countries endorsed the start of work on a new "Sustainable Chemistry" initiative to encourage fundamental breakthroughs in chemistry that would prevent pollution and, in most cases, improve performance and reduce costs. As a first step, they agreed that a workshop should be held.

This workshop, which took place in Venice in October 1998, was hosted by the Inter-university Consortium, Chemistry for the Environment (Italy) and co-sponsored by the Governments of Germany, Italy, Japan and the United States, in co-operation with the International Union of Pure and Applied Chemistry (IUPAC) and the Business and Industry Advisory Committee to the OECD (BIAC). The following contributed to the funding of this workshop: the Inter-university Consortium, Chemistry for the Environment; the Governments of Germany and the United States; the Japan Chemical Innovation Institute (JCII); IUPAC; Euro Chlor; and Verband der Chemischen Industrie e.V. (VCI, Germany).

Joe Carra (United States Environmental Protection Agency) and Pietro Tundo (Ca' Foscari University, Venice) co-chaired the workshop. The 75 experts who attended represented 16 OECD countries, the European Commission, industry and non-governmental organisations.

The workshop focused on the policy/programmatic aspects of Sustainable Chemistry[1] initiatives, with a mandate to:

- identify the types of Sustainable Chemistry activities already under way, supported in part by the results of an OECD-wide survey;
- identify effective techniques and approaches in the field of Sustainable Chemistry (including educational approaches), considering problems and highlighting solutions; and
- identify activities that could further the development and use of Sustainable Chemistry.

With respect to the last item, the workshop examined mechanisms to:

- recognise, and promote as models, Sustainable Chemistry achievements by the chemical industry and by scientists in universities and research institutions;
- disseminate technical and event-related information concerning Sustainable Chemistry (e.g. via the Internet);

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[1] Within the broad framework of sustainable development, one should strive to maximise resource efficiency through activities such as energy and non-renewable resource conservation, risk minimisation, pollution prevention, minimisation of waste at all stages of a product's life-cycle, and the development of products that are durable and can be re-used and recycled. Sustainable Chemistry strives to accomplish these ends through the design, manufacture and use of efficient and effective, more environmentally benign chemical products and processes.

- promote the incorporation of Sustainable Chemistry principles at various levels of chemical education;
- support and promote research, discovery and development in regard to innovative Sustainable Chemistry technologies; and
- develop guidance on implementation of Sustainable Chemistry programmes for use by OECD countries and others.

Before the workshop, a survey was carried out to collect basic information on Sustainable Chemistry activities recently completed or ongoing in Member countries. These included activities initiated by governments, academia and industry, and managed by one of these parties alone or collaboratively (e.g. through government/industry partnerships). The United States Environmental Protection Agency developed a report summarising survey responses and identifying trends across Member countries. This report, distributed to participants a few weeks before the Workshop, was introduced by US EPA (see Annex I to these Proceedings).

It was evident during the workshop that considerable interest and enthusiasm exist among governments, industry, NGOs and academia both for Sustainable Chemistry's basic concepts and for practical developments. Speakers from Austria, Germany, Italy, Japan and the United States presented considerable information on work in this field. The keynote speaker, Professor John Warner (University of Massachusetts), discussed the imperative and desirability of integrating Sustainable Chemistry thinking into the fields of chemistry and environmental sciences, and throughout the vast array of industrial sectors that they affect. Poster sessions made clear that very promising cutting-edge research and commercialisation have begun.

Workshop participants agreed that Sustainable Chemistry provides a cost-effective means of:

- reducing chemical threats to health and the environment;
- accelerating the pace of chemical innovation; and thereby
- contributing to economic competitiveness and sustainable development.

Participants also agreed that efforts should be made to promote the establishment of such programmes by governments, industry and academia. A series of recommendations were made for achieving this aim (see Report of the Workshop). These recommendations were considered by the Joint Meeting when it met in November 1998.

INTRODUCTION

OECD Risk Management Activities

OECD's work related to chemical risk management began in 1990, when the Council of the OECD adopted a Decision-Recommendation on the Co-operative Investigation and Risk Reduction of Existing Chemicals [C(90)163/Final]. This OECD Council Act is aimed at the reduction of risks from chemicals to the environment, and/or to the health of the general public or workers. It is based on the premise that international co-operation in risk reduction activities can enhance the technical and institutional aspects of risk management in Member countries through burden-sharing and a reduction of duplicative efforts. Furthermore, such activities can lead to more effective use of the knowledge of risks being generated through, for example, national chemical reviews and assessments; the OECD co-operative investigation of existing chemicals; and the work of other international organisations conducting hazard and risk evaluations.

The initial work of OECD's Risk Management Programme focused on five chemicals (or groups of chemicals): *lead, mercury, cadmium, brominated flame retardants, and methylene chloride.* For each, a "Risk Reduction Monograph" was published which described the commercial and environmental life cycle of the substance(s), international and national positions concerning risk to man and the environment, and measures taken by OECD countries to reduce such risks. Based on this material, various actions were initiated within the OECD, ranging from the collection of additional information on some chemicals, to overseeing voluntary industry initiatives to reduce certain risks, to a declaration by Member governments that they would advance national and co-operative efforts to reduce other risks.

In 1995, the Joint Meeting of the OECD's Chemicals Group and Management Committee agreed to review the Risk Management Programme in the light of technological advances and lessons learned since the Programme was launched in 1990. It was decided that the Programme should focus on two areas: (1) developing methods and technical tools that can be used by OECD and Member countries to enhance their current risk management programmes; and (2) identifying chemical exposures of concern in Member countries and evaluating possible risk management opportunities.

Methodologies and Technical Tools

Work on methodologies began in 1996 with the Workshop on Non-Regulatory Initiatives hosted by the United States (Crystal City, Virginia, 10-12 September). This workshop (1) provided a forum for governments, industry and non-governmental organisations to share experiences with non-regulatory initiatives, and (2) provided guidance to the OECD Risk Management Programme on the value and promise of non-regulatory measures.

The results from this workshop provided the foundation for the new Risk Management Programme of Work, which relies, to a considerable degree, on identifying and applying new, innovative and effective techniques for managing risk. One such innovative technique is sustainable chemistry.

The Project on Sustainable Chemistry

The Joint Meeting of OECD Chemicals Group and Management Committee agreed to the initiation of work on Sustainable Chemistry in February 1998. As a first step to begin this work, a survey was conducted to collect basic information on Sustainable Chemistry activities recently completed or ongoing in Member countries. This included activities initiated by governments, academia and industry, and those managed solely by one of these parties or in a collaborative fashion (e.g. through a government/industry partnership). The survey results were discussed at the Venice workshop. The survey report included in this document as Annex I was distributed to participants prior to the workshop.

The objectives of the Venice workshop were: 1) to identify the types of sustainable chemistry activities under way (supported by the results of the survey); 2) to identify effective techniques and approaches in the field of sustainable chemistry (including educational approaches), highlighting problems encountered and considering solutions; and 3) to identify activities that can further the development and use of sustainable chemistry programmes. The results from the workshop were discussed at the November 1998 meeting of OECD's Working Party on Risk Management, and subsequently reported to the Joint Meeting.

The workshop was hosted by the Interuniversity Consortium, Chemistry for the Environment (Venice) and co-sponsored by the Governments of Germany, Italy, Japan and the United States, in co-operation with the Business and Industry Advisory Committee to the OECD (BIAC). The following contributed to the funding of the Workshop: the Interuniversity Consortium, Chemistry for the Environment; the Government of Germany; the Government of Japan; the Government of the United States; the International Union of Pure and Applied Chemistry; and two BIAC organisations, the European Chlorine Manufacturers Association (Euro Chlor) and Verband der Chemischen Industrie e.V. (VCI), Germany.

PAPERS PRESENTED AT THE WORKSHOP

The Interuniversity Consortium "Chemistry for the Environment"

Pietro Tundo
Professor of Organic Chemistry
Environmental Chemistry Department
Ca' Foscari University
Venice, Italy

http://www.unive.it/inca

CONSORTIUM UNIVERSITIES, LABORATORIES AND RESEARCH CENTRES.

THE INTERUNIVERSITY CONSORTIUM *CHEMISTRY FOR THE ENVIRONMENT* (INCA) WAS FOUNDED IN VENICE IN OCTOBER 1993.

IT GROUPS ABOUT THIRTY ITALIAN UNIVERSITIES AND RELIES ON THE RESEARCH CONTRIBUTIONS OF CHEMISTS HAVING DIFFERENT SPECIALITIES (ENVIRONMENTAL, PHYSICAL-CHEMICAL, ORGANIC, INORGANIC, ANALYTIC, INDUSTRIAL AND BIOCHEMICAL) TOGETHER WITH RESEARCHERS COMING FROM OTHER DISCIPLINES ENGAGED IN ENVIRONMENTAL RESEARCH.

Consortium INCA has its administrative offices in Venice.

Introduction

The INCA Consortium seeks to increase the involvement of chemists in environmental research, qualitatively and quantitatively.

By identifying the most recent and emerging scientific developments in this quickly evolving field, it is possible to channel the intellectual resources and technological know-how of its members.

Special attention is devoted to interaction with industry, including small and medium-sized firms, in order to support the transfer of different areas of knowledge acquired from research.

