History and Effectiveness of CHEMRAWN Conferences, 1978–2006

John M. Malin
Chair, CHEMRAWN Committee

Introduction

The 28-year history of CHEMRAWN (CHEMical Research Applied to World Needs) has produced 14 full-fledged CHEMRAWN conferences. The meetings have varied in subject, location, size, and budget, but they have all addressed a single goal—to catalyze the use of chemistry and related sciences and engineering to meet world needs. This article summarizes those conferences to form an understanding of how the CHEMRAWN process has fostered new ideas and supported solutions to world problems.

Bryant Rossiter, the first Chair of the CHEMRAWN Committee, described the beginnings of IUPAC's CHEMRAWN conferences and their purposes as follows:

> *"138 years ago at Cambridge, England, the 18-year-old William Perkin undertook an independent research study that resulted in the discovery of aniline dyes. Against the advice of his teacher, Professor Hoffman, Perkin applied his research to world needs—and launched the coal-tar-dye industry. Therefore, in reality, the concept of CHEMRAWN, "**CH**emical **R**esearch **A**pplied to **W**orld **N**eeds," is not new. What is new is the increasingly complex, interdependent world, with a burgeoning population, limited resources, rising middle class expectations, vastly improved communications, the possibility of nuclear war, and the new spectre of global terrorism. These and other major world problems are not unique to chemists, but afflict the whole of humankind. Solutions to many of the world's material, economic, social, and even political problems rest in our ability to: transform basic elements of raw materials into new means to increase food production; provide alternative sources of energy and chemical feedstocks; deliver new drugs for the alleviation of human disease; supply less costly and corrosion-free substances for building and fabrication; and innovate new materials for communications. These are the domain of chemistry and chemists, therefore, and have a special and vital role to play. Stated simply, chemistry is a central discipline that interacts with virtually every aspect of human endeavor. Indeed, chemistry is the wellspring of life itself. Little wonder then that chemists should be called upon to address the world's most pressing needs.*
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> *"In 1973, the IUPAC conference in Munich included on its agenda a session on "opportunities for international cooperation through IUPAC". The suggestion proposed a new mechanism in IUPAC, a mechanism whereby member nations could aid in identifying and solving important chemistry problems that have a direct impact on world needs.*
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> *"The general idea was unanimously approved and the U. S. delegation, which had begun the discussion, was asked to define and elaborate on the*

proposal. The US national committee, of which I was privileged to be a member, subsequently drafted a statement under the heading "Chemical Research Applied to World Needs". Like so many other long titles, this one became known by its acronym, CHEMRAWN.

"The CHEMRAWN statement, designed to reflect a set of purposes around which various activities might be organized, proposes:

A. To identify human needs amenable to solution through chemistry with particular attention to those areas of global or multinational interest.

B. To serve as an international body and forum for the gathering, discussion, advancement and dissemination of chemical knowledge deemed useful for the improvement of humankind and our environment.

C. To serve as an international, nongovernmental source of advice for the benefit of governments and international agencies with respect to chemistry and its application to human needs.

"To achieve these ends, it was proposed that CHEMRAWN activities should:

1. *Provide scientific and organizational leadership for the purpose of identifying chemically related needs, opportunities and priorities on an international and worldwide scale.*
2. *Organize, in cooperation with established scientific bodies and international conferences, forums, workshops, symposia, collaborative studies, etc., for the gathering, presentation, discussion, evaluation, publication and dissemination of information relating to chemistry and the needs of humankind in our environment.*
3. *Help provide an understanding of trends, consequences, alternatives and resources relating to raw materials and supplies of chemical intermediates.*
4. *Act as a focal point, clearinghouse and coordinating body for individual conferences relating to chemical research and world needs.*
5. *As a part of the International Council for Science (ICSU), serve as an advisory body to the United Nations, its member nations and agencies—with special attention to developing nations.*
6. *Develop means to assist public understanding of chemistry and its relationship to the world economy and the betterment of humankind.*

"The above purposes make very clear it was <u>not</u> proposed that IUPAC undertake research of its own; rather, it should provide leadership and a much-needed, independent, nonpolitical, central forum for the discussion of critical needs and solutions under conditions that might otherwise be impossible. In addition, it was envisioned that CHEMRAWN activities would provide the basis for treating chemical-based human needs as systems. Thus, CHEMRAWN

conferences by their very nature would be highly interdisciplinary and would take into account the social, economic, environmental and political factors, as well as the technical components involved. It was planned that these international conferences would attract world leaders from governments, industries and academia, and that the goal and focal point of the conference activities would be an attempt by recognized and influential world leaders to take an initial step toward developing a sense of future direction that would be of value to the world chemical community. Such direction would be provided in recommendations set forth in conference proceedings and made available to participants and policymakers and governments, industries, and academic institutions worldwide. Further, it was determined that CHEMRAWN conferences would provide continuity in areas where there is a persistent need."