Based on its statute, specific objectives of the Consortium are:

a. to establish laboratories for advanced research, and to organise Research Units involving universities and public-private corporations;

b. to assist in the co-ordination and development of scientific groups, especially between Research Units of associated universities and work groups of public and private chemical firms involved in environmental science;

c. to share the equipment and laboratories necessary to support the activities of doctoral programmes, and to appoint research personnel within the participating universities;

d. to encourage experts in environmental chemistry with scholarships and specialised courses;

e. to make independent scientific assessments of environmental problems, including the application of EU directives on eco-labelling and environmental risk assessment. Also, to carry out research programmes initiated by public administration as well as private institutions.

Chemistry for the Environment and the Consortium

The last few years have seen an increase in world-wide public interest in environmental issues. This has led to a change in governmental strategies concerning sustainable development, which now consider the environmental impact of the technological procedures implemented. The results can be seen in the birth of new themes, highly interdisciplinary, which include research on and production of chemicals and commercial products compatible with the environment, ever more selective and efficient analytical methodologies, effective decontamination techniques, and the study of the transformation of chemical products in the environment.

In order to take part in this profound transformation of chemistry, and grasp both national and international short and long-term opportunities, the Interuniversity Consortium “Chemistry for the Environment” (INCA) was founded in 1993. Although the scientific level of individual groups operating in universities and industry was high, overall activities were fragmented, lacked co-ordination, and above all were not aimed at finding solutions. The Consortium’s aim was to organise the particular expertise and resources of individual groups into a project and a broad system, thus creating a reference point and network giving added value to all. This would also facilitate contacts between the different disciplines and universities, research entities and industry, in order to form a strategic sector for our country.

The results of these few years of activity, which have been intense and full of enthusiasm but have lacked adequate funding, have been noteworthy.

On the national level, the first step was to classify the available resources and create an initial "network", defining thematic areas and co-ordinators.

The INCA Consortium now affiliates 28 universities (practically all those with this specific research area), with the participation of about 300 university professors and about 100 researchers.

On the international level of "green chemistry", the Consortium has developed many collaborations with other organisations, for example the US Environmental Protection Agency and the International Union of Pure and Applied Chemistry (IUPAC). The latter has formed a Working Party (Synthetic Pathways and Processes on Green Chemistry), the results of which will be presented in Berlin in 1999 during the IUPAC General Assembly, indicating guidelines and strategies for the academic and industrial world applicable to fundamental research using green chemistry technology. The Consortium is closely involved with this initiative, which includes the collaboration of the IUPAC, international industrial organisations and scientists from every part of the world, and which will result in the publication of a white book. The Consortium has also joined the Azione Concertata Europea (United European Action). This has given rise to the NICOLE network, whose aim is to oversee processes and procedures for environmental remediation of industrial waste sites, for public use, on the European level.

The Consortium is also a component of the OECD's Steering Group for Sustainable Chemistry.

Establishing a research network among Italian universities which aims to promote - through comparison and discussion - specific thematic areas which cross different disciplines is becoming indispensable. These areas must also be valid on an international level and be aimed at producing social, economic and scientific benefits on the national level. "Chemistry for the Environment" is certainly one of these.

It is not without a hint of pride that our Consortium has moved along these lines right from the beginning, trying to remedy the existing lack of co-ordination by creating a "gathering point" necessary to overcome the lack of an integrated synergetic system in Italy in all sectors, which was particularly true of Chemistry for the Environment at the time. The need, in this sector of such fundamental importance, not only for development of the country but also (a cardinal point) for global development (see the fifth Framework of the European Union) has become clearer as its inadequacies have become apparent.

In Italy, the progressive separation of fundamental chemical research and industrial development (the causes of which need not be listed here) has brought about a drop in researchers' scientific and technological productivity at the university level, accompanied by the senseless policy of closing those sectors of the chemical industry that are better equipped for research and laboratory facilities.

Nevertheless, no one questions that the contribution of fundamental research of this type - when co-ordinated and adequately funded - produces both economic and health benefits and a better quality of life, as is seen in other industrialised countries.

Objectives

The objectives of the Consortium are to expand the initiatives already underway on the national and international level, and to begin others, in order to enlarge its scientific and technological network, particularly in the following sectors:

- stimulation of fundamental research in the Chemistry for the Environment sector;
- development of activities oriented towards technological innovations favouring a clean technology approach and application;
- development of training activities;
- contribution to employment and economic development.

These objectives are easier for the Consortium to achieve than they are for individual associated universities since, from an administrative-management point of view, it has legislative and juridical standing as a private institution.

Research

We have realised, in light of comparisons with other industrialised countries which have invested much more in fundamental research than has Italy, that scientific progress is the basis of technological, economic and social progress once it as become structurally intrinsic to the country's economy.

In this perspective, distinctions between fundamental, financed and applied research are insignificant due to continued exchanges between these different approaches. In fact, if one can create efficient institutional channels, technological exchanges (the indispensable basis for industrial progress) should be quite natural. Specialised fundamental research, if co-ordinated and finalised with the help of research groups which are specifically concerned with applied themes, could in this way give new answers to the problems of the environmental sector. It is believed that only a gathering of homogeneous forces with motivation can attain a good scientific and technological level in a sector of such strategic importance for our country.

The Consortium is therefore the flexible instrument which can rapidly organise research directions with regard to international scientific reality, and to the objectives indicated by public institutions in Italy and internationally.

National research network

On the national level, through the Framework Agreements already stipulated with the ENEA (Italian National Agency for Energy and Environment), ANPA (National Agency for the Environment) and ENI (National Research Hydrocarbon Agency), the Consortium interacts with public administrations - regional and national - as co-ordinator, in agreement with the MURST (Ministry for Scientific Research) rules.

Through these Framework Agreements - which constitute a research network for applied research on a different level from its own - the Consortium develops research on the university level in different sectors. This research concerns, in particular, the Consortium's four National Thematic Areas:

1. chemical procedures and clean technology;
2. transformation mechanisms in the environment;
3. advanced analytical methodologies;
4. minimisation of wastes and of their contaminating effects.

The Scientific Board of the Consortium, based on the Assessment of the Research Units (see point 4), is in charge to follow the activities initiated and to programme new ones.

An important scientific field of activity for the Consortium regards the Plan "Ambiente Terrestre: Chimica per l'Ambiente" (Land Environment: Chemistry for the Environment) with funding from the MURST in the framework of Legislative Decree 488/92 "Aree Economicamente Depresse" (Economically Depressed Areas). The Consortium has presented the aforementioned Plan, composed of six research projects, and all have received funding. These projects bring together the seven Associated Universities of the Consortium which operate in Southern Italy (Objective 1 of the EU), along with the Laboratory of Marghera, until now the only laboratory of the Consortium placed in Objective 2 of the EU.

These six projects concern different fields such as decontamination of waste products, green chemistry technology, reactor technology and the production of active carbon. They are oriented towards promoting the resources of Italy's southern regions. Activities also include a project for enlarging laboratories (infrastructure) and the instruments necessary for their use. These six projects will start by 1999.

The Consortium assists National Research Projects concerning different environmental sectors, as well as promoting "button-up" collaboration between the university and industry in such sectors as clean chemistry, soil remediation and recovery, tanneries and environmental research.

International network

The Consortium has already begun to develop internationally through collaborations with the US EPA and the American Chemical Society (ACS), the development of agreements with Korea within the Scientific-Technological Protocol, and active participation in activities of the OECD (Environmental Health and Safety Division) relating to green chemistry. It has already obtained funding for a Summer School on Green Chemistry from the European Community (DGXII, Training and Mobility of Researchers). The Summer School, located in Venice, has a three-year programme (1998-1999-2000) which will bring together researchers and chemists interested in clean technologies and sustainable development. The subsequent international discussions will be all the more interesting due to this setting, which is of such national and international importance for chemistry and industry.

This Summer School on Green Chemistry is expected to create and develop a network of research and know-how in connection with the development of clean chemistry in our country. This is of special importance in areas of industrial decline, where scientific and technological transfer is indispensable in order to reconvert their economies. In our opinion, the new opportunities for research and economic development associated, for example, with more reliable and cleaner chemistry must be given very high consideration.

The medium and long-term objective is to create centres for research which can achieve recognition of excellence from the European Community, and thus attract graduate and post doctoral scholars using the resources of the next programme of Training and Mobility of Researchers. It is known that the fifth Framework foresees an enlargement of the European Community Network, basing its activities on these centres of excellence, in order to train European researchers through the promotion of exchange programmes. Italy cannot be left out of this competition, where sectors such as Chemistry for the Environment will be a great proving ground and should be promoted. The scholarships available for young researchers have a strong impact and great importance for the European Community. Unfortunately, Italy is not yet the “place to be” for these researchers, who do not recognise its full potential. The recognition of the Consortium laboratories as centres of excellence will constitute an incentive for Europe's youth.

The IUPAC Working Party will gather scientists from all over the world, particularly the United States, Japan, South Africa, Germany and the UK, and will define “green chemistry” using a molecular approach. This activity will be connected in a functional manner with the analogous network already established for the OECD; in fact, while the first activity (IUPAC) will be principally concerned with scientific aspects, the second (OECD) will treat socio-economic issues. It is important for the Consortium to participate in both these networks, which deal with the same topic (green or sustainable chemistry) in order to have greater responsibility and a clearer view of the problem.

The Consortium plans to be a reference point for projects and research programmes in the sphere of the fifth Framework of the European Community. It plans to reach this objective not only through a widespread information network, but also through direct contacts and co-ordinated actions between the Consortium and the European Community. Generally speaking, the Consortium intends to support Italian initiatives aiming at the development of scientific collaborations between Italy and various other countries - for example, by working in collaboration with the Department of Foreign Affairs to present Italian scientific and technological activities through our embassies abroad.

Training

Another topic the Consortium deals with is training. It has already published its own “Programma Nazionale di Formazione Professionale Chimica per l'Ambiente”, in which it plans to co-ordinate activity in this important sector, requalifying personnel at all levels and inserting them in a new production context through the exchange of scientific and technological know-how. It relies on its network in this case as well.

Assessment

In order to programme the activities of the Consortium, and the correct distribution and management of its resources, a clear idea of the strengths and weakness of the Research Units which operate within the structure of the Consortium - and of the Consortium itself - is indispensable. The Consortium is therefore proceeding with a self-assessment which will be handled by the Centre for Higher Education Policy Studies (CHEPS) of Twente University (NL). This organism, which is specialised in research evaluation on a European level, guarantees an assessment of the institution under examination based on international standards. The CHEPS has recently conducted an assessment of all the chemistry groups in Holland. The International Committee is composed of the following: Prof. A. Amaral, Rector of the University of Oporto and delegate for the evaluation of the Conference of the European Rectors, Prof.

Luisi (ETH, Zurich, Switzerland), Prof. Preston (University of Liverpool, UK), Prof. Zwanemburg (University of Nijmegen, NL) and Prof. Parlar (Technical University of Munich, Germany). We would like to thank Ministro Belinguer for having assigned Dott. Luciano Crisuoli as his delegate for the Consortium's assessment on the part of the CHEPS.

This initiative will also be useful for the Associates in making the self-evaluation methods a constant in their research activities. In fact, the necessity of adapting aims and operative methods in a constant and continuous manner, in order to respond to the changes and needs of society, can be seen through the self-evaluation. This strategic instrument can verify the quality and quantity of the research, training and management of the programmed objectives.

Following the aforementioned logic, the assessment of the Consortium's activities, which will follow that by the CHEPS, will be done on two levels. On an internal level, a group will be formed for the self-assessment of the Consortium's efficiency. An external assessment will be handled (most probably) by the MURST in a continuous manner, and every three years by the CHEPS.

With the assessment that is underway (which the CHEPS will finish in 1998 with the publication of a book), the Consortium has been the first in Italy to immediately offer a complete picture of its Research Units and management to the Ministry and other public institutions.

Green Chemistry:
Theory and Practice

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Chemical Products of the 20th Century

- Antibiotics and other medicinal chemicals.
- Modern fertilizers and pesticide formulations.
- Polymeric and composite products.

Chemical Products of the 20th Century

- Thalidomide.
- DDT.
- CFCs.
- Endocrine disruptors.
- Bioaccumulating substances.
- Persistent/non-biodegradable materials.

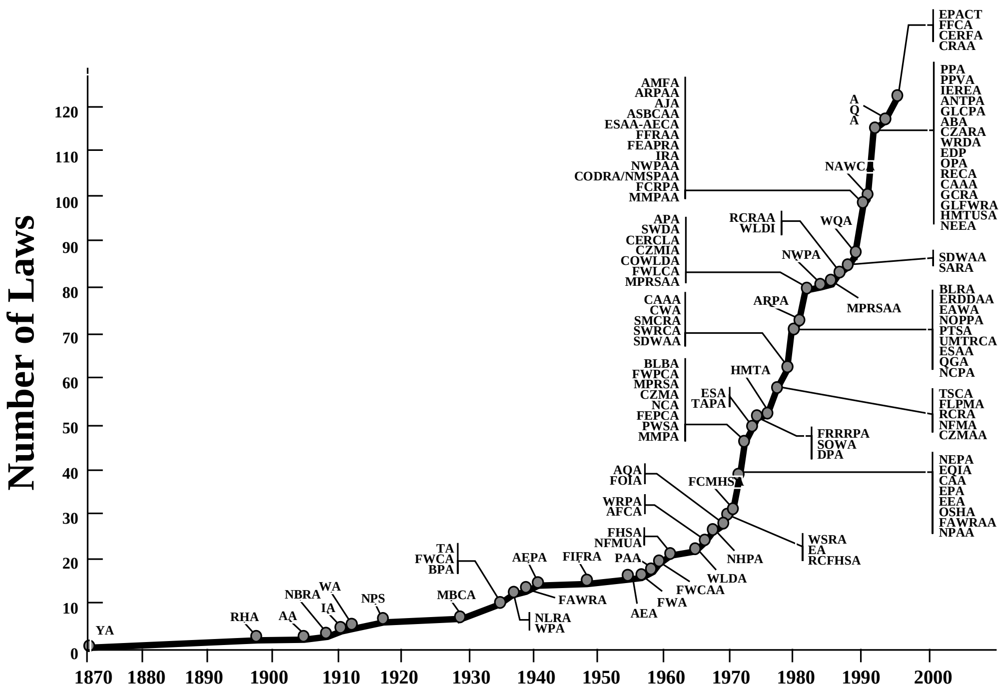
Societal Image of Chemistry

- Chemistry was once viewed as a field of innovation resulting in medical break-throughs and modern convenience.
- Chemistry is now viewed by many as fouling the planet.

Impact of Chemicals on the Environment

- The manufacture, processing, use, and release of chemicals has had an impact on the environment.
- The chemical industry releases significant quantities of hazardous substances to all media.

Growth in Environmental Regulation



Historical Approach to Environmental Problems

- Waste treatment, control, and disposal; pollutant monitoring; hazardous waste site cleanup.
- Development of standards for emissions to air, releases to water, and disposal by land, as well as regulation of these standards.
- "Command and Control."

"Command and Control" Cost to Industry

- The vast majority of industrial chemical processes were developed over 20 years ago.
- The costs associated with these processes have changed considerably over this time period.

"Command and Control" Cost to Industry

- Prior to the 1960s, process costs were largely operational.
- Now, total process costs include liability, regulatory compliance, and waste treatment/control/disposal costs.

"Command and Control" Cost to Industry

- Industry spent $115 billion in 1992 on waste treatment, control, and disposal.
- It was estimated at that time that it would cost as much as $700 billion to clean up existing hazardous waste sites.
- These costs, and the costs associated with regulatory compliance, are rising.

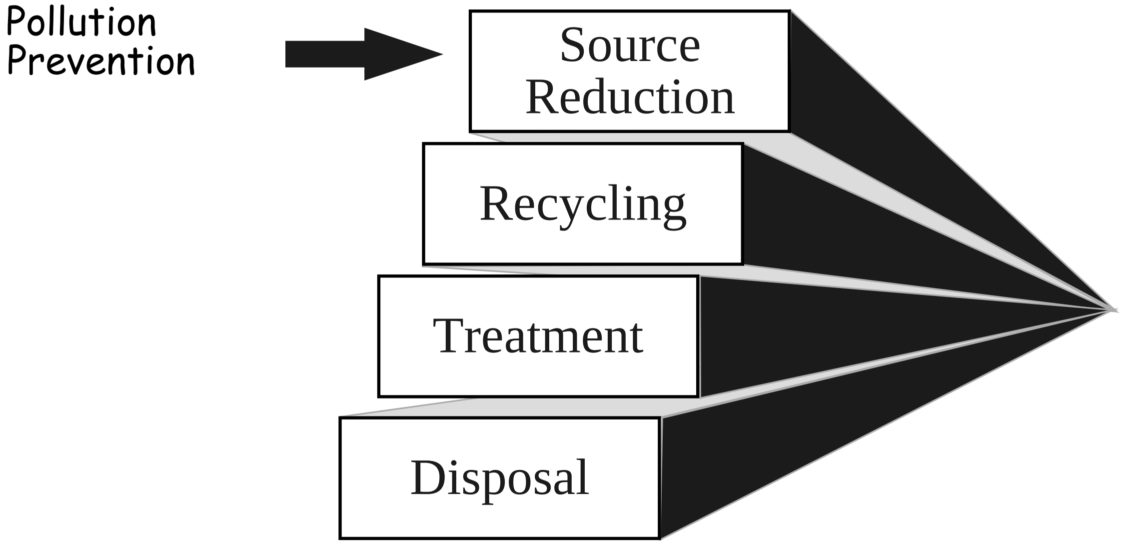
“Command and Control” Cost to Industry

- DuPont’s 1996 research budget: $1,000,000,000.00.
- DuPont’s 1996 environmental compliance budget: $1,000,000,000.00.
- Dupont’s 1996 chemical sales: $18,000,000,000.00 (41percent of total sales).

Pollution Prevention

- Pollution Prevention is the new environmental ethic.
- Waste is prevented, at the source, from ever being generated.
- Waste treatment, control, and disposal, therefore, is avoided.

Pollution Prevention Act of 1990



Pollution Prevention

- Pollution Prevention can be accomplished by several approaches:
  - Inventory controls.
  - Process controls.
  - In-process recycling.
  - Housekeeping changes.
  - Green Chemistry.