It is important to realize that CHEMRAWN conferences are designed to identify and focus attention on world needs and to recommend to the global scientific community regarding actions to be taken. Normally, a CHEMRAWN Future Actions Committee has been formed at each conference to promulgate the conference's recommendations and to encourage appropriate sectors of the community to carry them forward. However, it was never the intent of CHEMRAWN to lock academia, industry, and government into any particular structure to solve world problems, or to follow up to ensure that they did.

A study of the recommendations developed by CHEMRAWN conferences and their Future Actions Committees leads to the conclusion that most are being carried out, or have been carried out, somewhere on the globe. Many CHEMRAWN recommendations have informed the science policy of nations and the actions of engineers and scientists. However, it is difficult to take credit for specific CHEMRAWN contributions to society because so many people and factors have been involved. One hopes and expects that the world needs under discussion will always be addressed by a plethora of individuals, organizations, and governments. CHEMRAWN contributes especially by pointing the way to solutions and by establishing consensus. That it is rarely the only positive influence is evidence of the strength and synergy of the process.

The value of CHEMRAWN conferences to societies and governments can be judged on the type of leaders it has been able to attract to its cause. World-class leaders are very busy, have reputations to protect and careers to advance, and cannot afford to waste time and effort on activities that do not pay high dividends to themselves and the institutions they represent. Past conferences have attracted national Presidents, eight Nobel laureates, presidents of major universities, and senior industrial scientists and managers. Also, CHEMRAWN events have raised significant resources: some $3,000,000 in support costs and the collaboration of hundreds of scientists.

Important CHEMRAWN results have often been imbedded in some aspect of the bigger picture and were not widely recognized. For example, Alan Bromley, Science Adviser to U.S. President George H. W. Bush, informed Bryant Rossiter, first Chair of the CHEMRAWN Committee, that the Perspectives and Recommendations from CHEMRAWN VII: *Chemistry of the Atmosphere: Its Impact on Global Change,*

represented a very important input to the U.S. government, resulting in policy changes regarding global warming and atmospheric change. This policy change was aided by the fact that Representative Ron Packard, a member of the House Ways and Means Committee, ensured that every member of the House and Senate received a copy of the CHEMRAWN VII Perspectives and Recommendations.

The early history of CHEMRAWN is described in *History of IUPAC 1919–1987* (Fennell, 1994); and *History of IUPAC 1988–1999* (Brown, 2001). The CHEMRAWN Committee has been chaired by Bryant Rossiter (1978–1987), John Meurig Thomas (1987–1991), Alan Hayes (1991–1997), Parry Norling (1997–2003), and John Malin (2004–2007). For general information about CHEMRAWN conferences and projects, see the IUPAC Web site <http://www.iupac.org/standing/chemrawn/conferences.html>.

R. Fennell. *History of IUPAC 1919–1987*, pp. 329–332, IUPAC, Blackwell Scientific, Oxford (1994).

S. S. Brown. *History of IUPAC 1988–1999*, pp. 404–406, IUPAC (2001).

Summaries of Individual Conferences

In order to understand fully the results of CHEMRAWN, it is necessary to examine the conferences themselves, to remain mindful of each event's epoch and venue, and to consider the state of the particular chemical discipline and its needs.

CHEMRAWN I: Resources of Organic Matter for the Future. Toronto, Canada; July 1978.

IUPAC's first CHEMRAWN event was the World Conference on Future Sources of Organic Raw Materials held in Toronto, Canada, 10–13 July 1978. Approximately 800 scientists from 48 countries attended. The organizing committee and attendees included not only internationally recognized technical experts, but also board chairpersons, presidents, vice presidents, and research directors from industry; world banking leaders, advisers to top government officials, and other high-ranking influential people. The purpose of the conference was to seek solutions to the problem of increasing world consumption of organic materials—petroleum and biomass. Particular attention was given to the needs of developing nations. Leaders from those nations were instrumental in many parts of the conference-planning stages and were prominently featured in the plenary, technical, and summary sessions.

Prof. Max Tischler (USA) chaired the program committee. The meeting consisted of invited papers supported by contributory poster presentations. Plenary sessions were held at the beginning and the end. The opening plenary session, organized under the chairmanship of Prof. Glenn T. Seaborg of the University of California at Berkeley and recipient of the Nobel Prize for chemistry in 1951, included Mr. Irving S. Shapiro, Chairman of the Board, DuPont, who gave an introductory overview and perspective of the world chemical industry. Dr. Kenneth King, Assistant Director General of the Forestry Department, United Nations, spoke on renewable resource availability. Dr. M. King Hubbert, U.S. Geological Survey (retired), outlined world resources of fossil organic raw materials. Dr. Ibrahim Helmi Abdel-Rahman, Councilor to the Prime Minister, Cairo, Egypt, discussed social and environmental considerations of future sources of organic raw materials, particularly for developing countries. Dr. Herbert Grunewald, Chairman of the Board, Bayer A.G., focused on economic considerations. Dr. Roberto de Oliveira Campos, Ambassador of Brazil to the United Kingdom, presented price and output trends in raw materials production. Professor Dieter Behrens, Director, DECHEMA, Germany, discussed a joint national research program of the German government and industry to secure supplies for the chemical industry

The final plenary session was organized under the guidance of Dr. W. O. Baker, President of Bell Telephone Laboratories. In addition to Dr. Baker, the program included Prof. T. Mukaibo, President, University of Tokyo, who outlined challenges for the future of Japan's chemical enterprise. Dr. Jean Cantacuzene, French Scientific Mission, Washington, DC, described some recent French examples in organic chemistry research of cooperation between government agencies and industrial companies. Dr. Duncan S.