The Greening of Chemistry
C&EN

Making Molecules Without the Mess

Mettete fiori nelle provette

CHEMISTS MUST DEVELOP SYNTHETIC METHODS THAT REDUCE CONSUMPTION AND WASTE PRODUCTION
TODAY'S CHEMIST AT WORK

CHEMISTS MAP GREENER SYNTHESIS PATHWAYS
CHEMICAL WEEK

Kudos for Chemistry
C&EN

Design Chemicals for the Environment

THE CHEMICAL INDUSTRY WINS THE GREEN CHEMISTRY CHALLENGE
C&EN

Firms Give 'Green' Chemists Green Light
THE WALL STREET JOURNAL

EPA honors a greening of U.S. industry

Green Chemistry: Benign By Design

'Green' Technology Presents Challenge to Chemists
C&EN

It's Very Special Being Green
CMANews

Focus on Use and Generation

Risk = Hazard x Exposure

Chemists' Roles in Environmental Problems

Chemists' roles in environmental problems have historically been in response to the "Command and Control" approach.

Chemists' Roles in Environmental Problems

- Analytical Chemists have been involved in detecting and measuring environmental problems.
- Physical Chemists have been involved in developing models of complex environmental systems.
- Atmospheric Chemists have been involved in investigating global change.

Chemists' Roles in Environmental Problems

Historically, synthetic chemists have not played a major role in the environmental movement.

Chemists' Roles in Green Chemistry

Green Chemistry identifies synthetic chemists as the key practitioners in identifying, developing, and implementing pollution prevention technologies.

Green Chemistry

- Green Chemistry is the use of chemistry for source reduction, the highest tier of the Pollution Prevention Act Risk Management Hierarchy.

Green Chemistry

- Green Chemistry involves *designing* chemical products and processes that reduce or eliminate the *use and/or generation* of hazardous substances.

Focus on Design

Green Chemistry involves a fundamental shift in the way that science views chemical design and synthesis.

Focus on Design

The moment a chemist puts pencil to paper, he/she is making determinations about the human health and environmental impacts associated with the chemicals used in or generated from the manufacture, processing, use, and disposal of chemical products.

Focus on Design

- Factors driving green chemical design and synthesis:
  - Number of synthetic steps.
  - Cost and availability of starting materials.
  - Product yield.
  - Chemical handling costs.
  - Waste treatment/control/disposal costs.
  - Regulatory compliance costs.

Green Chemistry

- Green Chemistry involves *designing* chemical products and processes that reduce or eliminate the *use and/or generation* of hazardous substances.

Focus on Use and Generation

- Virtually all approaches to reducing environmental risk traditionally have focused on reducing exposure.
- Problems with exposure controls: they are necessarily a cost drain and can fail.

Focus on Use and Generation

- Green chemistry focuses on reducing environmental risk by reducing hazard.
- By reducing hazard, it is possible to lower both direct and indirect costs.
- Reducing intrinsic hazard cannot “fail.”

Green Chemistry

- Not a solution to all environmental problems.
- The most fundamental approach to preventing pollution.
- Recognizes the importance of incremental improvements.

Green Chemistry

- Designing chemistry for the environment.
- Pollution prevention at the molecular level.
- Preventative medicine for the environment.

Green Chemistry

Green Chemistry encompasses all aspects and types of chemical processes—including synthesis, catalysis, analysis, monitoring, separations, and reaction conditions—that reduce risk to human health and the environment relative to the current state of the art.

Green Chemical Synthesis

- Alternative synthetic pathway design.
- Alternative solvents/reaction conditions.
- Designing safer chemicals.
- Process analytical chemistry.
- Inherently safer chemistry.

Alternative Synthetic Pathway Design

The design of single chemical transformations or entire synthetic pathways that reduce or eliminate the use or generation of hazardous substances.

Alternative Solvents/Reaction Conditions

The development and utilization of more environmentally benign solvents and solventless systems that reduce or eliminate the use of toxic or environmentally hazardous solvents.

Alternative Solvents/Reaction Conditions

The development and optimization of reaction conditions to reduce or eliminate the use or generation of hazardous materials while maximizing product yield and minimizing energy usage.

Designing Safer Chemicals

Designing the molecular structure of a chemical product such that toxicity is reduced or eliminated while the efficacy of the chemical is maintained.

The Italian Chemical Industry and Environmental Issues: Commitment and Results

Paolo Giuiuzza
Director, Technical and Scientific Department
Federchimica, Italy

In November 1997, the Italian Ministry of Industry issued a document titled “Industrial Policy Guidelines for the Chemical Industry” with the major involvement of Federchimica, trade unions and other interested administrations.

The document states that the chemical industry is a pillar of the economy because of its impact on the growth of all other industries, on the quality of life, on environmental issues, and on the scientific and technological development of the country.

The challenges of innovation, environmental protection and internationalisation are seen as major driving forces for the growth of the chemical industry, and therefore as priorities of the new industrial policy of our industry. Great emphasis is put on minimization of the impact of chemical production and products on health, safety and environment, and on the need to rationalize the authorization procedures.

This new scenario is fully consistent with the strategic orientation of the Italian chemical industry in the area of health, safety and environment.

For many years, Federchimica has been promoting among its members voluntary programs and codes of practice for improving health, safety and environmental performance in manufacturing, transport, use and disposal of chemical products. More recently, Federchimica started negotiations with the public administration on the use of negotiated agreements as a solution in some major areas of crisis in the country, and for reaching more and more challenging environmental objectives at the national level. On the innovation side, Federchimica is giving advice to its members, mainly the small and medium enterprises, though a newly formed company.

Examples of the commitment of the Italian chemical industry are given in terms of the diffusion of the Responsible Care Program, the economic efforts relating to health, safety and environment (which now represent about 3% of the total turnover of the industry), the growing diffusion of quality, safety and environmental management systems and, of course, health, safety and environmental performance that in the last ten years have experienced, on average, a reduction of more than 50% in water and air emissions and solid waste with some excellent results: for exempla, for Volatile Organic Compounds (-81%) and Volatile Inorganic Compounds (-97%).

There is a special focus on 45 green processes and products recently developed and already available on the Italian market, as it turned out from a new survey on Responsible Care companies. Some considerations are developed on the major trends in this field, and on how to promote environmental innovations in the industry. *[The illustrations that accompanied this presentation are not included here.*]

International Diffusion of Sustainable Chemistry

Joseph Carra
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Office of Pollution Prevention and Toxics
United States Environmental Protection Agency

Introduction

"Sustainable Chemistry" is the design, manufacture, and use of environmentally benign chemical products and processes to prevent pollution, produce less hazardous waste, and reduce environmental and human health risks. In order to turn the concept of sustainable chemistry into reality, there needs to be a partnership between government entities, industry, and academic institutions. This partnership should focus on the development and dissemination of new science and technology that forms the basis of sustainable chemistry. OECD's role will be to assist countries in the establishment of sustainable chemistry programs, and to promote sustainable chemistry activities in governments, academia and industry.

Background

Many different approaches to protecting human health and the environment from the risks posed by the manufacture, processing, use and disposal of chemicals have been used by the nations of the world in their quest for a sustainable environment. Many of these approaches have involved waste treatment, control, and remediation and have been enforced through strict government regulations known as the "command and control approach". The result has been that over the past generation, the number of regulations put in place to address the issue of chemicals in the environment has proliferated at a significant rate. From the late 1800s through the 1950s, less than 20 environmental laws had been passed in the United States. By 1995, however, over 120 environmental laws were in place.

Despite this proliferation of environmental regulations put in place in the United States during the past several decades, hazardous chemicals are still being released to the environment in significant quantities. The reason being that, with the exception of the Pollution Prevention Act of 1990, all of the national laws passed allowed for this "command and control" approach to dealing with environmental problems (i.e. acting on the problems after they have already happened rather than preventing them from happening). For example, in 1994 more that 2 billion pounds of hazardous chemicals were released in the United States to air, water, and land by over 22 thousand reporting facilities as tracked by section 313 of EPCRA (the Emergency Planning and Community Right to Know Act). In addition, reporting facilities transferred almost 4 billion pounds of these chemicals in waste to off-site locations for recycling and remediation activities including energy recovery, treatment, and disposal. All totalled, more than 26 billion pounds of hazardous chemicals underwent on- and off-site waste management activities including recycling, energy recovery, treatment, release, and disposal.

It is important to note that the data collected under EPCRA section 313 in 1994 included only the 343 chemicals and 22 chemical categories of EPA's Toxics Release Inventory (TRI). This represents only a fraction of the number of chemicals in commerce in the U.S. today (it has been estimated that there are over 75,000 chemicals in commerce). Of the industrial sectors that must report under EPCRA section 313, the chemical manufacturing sector is, not surprisingly, the largest releaser of TRI chemicals to the environment, releasing almost as much as all of the other industry sectors combined, and is the second largest industry sector transferring TRI chemicals off-site. Another important point to note is that although the amount of TRI chemicals released to the environment decreased by approximately 44% between 1988 and 1994, the amount of TRI chemicals transferred and managed in waste has proportionately increased.

The costs of complying with the regulations that deal with environmental problems through remediation activities (i.e. waste treatment, control and disposal) rather than prevention activities has been estimated to be in the range of 100 to 150 billion U.S. dollars per year for industry in the United States alone. In addition, the costs of cleaning up existing hazardous waste sites, including Superfund sites and sites with so-called "legacy wastes" resulting from the activities of the Cold War, are estimated to also be in the hundreds of billions of dollars range. Many individual chemical companies have budgets for environmental compliance programs that are as large as their budgets for research and development, and for some of the largest chemical companies, environmental compliance budgets can approach one billion dollars per year. In many smaller chemical companies, the ratio between environmental program budgets and research program budget is significantly weighted toward environmental programs because of compliance costs. A realization that is currently taking place throughout the chemical and related industries is that implementation of an effective research program that includes green chemistry activities can not only substantially diminish the dollars needed for environmental programs but also can result in greater profits.