Davies, Chief Scientist, Department of Industry, London, and I. Lawrenson presented strategies for technologies with long lead times. Dr. James F. Mathis, Vice President, Exxon Chemical, gave his overview of the CHEMRAWN I conference.

The conference was described by an article in *Chemical and Engineering News* (Krieger, 1978) and in a Perspectives and Recommendations volume (St-Pierre, 1978).

J. H. Krieger. "CHEMRAWN I Faces up to Raw Materials Future", *Chem. Eng. News*, pp. 28–31, July 24 (1978).

L. E. St-Pierre. "Resources of Organic Matter for the Future," Perspectives and Recommendations Volume, Multiscience Publications Limited, Montreal (1978).

Significance and outcomes

The "World Conference on Future Sources of Organic Raw Materials" was the first significant gathering of major international scientists and decision-makers from industries, governments, and academia to address a major problem in a concerted way. According to Organizing Committee Chair, Dr. William O. Baker, President of Bell Telephone Laboratories, "IUPAC will be interested in seeing the response. There hasn't been this kind of nongovernment initiative to any great extent before."

CHEMRAWN I was held shortly after the OPEC oil embargo during a frantic effort to find a substitute for oil. Solar, wind, geothermal, biomass, coal, and shale oil deposits were being highly touted with an accompanying cry for money to fund the research. The major conclusion of the conference was that there is no substitute for oil and we should stop pretending that expending massive amounts of money will solve *immediate* problems. In the short term, the conference recommended, we should promote conservation, exploit untapped oil and gas reserves and begin research on alternative sources of organic raw materials, with close attention paid to the economics necessary to make the alternatives viable in a modern society. The conference adopted the following recommendations:

Recommendations

- An international group should be formed to assess the organic supply problem in a continuing way.
- An assembly of high-level government science advisers should be formed. The group should consider the problem of organic supply in terms of governmental actions, determine priorities for budgeting R&D, and provide socio-technical plans for inevitable changes in lifestyle.
- Industrial research and development bodies must address the problem. Industrial organizations should form a group to monitor and assess technical progress.
- The leading scientific societies should form a group to ensure that the basic scientific issues are identified, publicized, and presented at scientific gatherings.
- A task force should be organized, including media experts, to publicize the prospects and consequences of shortages of organic compounds.

All members of the Organizing and Future Action Committees were asked to carry the results back to their respective institutions and countries. As a direct result of CHEMRAWN I, Eastman Kodak and several other companies started research programs in photovoltaics. Bryant Rossiter, CHEMRAWN Chair, was asked by Calvin Rampton, Governor of Utah, to join a four-person multidisciplinary panel to help the State of Utah develop its coal, oil shale, and geothermal resources while avoiding the environmental damages seen in other states. Dr. James F. Mathis, Senior Vice President of Exxon, stated that Exxon revamped its approach to alternative sources of energy as a result of CHEMRAWN I. The Philippine government dropped a project promoting coconut oil as a substitute for diesel fuel because it failed to meet economic requirements, although it met technical requirements superbly. Dr. William O. Baker, Chairman of the Future Actions Committee, presented the results of CHEMRAWN I to the U.S. National Research Council, and Dr. William Schneider, Organizing Chairman, presented the same to the National Research Council of Canada of which he was president. Dr. T. Mukaibo, President of the University of Tokyo, did this in Japan, and the pattern was followed with many other institutions and people throughout the world.

There were many side benefits to CHEMRAWN I. The CHEMRAWN concept was judged to be a viable forum for addressing world needs. Dr. Thomas F. Malone, Foreign Secretary of the U.S. National Academy of Sciences and Treasurer of the International Council of Scientific Unions, was to write later to Colby Chandler, President of Eastman Kodak Company, that “CHEMRAWN is part of one of the more important processes of our generation—in addressing directly human needs amenable to solution through chemistry.” The ability of CHEMRAWN I to draw the very top leaders from all segments of the industrial, academic, and governmental enterprises captured worldwide attention and in many ways would redirect some of the major IUPAC programs as well as other international programs. Dr. William Schneider, who previously had never been associated with IUPAC, became a member of the CHEMRAWN Committee and a future president of IUPAC. CHEMRAWN I demonstrated that conferences devoted to world needs could be financial as well as scientific and technological successes.

In light of more recent petroleum shortages, CHEMRAWN I was prescient in detailing the importance of conservation of petroleum resources, the need for utilization of biomass, and the dearth of alternate energy sources. It was noted particularly that the chemical industry is primarily petroleum-based, and that increases in energy prices lead directly to increasing costs for chemical feedstocks.

CHEMRAWN II: Chemistry and World Food Supplies: The New Frontiers. Los Banõs, The Philippines; December 1982.

Jointly sponsored by IUPAC and the International Rice Research Institute (IRRI), CHEMRAWN II, the International Conference on Chemistry and World Food Supplies: the New Frontiers, was held Los Baños, The Philippines, 6–10 December 1982. IRRI was selected as host organization because of the significant role it played in the advancement of agriculture in developing nations through the "Green Revolution". CHEMRAWN II organizers concurred with the World Bank and many national and international authorities in recognizing that much of present agricultural technology would soon be utilized, and that the big breakthroughs leading to the "Green Revolution" would be inadequate to meet the increasing food needs of the future. CHEMRAWN II was first major IUPAC meeting to be held in a Third World country, the first to address major Third World needs, and the first major international, interdisciplinary conference to involve leaders from governments, industries, and academia for the express purpose of developing a strong sense of future research directions and priorities designed to meet the mounting world food problem.

CHEMRAWN II was convened with the following objectives:

- To identify and put in perspective those areas of research and development having the potential to significantly increase food production and improve food storage and processing.
- To strengthen scientific research in developing nations
- To foster much-needed cooperation among governments, industries, and academic institutions.

The conference was described in an article in *Chemical and Engineering News* (Krieger, 1982) and the results were outlined in a Perspectives and Recommendations volume (Bixler and Shemilt, 1983).

J. H. Krieger. "Chemistry Confronts Global Food Crisis", *Chem. Eng. News*, pp. 9–23, December 20 (1982).

G. Bixler, L. W. Shemilt. *Chemistry and World Food Supplies: The New Frontiers, Perspectives and Recommendations*, IUPAC and International Rice Research Institute (1983).

"If we are to increase food production fourfold, and not increase available land significantly, this means more intensive farming," said Bryant W. Rossiter, General Chairman of CHEMRAWN II. "And generally speaking, more intensive farming means more chemical input." The conference attracted representatives of funding institutions and government agencies, as well as scientific experts from industry, universities, and research institutes. At least 700 delegates represented some 40 countries from both the developing and developed world.

CHEMRAWN II Recommendations
The Future Actions Committee, chaired by Dr. Cyril Ponnamperuma, made 17 recommendations:

- **For longer-range research at the forward edge, that:**

1. Officials of public and private funding agencies, managers of research organizations, and agricultural scientists assign high priority to research and development programs in genetic engineering and particularly to programs dealing with increased nitrogen fixation, improved stress resistance in plants, control of animal diseases, and enhancement of efficiency in milk and meat production.
2. High priority be assigned to fundamental and interdisciplinary research in plant physiology, with particular attention to understanding the molecular basis of reproductive, growth, stress, nutritional, and preservation processes. Leaders in developing countries are especially encouraged to support research on plants that are vital to their own countries.
3. High priority also be assigned to the development of less expensive and more cost-effective nitrogen fertilizers. Among the routes to be investigated are processes for oxidative nitrogen fixation; for producing hydrogen from water using solar radiation as the source of energy; and for improved controlled-release fertilizers.
4. Institutions in developed and developing countries work together on programs designed to improve photosynthetic efficiency and, in the very long term, achieve artificial photosynthesis.
5. Research on plant and animal growth regulators be increased significantly.

- **For near-term research and development related to soils, crops, pests, and animal production systems, that:**

6. Multiple, interdisciplinary field studies be conducted throughout tropical and subtropical countries to find the limiting factors between present yields and the maximum yields possible under the most favorable conditions; and the results disseminated rapidly and widely in relevant rural areas through improved extension services.
7. Presently unavailable knowledge of pest control systems be distributed widely and adapted as quickly as possible to conditions and practices in developing countries.
8. Internationally accepted standards of safety be established for people in different environments and international agreements be reached on registration, licensing, and patent procedures for pest control chemicals and methods.
9. High priority be given to the development of new chemical and biological methods to control pests in developed and developing countries.
10. Integrated control programs for animals be devised that emphasize (a) new genetic types of animals bred for disease resistance, (b) continuous disease monitoring and diagnostic systems for appraisal of livestock diseases, (c) improved chemotherapeutic and prophylactic measures appropriate for large and small animal husbandry enterprises, and (d) production of medicinals to control infectious diseases and cancers in animals.

- **For near-term research and development on food processing systems, that:**

11. New and inexpensive packaging materials be developed that allow easy food sterilization, are impermeable to moisture and oxygen, and provide adequate protection under tropical conditions
12. Increased emphasis be given to programs to improve preservation methods, especially those that can be operated at the home or small community level without large infusions of capital, but that produce foods having good nutrition and good acceptability in light of local customs and preferences.
13. Specialists in genetics and genetic engineering rank post-harvest storage and processing characteristics on a par with yield, nutrition, and aesthetic properties in planning experiments and in evaluating experimental results.
14. About the present level be maintained on such recognized methods for enhancing food supplies as producing intermediate moisture foods; supplementation with amino acids and vitamins; and preparation of food analogues, regenerated protein foods resembling meat, and carbohydrates and fats derived from simpler chemicals.