It is clear that the "command and control" approach that has defined environmental protection in the United States for so many decades is not sustainable. Economically, costs associated with remediation activities must be reduced and reclaimed for use in the research and development of the substances and methodologies that will be needed in support of future technologies and to enhance quality of life. Environmentally, it is essential that the chemical sciences and industries must also proceed in a manner that does not continue to cause harm to human health and damage to the environment. Socially, it is imperative that the populace become aware of the innocuous and even beneficial chemicals that have been manufactured and used, and that chemicals can be designed to be both safe and efficacious.

More recently, the pursuit of pollution prevention conducted in a more collaborative fashion between industry and government has emerged as a desirable path toward sustainability. The next step in this progression toward sustainability is the development of a new area of scientific investigation and application known in the United States as "Green Chemistry" or for the purposes of OECD, "Sustainable Chemistry". Achieving these goals through the central science of chemistry is the primary objective of sustainable chemistry.

Sustainable Chemistry

Sustainable Chemistry is the design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances. This new utilization of scientific principles and industrial implementation is already yielding quantifiable benefits in both environmental protection as well as economic considerations for business.

The following are the major technical focus areas of sustainable chemistry:

- **Use of Alternative Syntheses**

  The use of alternative feedstocks that are both renewable rather than depleting and less toxic to human health and the environment, and/or the use of reagents that are inherently less hazardous and are catalytic whenever feasible. The utilization of biosynthesis, biocatalysis, and biotech-based chemical transformations for efficiency and selectivity.

- **Use of Alternative Solvents and Reaction Conditions**

  The design and utilization of solvents which have reduced potential for detriment to the environment and serve as alternatives to currently used volatile organic solvents, chlorinated solvents, and solvents which damage the natural environment. The design of reaction conditions that increase the selectivity of the product and allow for dematerialization of the product separation process. The design of chemical transformations that reduce the required energy input in terms of both mechanical and thermal inputs and the associated environmental impacts of excessive energy usage.

- **Design of Safer Chemicals**

  Utilization of molecular structure design to incorporate principles of toxicity and mechanism of action to minimize the intrinsic toxicity to life and the ecosystems while maintaining efficacy of function of the product substance.

Specific examples of sustainable chemistry technologies that have been researched, developed, and implemented in all of the technical focus areas in the United States by academia, industry, and government are numerous, and illustrative examples will be presented.

One possible model for promoting sustainable chemistry technologies through various sustainable chemistry activities is the United States Environmental Protection Agency’s Green Chemistry Program. This program was initiated in 1991 to promote sustainable chemistry activities both within the US and internationally in all of the technical focus areas. Since that time the program has built many collaborations with academia, industry, and other federal agencies through completely voluntary, non-regulatory partnerships to promote pollution prevention and sustainability. To accomplish its goals, the Green Chemistry Program recognizes and promotes chemical technologies that reduce or eliminate the use or generation of hazardous substances during the design, manufacture, and use of chemical products. More specifically, the Green Chemistry Program supports fundamental research in the area of environmentally benign chemistry as well as a variety of educational activities, international activities, conferences and meetings, and tool development.

OECD’s Role

In order to realize the full potential and promise of the new area of sustainable chemistry on a global scale, however, there needs to be a dissemination of information about the theory and practice of this new area throughout the nations of the world. This dissemination could be achieved through the combination of several mechanisms.

- **Multi-National Research Collaborations**

This effort could include coordination of the scientific funding organizations of individual countries, as well as multinational organizations which fund research to promote collaborations between researchers of different countries who may not otherwise interact in sustainable chemistry. Multinational research could also be promoted to better facilitate collaborations between universities, industry, independent and government laboratories.

- **International Educational Mechanisms**

Expertise from around the globe in the area of sustainable chemistry could be tapped to educate students and professions at all levels and from all countries on the theory and practice of sustainable chemistry.

- **Coordinated Governmental Recognition Programs for Industrial Accomplishments**

Governmental agencies should coordinate to recognize the accomplishments of industry around the world in using sustainable chemistry for environmental improvement to both showcase the state of the art as well as provide incentives to companies dedicated to being environmental stewards.

- **Internet Distribution of International Information on Sustainable Chemistry**

The Internet must be developed as a tool for the dissemination of information on sustainable chemistry for the scientific community, business community and general public. From the point of view of information exchange on sustainable chemistry between nations, there must be no “haves” and “have nots”.

By leveraging the individual national efforts that are currently being conducted and allowing these efforts to cooperate where appropriate, the area of sustainable chemistry will achieve its promise more quickly and the quantifiable reductions of risk will continue to provide testimony to the effectiveness of this new approach.

The Green Chemistry Institute: An Overview

Joseph J. Breen
The Green Chemistry Institute, USA

Dennis Hjeresen
Environmental Management Programs
Los Alamos National Laboratory, USA

Paul T. Anastas
Office of Pollution Prevention and Toxics
US Environmental Protection Agency

The Green Chemistry Institute (GGI) is a not-for-profit virtual organization dedicated to environmentally benign chemical synthesis and processing research and education. Following months of discussion on how to promote the effective use of limited public and private sector resources for Green Chemistry research and education, a group of professionals from industry, academia, national laboratories, and government established GCI on May 30, 1997.

GCI's vision is: "*Working today to prevent pollution tomorrow through chemistry research and education.*" Its mission is to promote and foster Green Chemistry through four types of activities: information dissemination, chemical research agenda setting, conferences/workshops, and education through curriculum materials development and distribution.

GCI's approach to promoting Green Chemistry is to engage academic, industrial, national laboratory, and government professionals in some or all of the four types of activities identified above. For example,

Information dissemination on GCI activities, workshops and educational programs is available in greater detail through the GCI website:

http://www.lanl.gov/Internal/projects/green/index.html

The website is hot-linked to Green Chemistry efforts in Italy (Interuniversity Cornsortium on Chemistry in the Environment - INCA), and the UK (Institute for Applied Catalysis - IAC). Plans are in the offing to hook up with the People's Republic of China's University of Science and Technology in Hefei, which has recently established the Center for Green Science and Technology.

GCI also has an email list server, the GreenChemExchange, to which interested parties may subscribe. Currently, there are some 100 subscribers who exchange Green Chemistry information via the list server. The GCI web site serves as an *information mall*, while the list server is the *chat room.*

Clearly, the area of information dissemination and exchange is one suited to collaboration amongst the OECD Member countries. The challenge is how to do it efficiently and effectively.

Green Chemistry research agenda setting. GCI, with industrial sponsors interested in particular chemistries or technologies, promotes Green Chemistry by convening focused workshops to develop a needs-based research agenda in identified areas. GCI works directly with the *U.S. Environmental Protection Agency's (EPA) Office of Pollution Prevention and Toxics (OPPT*) to promote fundamental breakthroughs in chemistry that accomplish pollution prevention through source reduction *and* are economically interesting to industry. GCI works with the *Department of Energy's Office of Industrial Technologies (OIT)* to promote similar objectives to achieve energy conservation. GCI supports OPPT and OIT in their joint efforts with the American chemical industry to implement *Vision 2020*, a long term strategic plan to make the chemical industry more efficient and sustainable in the 21st Century.

We should explore the role OECD might play in facilitating the development of coordinated Green Chemistry research agendas across the Member countries, particularly in areas of pre-competitive research.

Conferences/Workshops. GCI works collaboratively with the American Chemical Society's Committee on Environmental Improvement, its Divisions of Environmental Chemistry and Industrial and Engineering Chemistry to program Green Chemistry symposia at National ACS meetings each year. GCI along with a number of other chemical industry related organizations support, as cosponsors, the highly successful EPA-ACS *Annual Green Chemistry and Engineering Conference* held at the National Academy of Sciences in Washington, D.C.

GCI members have also played a leadership role in co-chairing the *Green Chemistry Gordon Research Conference (GRC)* which is supported by OPPT. The Green Chemistry GRC is a model for success in sharing the latest chemical research information on an international basis. The Conference is held annually, rotating its venue between the USA and an overseas site. The 1999 GRC will be held at Oxford University in the U.K, with its co-chairs being from the University of York and Delft Technological University. Discussions are underway to have future overseas sites in Italy, Germany and China.

GCI members have also been fortunate in collaborating with Professor Pietro Tundo's research group at the University of Venice, and with the Italian *Interuniversity Consortium on Chemistry for the Environment (INCA)*, who are our gracious hosts for this, the first OECD Workshop on Sustainable Chemistry. If OPPT provides the leadership role in making Green Chemistry a reality in the USA, then clearly INCA and Ca' Foscari play a similar role on the Continent.

An exciting development that has recently occurred is the interest on the part of IUPAC's CHEMRAWN Committee to join with GCI to host a World Conference on Green Chemistry in 2001. (CHEMRAWN stands for Chemical Research Applied to World Needs). There will be a CHEMRAWN poster with details on the project during this workshop.

A list of Green Chemistry conferences and workshops for 1998 is presented in Figure 1 [not included here]. A lot of "stuff" is going on.