- **In the field of education, that:**

15. Developing countries formulate long-term programs to attract to agricultural and food-related scientific disciplines those students and workers who are better and more qualified by improving their educational programs at the primary, secondary, and technicians levels; by providing scholarships and awards to qualified citizens to complete their education to the highest level possible in domestic and foreign institutions; and by increasing the prestige and public understanding of food-related sciences and technologies through educational and public communication channels.
16. Major efforts be made in all countries to educate persons in policy positions, members of special interest groups, and citizens in general to the benefits as well as the risks of chemicals in agriculture and food processing.
17. IUPAC continue the CHEMRAWN II initiative and convene conferences in the future on a regular basis to assess progress, needs, and priorities.

Long-term results

Three post-CHEMRAWN II regional conferences were held in Colombo, Sri Lanka (1985), Buenos Aires, Argentina (1986), and Nairobi, Kenya (1988). At the 1988 conference, participants endorsed the following recommendations and noted results:

- An infrastructure in biotechnology should be developed in Africa after establishment of a regional training center.
- Policymakers in Africa should encourage client-driven research, defined as that focused on problems linked directly to local agricultural enterprises.
- An effective system of electronic communications should be established among African scientists to overcome the isolation experienced by those operating independently.

- Governments must find ways to eliminate or reduce import duties on materials needed to set up an agricultural industry in African countries.
- Governments must set up programs for the education of local farmers; the importance of the role of women in African agriculture must be recognized.
- Existing institutions in Africa should redouble their efforts in integrated pest management and biological control.

CHEMRAWN II accomplished the following:

- The fact that this was the first IUPAC meeting to be held in a Third World county developed great visibility for IUPAC. For example, to mention just a few, David Hopper, Senior Vice President of the World Bank; Bon Tonko, President of the World Food Council; Norman Borlaug, Nobelist; Ferdinand Marcos, Philippine President; M. S. Swaminathan, Director General of IRRI; and most leaders of the U.S. Agency for International Development (USAID), The Ford Foundation, The Rockefeller Foundation, etc. had never heard of IUPAC before the conference.
- For the first time at an IUPAC meeting, the president of a nation, Ferdinand Marcos, give the opening address. Regardless of how some felt about Marcos as a politician, he gave a superb technical talk and provided enormous financial and political support to the conference. For example, he made one of the world's most modern conference centers available to the conference and in spite of Muslim-inspired, governmental restrictions against Jews, he found ways for Jewish scientists to enter the country and to participate in the conference. Dr. Rossiter had a private meeting with President Marcos and his Secretary of Agriculture, Bon Tonko, where he discussed with him the release of certain scientists believed to be political prisoners.
- USAID judged CHEMRAWN II results to be of sufficient importance that it sponsored an international meeting in Singapore a few months after the conference to discuss the implementation of CHEMRAWN II Perspectives and Recommendations throughout the developing world. Later, USAID made the role of chemistry in agriculture one of the four major research goals of the agency. It is thought that this pattern was followed in a number of subsequent instances.
- As a result of his involvement in CHEMRAWN II, Bryant Rossiter was invited to become a member of the Scientific Advisory Committee of USAID to assist the United States in its broad development program in Third World countries. He served on the Advisory Committee for six years, three years as its Chairman. In this position, he interacted with scientific, industrial, academic, and development leaders from around the world. In addition, he was asked to serve on the Scientific Advisory Committee of the Cornell University International Institute for Food, Agriculture and Development and continues in service to the present day. He also served as a consultant to the U.S. Presidential Commission of Science and Technology as a result of CHEMRAWN.
- The CHEMRAWN II Perspectives and Recommendations were distributed to every member of the U.S. Senate, the House of Representatives, and many other organizations by Ron Packard, a member of the House Ways and Means Committee. Each member of the Organizing and Future Actions Committee was asked to make similar distributions in his/her own country.

- The CHEMRAWN II Perspectives and Recommendations were the most widely published and distributed IUPAC publication at the time, exceeding all other IUPAC publications combined. A simplified version was published by the American Chemical Society and distributed to high schools throughout the United States.
- Dr. S. Nagakura, President of the Institute for Molecular Science, Japan, was a member of the Organizing Committee. He later became a member of the CHEMRAWN Committee and President of IUPAC.
- A follow-up meeting was held in Colombo, Sri Lanka, where members of the Future Actions Committee and Bryant Rossiter held a two-day conference attended by Cabinet ministers and leading figures in the Sri Lankan educational, agricultural, and scientific communities. The Perspectives and Recommendations were interpreted and discussed in terms of the Sri Lankan geographical, agricultural, and economic environments. The conference was televised nationwide. Later, Cyril Ponnamperuma, President of the Third World Academy of Sciences and Science Advisor to the President of Sri Lanka, as well as David Hopper, Nyle Brady, and Bryant Rossiter met with the President who voiced full support for a plan put together by Dr. Ponnamperuma to implement recommendations appropriate to Sri Lanka.
- Both Kenya and Zimbabwe established biotechnology research centers with impetus from CHEMRAWN II.
- The International Centre of Insect Physiology and Ecology (ICIPE) in Nairobi, Kenya has carried out research on insects for over 20 years, as recommended by CHEMRAWN II.
- Researchers in Africa are being aided in communications through extension of the Internet, as recommended in CHEMRAWN II.
- Two full-page editorials were published in *Science* magazine, one by the editor, Phil Abelson, and one by Nyle Brady, Associate Director for USAID, describing CHEMRAWN II and the need for more chemical research devoted to agriculture.
- Initially, many international chemical companies were reluctant to participate in CHEMRAWN II out of concern that chemical companies would be accused of "dumping chemicals on developing countries." Up to this point, virtually no industrial chemical companies had participated in large, interdisciplinary, international, Third World development meetings. Eventually, these concerns were abated and many companies such as DuPont, Bayer, Eastman Kodak, ICI, Dow, and others became full participants. The President of the Board of Directors and Managing Director of CIBA-GEIGY was a keynote speaker. The willingness of industrial leaders to participate in CHEMRAWNs I and II set the pattern for future CHEMRAWN conferences and international development programs, including those at USAID.
- The Eastman Kodak Company sponsored, equipped, paid for, and trained personnel for a scientific photographic laboratory at IRRI in Los Baños, Philippines as a direct result of CHEMRAWN II. This laboratory served as a template for similar laboratories in other agricultural centers around the world.
- CHEMRAWN II conferees participated in an ACS-sponsored briefing on the CHEMRAWN II Recommendations before the U.S. House of Representatives Committee on Agriculture.

Future Actions Committee: Cyril Ponnamperuma, Chair; Bansi Amla (India); Norman E. Borlaug (Mexico); Nyle C. Brady (USA); Teresa Salazar de Buckle (Peru); Melvin Calvin (USA); Fujio Egami (Japan); Masao Fujimaki (Japan); W. David Hopper (World Bank); Herwig Hulpe (Germany); Emil Q. Javier (Philippines); K. T. Li (China); Li Su (China); P. Mahadevan (India); John W. Mellor (USA); Louis G. Nickell (USA); T. R. Odhiambo (Kenya); Raul N. Ondarza (Mexico); Thomas W. Parton (Switzerland); Charles Pereira (UK); George Porter (UK); Abdus Salam (Italy); Glenn T. Seaborg (USA); Khaled El-Shazley (Egypt); M. Swaminathan (Philippines).

Organizing Committee: Bryant Rossiter, Chair (USA); Adnan Al-Ageel (Kuwait); Eduardo Alvarez-Luma (Mexico); William O. Baker (USA); Charles Dennison (USA); Jacques Diouf (Senegal); Nicholi Emmanuel (USSR); He Kang (China); Kenzo Hemmi (Japan); W. David Hopper (World Bank, USA); John H. Hulse (Canada); Franklin Long (USA); Jamal T. Manassah (USA); William G. Padolina (Philippines); Bukar Shaib (Nigeria); M. S. Swaminathan (Philippines); Werner Treitz (Germany); Moriya Uchida (Japan).

CHEMRAWN III. Resource Material Conversion: (Bio)Chemical Process Bridges to meet Future Needs. The Hague, Netherlands; June 1984.

D. A. O'Sullivan. "CHEMRAWN Conference Probes Future of Chemical Feedstocks", *Chem. Eng. News*, pp. 63–66, August 20 (1984).

CHEMRAWN III, chaired by Wiro J. Beek, Head of Unilever Engineering Research, continued the work begun six years earlier at CHEMRAWN I. At the time of CHEMRAWN I (1978), the high prices of petroleum feedstocks and a strong dependence of the industry on those feedstocks created real concern about the short-term outlook for the chemical industry. Supplies of oil had recovered by 1984, companies had managed to cope with higher prices by a variety of technical means, and the outlook for the industry was considerably brighter. Executives were convinced that the industry would continue to rely on petroleum feedstocks for at least several decades. At the same time, the chemical industry was placing increasing emphasis on energy conservation and developing and implementing new technologies. Bryant Rossiter, CHEMRAWN Committee Chair, said about CHEMRAWN III, "It builds upon and it updates the earlier findings and recognizes the importance of chemical process engineering as the key to the economical transformation of raw materials into articles of commerce."

Two hundred and twenty scientists attended CHEMRAWN III. Some 60 lectures were presented during the three days of the conference. Topics included scenarios for development and conservation of coal, oil, and gas resources; biotechnology; renewable sources of chemical feedstocks and fuel; new materials; novel chemical conversion processes; risk prevention; and recycling. Companies had managed to cope with higher oil prices in various technical ways, and some participants were relieved to report that petroleum consumption had moderated since CHEMRAWN I.