Clearly, international collaboration is underway in terms of conferences. The challenge is how to do it more efficiently and effectively through resource sharing.

Education through curriculum materials development and dissemination*.* GCI participates in the recently placed Cooperative Agreement between OPPT and ACS HQ's Education Department to develop Green Chemistry curriculum materials for all education levels. The initial thrust of this program will be to develop materials for undergraduate and graduate level programs as well as in-service training for working professionals. The first formal working session of this project will take place October 23-25 at the National Academy of Sciences in Washington, D.C. Informal meetings have taken place with the Senior Author of the ACS Writing Team for the 3rd edition of Chemistry in Context. Green Chemistry principles and real world examples will be integrated throughout the text to illustrate that Green Chemistry challenges and opportunities are everywhere.

The recent publication of *Green Chemistry: Theory and Practice* by Oxford University Press, as the first textbook in this area, with its articulation of a set of twelve Green Chemistry principles should provide the focus around which to develop and elaborate Green Chemistry curriculum materials.

One model for professional training in Green Chemistry is provided by the recent European Union First Post Graduate Summer School on Green Chemistry held here in Venice under the direction of Professor Tundo. It was a major success that completely engaged the students and faculty involved. Follow-on programs in 1999 and 2000 should receive everyone's support.

A second professional training model, this one using the Internet, is illustrated by the collaboration between GCI and California State University (CSU) - Bakersfield's Institute of Environmental Management Systems (IEMS). GCI-IEMS will be offering an "Industrial Ecology: Design for the Environment" symposium series via the Internet in early 1999. A preliminary schedule is presented in Figure 2 [not included here]. I encourage you to check out the web site for more information. We are currently recruiting international presenters for each of the three Rounds of the Symposium Series. It will be an excellent opportunity for all OECD Member countries to participate.

*Once again, clear opportunities exist for OECD Member countries to collaborate and share educational materials developed in the area of Green Chemist*ry. *The challenge is to coordinate our efforts.*

In closing, GCI looks to play a leadership role in promoting Green Chemistry both domestically and internationally. There has been a strong international flavor to the GCI program from its inception, with interest in GCI chapters being developed in China, Australia, the United Kingdom, Italy, Russia, and for the Baltic Countries (Estonia, Latvia and Lithuania). The growing international interest in Green Chemistry is presented in Figure 2 [not included]. The world map highlights where some of the more prominent activities have taken place or will take place in the next year on a global scale. It indicates the varied types of programs - ranging from technical research conferences to educational programs, and research agenda setting workshops. The map also serves to identify opportunities internationally where Green Chemistry programs need to be formulated for the 21st Century.

GCI looks forward to working with all of you - both during the Workshop, and in follow-on activities in the coming months.

Sustainable Chemistry in the Japanese Chemical Industry

Akira Kanai
Japan Chemical Innovation Institute (JCII)

The Japan Chemical Innovation Institute (JCII) was founded in March 1998, sponsored by more than a hundred leading companies as well as the related academic and industrial associations. It aims at the sustainable development of society by collaborative efforts of industry and academia. Putting diverse knowledge of academia and industry together, it advances innovation and creates new industrial areas.

1. Summary

The Japanese chemical industry has been promoting voluntary action plans to improve many environmental aspects. The plans are announced publicly.

Government councils check and review annually the results of these plans.

The Japanese chemical industry has been involved in “sustainable chemistry” research and development under its own initiatives.

In 1995, the “Simple Chemistry” research program was started with the cooperation of industry, academia and national institutes.

A new organization, JCII, was established to promote technology innovation compatible with sustainable development of human society.

JCII is expected to play a focal role for the OECD sustainable chemistry initiative.

2. Activities hitherto

2.1. Voluntary action plans

Examples of voluntary action plans by the Japanese chemical industry:

- Energy-saving process development
- Industrial waste reduction
- Reduction of releases of volatile organic compounds (VOCs)

2.1.1) Energy-saving process development

Since the first petroleum crisis of 1973, the Japanese chemical industry, especially the petrochemical industry, has been putting much of its efforts into improving energy effectiveness throughout its whole process. Energy consumption per product weight of ethylene in 1996 reached around half that in 1976.

In 1996, the Japanese chemical industry announced a further 10% reduction in energy consumption per product weight by the year 2010 compared to 1990. This plan is one of the frameworks of the Japanese national numerical target value, which the government declared at the Kyoto Conference (COP3).

2.1.2) Industrial waste reduction

The total weight of industrial waste in Japan amounted to around 400 million tons in 1995, of which the chemical industry's share was 4%, or 16 million tons. In 1996, the chemical industry announced reduction of its industrial waste by the year 2010:

- 40% reduction of final landfill volume compared to 1990
- 15% increase in recycling ratio

2.1.3) Reduction of VOCs release

In 1996, the chemical industry announced reductions in the total amounts of the following seven VOCs released: acrylonitrile, benzene, acetoaldehyde, 1,3-butadiene, chloroform, vinyl chloride monomer and ethylene oxide.

The chemical industry is making plans to reduce the amount released by 30% compared to 1995 during the coming three years.

2.2. Sustainable chemistry so far

Examples of activities:

- Research and development
- Education
- Awards

2.2.1) Research and development

Typical examples of the Sustainable chemistry process introduced commercially:

- Enzymatic synthesis of acrylamide
- Alternative anti-fouling paint to TBT
- Changeover of caustic soda production process

(1) Enzymatic synthesis of acrylamide by nitrile hydratase

The Nitto Chemical Industry Co. developed production of acrylamide using an enzymatic process. In 1985, the company introduced the enzymatic process using an immobilized microorganism method. They improved the activity of the microorganism 4-fold to produce 20,000 t/y. The company is now testing mutant enzymes obtained by gene technology in a commercial pilot plant.

(2) Alternative anti-fouling paint to TBT

The use of TBT, tributyl tin compound, as anti-fouling paint started in 1978, but the Japanese government announced prohibition of its usage in 1990 because of TBT's safety issue in regard to human health. Many paint makers in Japan developed a new anti-fouling paint, cupric acrylic polymers, which is less toxic to humans, as the first alternative to TBT in the world. The Japanese government is appealing for total prohibition of TBT internationally.

(3) Changeover of the caustic soda production process

In Japan, the mercury method for the caustic soda production process was stopped by the government authority in 1976 because of the latent effect of mercury. At present over 80% of the process has changed to the ion-exchange membrane method.

The energy efficiency of the ion-membrane method is almost 30% higher than that of the mercury method.

2.2.2) Education

Examples of education in sustainable chemistry:

- Dream Chemistry 21: meaning that chemistry will make our dreams come true in the 21st century
- Public courses for citizens

(1) "Dream Chemistry 21" movement for students. Industry and academia have been promoting this movement cooperatively for 7 years. It has three aspects:

– for elementary school pupils

Experience of chemical experiments in summer vacation

About 4,500 visitors including parents in 1997

– for junior high school students

Contests for essays on chemistry, including environmental activities

About 9,000 applicants annually since 1995 for senior high school students
Open house and exposition of chemical laboratories of universities
About 6,000 participants at 42 universities all over the country in 1997

(2) Public courses for citizens

Typical examples:

- Open symposia by the Environment Agency

  More than 1,000 citizens took part in symposia on dioxin this year.

  Panellists were from industry, academia, government and NGOs.

  Symposia for local government officers

  The Japan Responsible Care Council (JRCC) held symposia on RC activities 9 times in 9 different areas, and about 500 officers joined.

2.2.3) Awards of the Japan Chemical Industry Association (JCIA)

JCIA is the association which covers almost all the chemical industry in Japan and has around 180 member companies. JCIA has been awarding member companies which have accomplished the development of unique industrial processes and products in which environmental aspects are essential.

Each of the two awards in 1997 came under the category of sustainable chemistry.

- Award to Konica Co.

  Title: development of photo finishing reagents tablets.

  They developed a dry chemical process in silver halide photo finishing technology and improved the drawbacks of conventional wet technology.

- Award to Kao Co.

  Title: Development of CFCs-alternative cleaning system.

  They developed new detergents consisting of non-ionic surfactant, whose cleaning activity is almost the same as that of CFCs detergents.

3. “Simple Chemistry” program

The Japanese chemical industry has been continuously developing technologies for maximizing energy- and resource-saving processes since the first petroleum crisis. Almost all measures were introduced commercially by 1988, meaning that energy- and resource-saving technology peaked at that time. In 1994, the Society of Chemical Engineers, Japan (SCEJ) started studies of breakthrough technologies to maximize energy- and resource-saving processes by industry and academia in cooperation.

Based on the proposals of SCEJ, in 1995 the government, MITI, started the “Simple Chemistry” program, which aims to introduce an innovative concept for the future chemical industry by simplifying production processes. Research teams, composed of national institutes, universities and private chemical companies, have been promoting the projects through governmental budget support.

Main projects:

- Catalytic conversion of naphtha to lower olefins

  Research team: 4 companies, 3 universities and 1 national institute

- Novel catalysts and chemical reaction processes for selective oxidation of light alkanes

  Research team: 5 companies and 7 universities

- Simple synthetic processes using solidified catalyst
  Research team: 3 companies and 1 national institute

- New membrane technology which combines reaction and separation processes
  Research team: 4 companies, 8 universities and 1 national institute.

The concept of projects will be introduced in detail by the poster.

In addition to the above mentioned projects, preparatory studies are going on under the study group of JCII and SCEJ. Several promising projects are as follows:

- Non-halogen chemical process
- Non-aqueous enzymatic process

4. Conclusion

4.1) New organization

JCII will organize a cooperative committee of academia, industry and the government, taking the OECD sustainable chemistry initiative into account. The main missions which are effective to promote sustainable chemistry are:

- organize study group to select specific R&D themes
- construct a data base
- study a new framework for education of citizens
- study new scholarships and awards
- promote international cooperation

4.2). Symposia

JCII will support the first symposium on sustainable chemistry at the Annual National Meeting of Chemical Society of Japan (CSJ) in the spring of 1999. The symposium will be the full-scale start of the sustainable chemistry initiative in the Japanese chemical industry.

Research Project on Supercritical Fluids: Promising Sustainable Chemical Processes

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Supercritical fluids (SCFs) are attractive solvents for chemical processes because of their unique properties. Carbon dioxide and water are mainly used as SCFs which are benign to the environment. The SCF utilization technology allows advanced chemical processes, which consume less energy, use no harmful organic solvents and decompose hazardous wastes. The leading national project applying SCF to chemical processes is carried out by AIST and NEDO for 1997-1999. In this project, basic reactions in chemical processes such as oxidation, hydrogenation and solvolysis and catalytic reactions are studied to ascertain the applicability of SCFs to chemical processes. Based on the results, a large-scale national project will be proposed in 2000.

Introduction

Much attention has been focused on supercritical fluids (SCFs) as an advanced solvent of chemical processes during the past two decades, and they have been mainly applied to extraction technology. Recently, SCFs has been rediscovered as environment-friendly solvents where CO_2 and water are used most frequently. Potential advantages of using SCF in chemical reactions are: increasing the selectivity and the yield of a desired products, increasing reaction rate, decreasing energy consumption, etc. Therefore, SCFs will be able to contribute to a sustainable society. We have investigated the possibility of SCFs to solve the problems of energy, resources and global environment, and started a new national project in 1997. In this paper, the topics of SCF research at the National Institute of Materials and Chemical Research (NIMC) and the outline of the national project will be presented.

Supercritical Fluid

The SCF is the fluid whose temperature and pressure exceed the values at the critical point. Figure 1 shows a general phase diagram of a pure substance, which exists as a solid, liquid and gas according to the temperature and pressure. Above the critical temperature, the distinction between gas and liquid disappears and the fluid is not condensed into liquid any more despite pressurization, i.e., is dense and compressible.

Table 1 shows the comparison of the order of magnitude values of SCFs' properties. The properties of SCFs vary from gas-like to liquid-like values with density, which is strong function of temperature and pressure. Consequently, when the SCF is used as a reaction solvent, we can control the reaction environment by manipulating temperature and pressure. This is the most important and unique property of the SCF.

Table 1 Comparison among properties of typical SCF, liquid, and gas

	Liquid	SCF	Gas
Density [g/cm^3]	1	0.1-0.5	10^{-3}
Viscosity[Pa·s]	10^{-3}	10^{-4}-10^{-5}	10^{-5}
Diffusivity[cm^2/s]	10^{-5}	10^{-3}	10^{-1}

Table 2 shows the critical parameters of compounds frequently used as SCFs. CO_2 is an SCF most widely used as a solvent for separations, chemical reactions and material processing, because it is nontoxic and nonflammable and has moderate critical temperature and pressure, and is promising as an environmentally benign substitute for some halogenated or organic solvents in chemical processes. Water possesses much higher critical temperature and pressure, and supercritical water (SCW) is employed as a medium to decompose hazardous substances and waste plastics. Alcohols such as methanol and ethanol are also important candidates of SCFs, because they have intermediate critical temperature and pressure between CO_2 and water and can be produced from renewable resources like biomass. They can be used for alcoholysis of condensation polymers and some other interesting chemical reactions.

Table 2 Critical properties of compounds used as SCF

	Critical temperature [K]	Critical pressure [MPa]	Critical density [g/cm^3]
CO_2	304.1	7.38	0.469
water	647.3	22.12	0.315
methanol	512.6	8.09	0.272

Research and Development in NIMC

Chemical recycling of plastics by SCF

Chemical recycling of waste plastics becomes more important from the viewpoint of preservation of natural resources and global environmental protection. We investigate decomposing synthetic polymers with supercritical/subcritical methanol and water.

Depolymerization of polyethylene terephthalate (PET) with supercritical methanol was studied. PET was converted completely to its constituent monomers, dimethyl terephthalate and ethylene glycol, and oligomers at 573 K above 8 MPa. The decomposition rate was much higher than that using liquid methanol, which is employed in conventional recovery methods.

Recycling of composite plastics is more difficult than recycling those composed of a single polymer. We tested recycling of the laminate film composed of polyamide and polyethylene. Using subcritical water, the polyamide was hydrolyzed to a monomer, ε-caprolactam, which dissolves in water. However, the polyethylene was not decomposed, but deposited in water. Therefore, polyamide was recovered as ε-caprolactam and polyethylene as a single-component polymer.

We also investigate the decomposition of additional polimerization plastics like polystyren and will challenge the recycling plastics mixture with SCFs in future.

Decomposition of hazardous wastes

Supercritical water oxidation (SCWO) is an attractive method to decompose refractory and hazardous waste such as chlorinated organic substances. In Japan, dioxin emitted from municipal waste incinerators causes a serious problem. We tried to decompose the dioxin contained in fly ash from a municipal waste incinerator with SCW and oxidizer. It was clarified that the dioxin was almost decomposed at 673K and 30 MPa for 30 minutes with a small autoclave test. Based on these results, the pilot-scale plant shown in Figure 2 was constructed.

Chemical reactions in SCF

Supercritical CO_2 (SC-CO_2) can be used as a substitute of toxic organic materials. We have studied the synthesis of dimethyl carbonate using SC-CO_2 for toxic phosgene or carbon monoxide in conventional processes. The yield and selectivity of dimethyl carbonate increased in high pressure SC-CO_2 and further investigations are continuing.

Study of solvent properties of SCF

To understand reaction mechanisms in SCF, the solvent properties are studied from a macroscopic and microscopic point of view with in-situ measurement using spectroscopic techniques, such as UV spectroscopy, fluorophotometric analysis, FTIR, NMR, and Raman spectroscopy.

National Research Project

Outline of the project scheme

The new project on SCFs was started in October 1997 based on the concept of the R&D project shown in Figure 3, which was proposed by a committee organized and supported by MITI for 1995-1996. The outline of this project is summarized in Table 3. The project, which is just pre-stage of a large-scale project, will be continued until the end of March 2000 and the total budget is expected to be about 640 million yen. The targets of a future large-scale project may be the establishment of cleanup and recycling processes, utilization of unused resources, advanced chemical reaction and innovative materials processing. However, in the first stage project, our objectives are to build up the engineering bases and both basic and scientific research is necessary. The governmental research institute can support the project from the scientific viewpoint.

Table 3 Outline of the project on SCFs

1. Period of R&D Oct/1997 - March/2000
2. Total budget 640 million yens
3. Targets Establishment of engineering bases for SCF utilization
   (1) Typical chemical reactions:
   Solvolysis
   Oxidation
   Reduction by hydrogenation
   (2) Technological infrastructure:
   Databases
   Simulation programs
   Search of materials for SCF plant
4. Promotion of R&D
   Experiments are carried out by collaboration of NIMC and 8 member companies (belonging to JCII).
   NEDO (under leadership of MITI) entrusted the project to JCII.
5. Support of project
   Fundamental research (properties of SCF & reaction mechanisms) conducted in NIMC.
6. Proposal for (2nd stage) large-scale national project on SCF

The target of this project can be categorized into two items. One is typical chemical reactions, which include solvolysis, oxidation and reduction by hydrogenation. The other is the establishment of technological infrastructure, which includes databases, simulation programs and search of materials for SCF plant. For the promotion of the project, NEDO entrusted the management and execution of the project to JCII under the leadership of MITI. Experimental research is carried out by the collaboration of NIMC and JCII. Eight companies participate in this project and collaborate with JCII. Main experiments are conducted at the site in NIMC.

Outline of research

(1) Solvolysis group

The decomposition and recycling of plastics such as PET, PVC, polyurethane and polyphenol resin are studied. The synthesis of carbonates is also studied in this group. Carbonates are synthesized from epoxides like propylene oxide and carbon dioxide as supercritical state catalyzed with alkali metals. Carbonates are very useful additives to Diesel fuels to suppress the generation of particles.

(2) Oxidation group

SCWO has been studied as a promising technology to decompose hazardous wastes; however, this group tries to apply SCWO to the recovery of energy from low grade fuels like heavy oils or brown coals. In this process, fuel is burned in SCW and combustion heat is directly or indirectly conducted to steam which will be provided to power generators. This system will be environment-friendly power generation system. The problem will be how to remove some contaminated materials like ash and sulfate and how to prevent the corrosion of the reactor.

(3) Hydrogenation group

Upgrading of heavy oil is investigated using SCW. The first step of the reaction is the partial oxidation of heavy oil to produce carbon monoxide. The second step is the shift reaction between water and the carbon monoxide produced. Finally, the heavy oil is hydrogenated by hydrogen produced through the shift reaction.