At the time of CHEMRAWN III, the globalization of the chemical enterprise had begun in earnest. It was predicted that in Japan, for instance, industries centering on advanced technologies might account for up to 20% of the country's GNP by the end of the next decade, markedly up from 2% in 1984. Accordingly, Japan's Ministry of International Trade and Industry (MITI), was emphasizing three areas of technology that were seen as the most important for long-term development. They were biotechnology; new functional devices in the fields of communications, computers, and microelectronics; and novel materials. The forces driving interest in biotechnology included process improvements that would reduce energy use, enhance the likelihood of increased yields, and lead to alternate energy sources. In the field of industrial chemicals, researchers were seeking not so much for new products as for better technologies to produce existing ones. Genetic engineering, use of bacteria for extraction of metals, and use of biotechnology for food processing and generation of fuel from cellulose wastes were seen as promising areas.

CHEMRAWN III continued to demonstrate the ability of an IUPAC conference to draw not only outstanding scientists but important figures in the public sector as well. The Crown Prince of the Netherlands gave the opening address. This conference came at a time when biotechnology was still in its infancy but rapidly gaining momentum. New

strides were being made in scientific laboratories but, with the exception of fermentation technology, little was known about scale-up and bioengineering. This conference was targeted to future needs of industries operating or moving into the bioengineering areas; consequently, the audience was somewhat limited and the conference did not meet all of its expenses. This was made up by excess funds from CHEMRAWNs I and II. Although some found this a matter of concern while overlooking the bigger picture, subsequent experience has shown that if proper attention is given to finances, it is likely that most if not all CHEMRAWN conferences could show a considerable profit. As in the previous conference, the Perspectives and Recommendations were widely distributed and decision-makers drew from the conference those ideas which met or were germane to their needs.

CHEMRAWN IV: Modern Chemistry and Chemical Technology Applied to the Ocean and its Resources. Keystone, Colorado, USA; October 1987.

Given increasing recognition of the problems of global change, and realizing the importance of the oceans as buffering systems, CHEMRAWN IV sought to "seek out from the information base of present-day chemistry those novel techniques and concepts that deepen our knowledge of seawater and the chemical reactions occurring in the marine environment." Organizing Committee Chair Derek Spencer divided the 150 participants among five panels, each of which wrote a paper on its subject of concentration.

1. *Oceanic Reactive Chemical Transients*. T. David Waite, Donald T. Sawyer, and Oliver C. Zafirou.
2. *The Nature of Reactions on Marine Particle Surfaces*. Bruce O. Honeyman, Arthur W. Adamson, and James W. Murray.
3. *Chemical Models of Sea Water Systems*. Andrew G. Dickson, Harold L. Friedman, and Frank J. Millero.
4. *Chemistry at the Air–Sea Interface*. Thomas E. Graedel, Peter G. Brewer, and F. Sherwood Rowland.
5. *Chemical Processes at the Ocean Bottom.* William R. Martin, Steven R. Emerson, and Charles Lochmuller.

The papers were included along with individual contributions by the panelists in a volume of *Applied Geochemistry*, edited by Edward D. Goldberg. The conference was described in *Chemical and Engineering News*.

A. Bard, E. D. Goldberg, D. W. Spencer. "Modern Chemistry and Chemical Technology Applied to the Ocean and its Resources", *Applied Geochemistry*, Vol. 3 (1) (1988).

Chem. Eng. News, pp. 5–6, October 12 (1987).

Long-term results

CHEMRAWN IV: Modern Chemistry and Chemical Technology Applied to the Ocean and Its Resources was a unique conference that illustrated the ability of CHEMRAWN to target very specific needs in highly specialized areas. It admirably illustrated one of the articles of faith of CHEMRAWN: namely, that *it is more important who attends a conference than how many persons attend*. Participation in CHEMRAWN IV was by invitation only and restricted to a relatively few leading scientists in the fields of analytical chemistry and oceanography. Prior to the conference, analytical chemists had little interest or concern for how analytical measurements were made peculiar to conditions found in the oceans; i.e., high salinity, extremes of temperature and pressures, precise and accurate measurements of one chemical component in the presence of many others, remote sensing, etc. At the same time, oceanographers were struggling with these problems and conditions mostly on their own. Literally, the very top scientists in the world in their respective fields were brought together for the first time to create scientific synergies and associations between the two fields that would last far beyond the

conference itself. CHEMRAWN IV contributed in a fundamental way by encouraging development of new chemical measurement technologies in ocean studies.

CHEMRAWN V: Current and Future Contribution of Chemistry to Health—The New Frontiers. Heidelberg, Germany; September 1986.