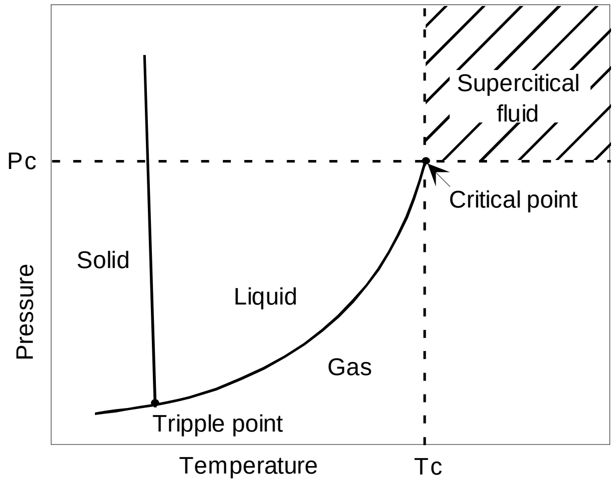

Figure 1 Pressure and temperature diagram of pure substance

Figure 2 Pilot plant of decomposition of dioxin by SCWO

Construction of supercritical fluid technologies supporting "Sustainable Development" society

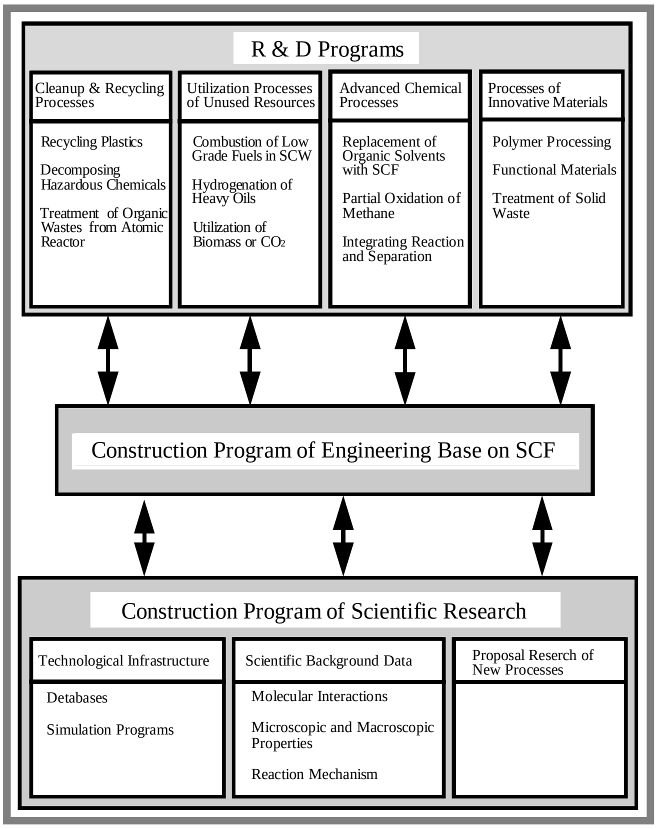

Figure 3 Concept of R & D

Cooperation in Sustainable Chemistry between Academia and Industry through CSJ

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1. Introduction - Outline of CSJ (The Chemical Society of Japan)

CSJ (the Chemical Society of Japan) is one of the biggest academic societies in Japan and has a 120-year history. It has about 40 thousand members, an annual budget of about $8 million (about 1,100 million yen) and 30 staff. CSJ publishes an English Bulletin, an English letter journal, a Japanese journal and 2 newsletters. CSJ is also providing a full English Bulletin on WWW since last year. It holds two annual national meetings, in spring and autumn, and other regional symposia, lectures and meetings in some specific fields.

CSJ has a dependent organization for Chemical Education that works for chemistry education from primary school to university, including a teacher training course.

CSJ is in the position to connect academic and industrial research activities as the biggest academic association in the chemistry field. Actually, more than half the individual members are chemists and chemical engineers in the industry, and corporations can also be society members, which bear a quarter of the total membership fee income of the Society.

2. Activities of CSJ Activities So Far

2.1 Joint Studies with RITE - an example of joint sustainable chemistry research of academia, government and industry

RITE (Research Institute of Innovative Technology for the Earth) and CSJ jointly performed study projects on “Carbon Dioxide Reduction Technology” and “Environment Friendly Chemical Processes” several years ago.

The Carbon Dioxide study proposed the following 3 items as research and development targets for chemistry, for prevention of global warming:

1. development of new energy sources from non-fossil fuel, such as solar energy

2. innovation in chemical technology for energy saving:

   - increase in energy efficiency of chemical processes by use of an iso-thermal or thermo-neutral reaction system
   - drastic improvement of chemical reaction selectivity
   - improvement of performance of fuel cell and secondary battery

3. improvement of carbon dioxide conversion by catalytic, electrochemical or photoelectrochemical process or bio-system.

The second study, on Environment Friendly Chemical Processes, pointed out the importance of friendliness with both the global environment and natural resources, and surveyed chemical reactions from four viewpoints:

- waste (by-products) quantity
- materials hazard
- energy consumption
- complexity of reaction

and evaluated more than 20 relevant chemical processes using E-factor and degree of atom utilization.

The study revealed that the following are key technologies for environmental benignity:

1) oxidation-dehydration catalyst

2) solid catalyst system for easy separation and recovery

3) solid superacid catalysts for high selectivity

It also showed evaluation procedures for the environmental friendliness of chemical processes, taking two specific fine chemical processes as examples.

Based on the results of the above two studies, research on new catalyst design and catalytic chemical processes was initiated with the financial support of the Ministry of Education.

2.2 Safety of Chemical Substances

As the traditional activities of CSJ have been limited to the fields of conventional chemistry, almost all the individual members are “chemists” who have majored in chemistry in universities. Therefore, CSJ does not have enough activity in chemicals safety research except a standing Committee for the Environment and Safety, with two specialist groups for Environment and for Risk Prevention. This means that CSJ limits its safety related activity to explosion danger evaluation and preparation of standards for safety handling of chemicals, and cannot sufficiently satisfy the social requirements of coping with currently raised problems such as endocrine disrupters.

3. Chemical Substances and the Environment

3.1 Social acceptance

In Japan, such safety problems of chemical substances as dioxin or endocrine disrupters have often been raised as social affairs that the mass media prefer publicizing in an emotional way rather than based on scientific facts. Industrial associations have refuted the results, following investigations, but their refutations are not easily accepted by the public due to the prevailing distrust of information from industry.

The action now necessary is the dissemination of scientific facts and judgements by neutral (academic) bodies like CSJ. It can be said that social circumstances tend to support the view that new chemical substances are no longer required, and that further research activity in chemistry to produce those substances is not necessary. This opinion is obviously not appropriate.

3.2 Academic interests

Joint study programs by OECD or other international organizations on the safety of chemical substances have often been proposed, but so far the Japanese government cannot properly commit itself with confidence to such significant projects, as they cannot find reliable parties from academia who take an interest in and responsibility for the program. There are no proper academic organizations in these fields in Japan. This is what CSJ is going to do to fulfil international expectations, in cooperation with the government.

4. What CSJ Must Do

In order to improve the situation and cope with those problems, CSJ decided early this year to establish an ad hoc committee to report directly to the president of CSJ on what CSJ can work on in regard to environment and chemical substance issues, and how. The committee is called the "Ad hoc Committee for Environment and Chemistry".

The outline of the Committee discussion is presented, as a small but actual example of Sustainable (Green) Chemistry promotion:

1) Objectives of the Ad hoc Committee
2) Current Status of Committee Activities
3) Future Tasks of the Committee

4.1 Objectives of the Ad hoc Committee

As the result of discussions so far, the Ad hoc Committee has decided on the following items as its major objectives:

- To survey scientific subjects pertaining to chemical substances and the environment
- To propose research objectives that CSJ should promote
- To create road maps for the research objectives
- To announce the objectives to the public and to CSJ members

These will be made more substantial through the discussion during this year.

4.2 Current Status of Committee Activities

4.2.1 Survey of scientific subjects for Sustainable (Green) Chemistry

Collected opinions from major Society members concerning scientific tasks that may contribute to establish environmentally benign chemistry are:

- mechanism of physiological activity of chemical substance
- eco-dynamic behavior of chemical substance
- advanced analysis methodology for ultra small quantity
- database on chemical structure - physiological activity relationship
- decomposition processing technology for hazardous chemical substances
- evaluation methods for hazard and risk of chemical substances
- risk communication procedures
- LCA procedures
- new energy system, etc.

4.2.2 Research Objectives of CSJ

Three working groups were established to perform the tasks:

- CSJ Action Codes for environment and chemistry
- Research road map
- Publicity

4.2.3 Road mapping

Preparation of research road maps for several research subjects is now going on.

4.2.4 Publicity

- monthly reporting of the Committee discussion in the CSJ Newsletter
- year-end symposium at the 1999 CSJ Annual Meeting (planned)
- joint symposium with IUPAC on the environment and chemistry (October, 98)

4.3 Future Tasks of the Committee

- reorganize the Committee into “Promotion Committee for the Environment and Chemistry” in order to promote and perform its tasks, considering the OECD program
- work together with JCII
- declaration of CSJ Code of Practice for the Environment and Chemistry

5. Proposal for Action by CSJ

- **Declaration of *OECD CHEMOETHICS* to promote Sustainable (Green) Chemistry Program**
- **Cooperation with *ICCA***
- **Preparation of Sustainable (Green) Chemistry Fund**