CHEMRAWN V was organized and sponsored by the West German Chemical Society. Its purpose was to discuss the role of chemistry in a broad spectrum of health-related topics, including diagnosis, antibacterial and antiviral chemotherapy, cardiovascular diseases, metabolic disorders, parasitic infections, cancer, and neuropsychiatric disorders. The technical part of the conference was excellent, and the recommendations helped lead to important new technologies. The organizers realized that the chemical sciences presented great opportunities in such fields as strategy of drug design, synthesis of natural medicines and their analogues, biotechnology, and genetic engineering.

One hundred scientists attended. An article describing the conference was published in *Chemical and Engineering News* (O'Sullivan, 1986).

D. A. O'Sullivan. "Chemistry's Contributions to Health are Focus of Heidelberg Conference", *Chem. Eng. News*, pp. 7–12, November 3 (1986).

The meeting dealt first with issues of progress in analytical chemistry for clinical testing, including the increasing desire of the public for self-testing and the challenges of low-cost testing in developing countries. A half-day session discussed antibacterial and antiviral chemotherapy, urging improved clinical trials. The conferees recommended development of gene technologies, especially for producing bioactive substances. Andrew Davis, Director of the World Health Organization's parasitic disease program, chaired a session on parasitic infections, noting that "Perhaps 3 billion inhabitants of Earth are infected with parasites, and infections of innumerable domestic animals aggravate the picture. Some 50% of the world's population is exposed to the threat of Malaria alone.…The importance of chemistry to this scene is of an importance that cannot be overemphasized. Without doubt, the most important of all control tools are the chemotherapeutic drugs."

While the program included a number of speakers from several countries, attendance consisted mostly of scientists from Germany. There was no Future Actions Committee and the Recommendations were restricted to the conference participants. CHEMRAWN V's major contribution was to focus attention on the need for major new drugs and techniques, many of which were soon developed for the benefit of human health. The conference made major recommendations which subsequently developed into numerous successful new therapy regimes, for example, calcium channel control for treatment of hypertension. The conference also was timely in underscoring the need for new drugs for treatment of Alzheimer's-type senile dementia (SDAT) and for new scanning techniques such as magnetic resonance imaging for studying human brain function in vivo. Finally, the conference urged further advances in cancer therapy through monoclonal antibody technology coupled with development of chemically defined biological response modifiers.

CHEMRAWN VI. Advanced Materials for Innovations in Energy, Transportation and Communications. Tokyo, Japan; May 1987.

The CHEMRAWN VI conference was cosponsored by IUPAC, the Science Council of Japan, and the Chemical Society of Japan, and financed largely by Japanese industries. It focused on advanced materials for innovations in transportation, communications and information, and energy. Some 600 conferees attended. Participants noted that the expectations for the possibilities and potentialities of creation of advanced materials were extremely high. During the same week as the CHEMRAWN V conference, Tokyo hosted the High Tech Materials Exhibition 1987, which attracted as many as 100,000 visitors.

Topics discussed during the conference ranged from the need for development of new photochemically active materials to the desire for enhanced industry–university collaboration. Japanese conferees stressed the importance of studying the process of innovation in the chemical industry, a topic that was revisited 16 years later by the CHEMRAWN XVI conference. Articles describing CHEMRAWN VI were featured in *Chemical and Engineering News* (Worthy, 1987) and in *Chemistry International*.

W. Worthy. "CHEMRAWN Conference Probes Future of Advanced Materials", *Chem. Eng. News*, pp. 7–14, June 15 (1987).

Chem. Int. **9**(6), 207 (1987).

In his plenary address, C. N. R. Rao, President of IUPAC, noted that the magnitude of a country's use of advanced materials could be seen as an indicator of that nation's economic development. After the first day's plenary sessions, participants divided into three groups for the three days of parallel sessions. Presentations dealt with the availability and needs for advanced materials within the sectors of transportation, energy, and information and communications. Discussions centered around structural composites, semiconductors, and new superconductors. Recommendations were made for stronger, lighter, inexpensive, more durable, and heat-resistant materials with designed electronic properties—and which presented no disposal problems. Teiji Tsuruta, of the Science University of Tokyo, noted the difficulty in disposing of tons of old auto body parts, constructed from composite materials, which cannot be recycled as easily as steel yet which are, as conferee Rudolph Pariser noted, "too valuable to burn."

Keichi Oshima, Chairman of the Future Actions Committee, commented that serendipity can be an important initiator of innovation, as demonstrated in the discovery of superconducting ceramics. But discovery is not enough, he noted. It is also necessary to have the capability to manufacture and process the new materials, as well as the imagination and capability to develop new applications.

The Future Actions Committee included representatives from most major industrial nations. The Chemical Society of Japan published the Perspectives and Recommendations volume. As in previous conferences, the Perspectives and Recommendations were distributed not only to the participants, but to virtually every

major industry, university, and government around the world. Dr. Sabura Nagakura was Chairman of the Organizing Committee, and Dr. C. N. R. Rao of India, and President of IUPAC, played a major role in the conference. Both started their involvement with IUPAC through their CHEMRAWN activities. Dr. Nagakura noted that the subjects of CHEMRAWN VI were of vital interest to Japan and that the leaders of Japanese industry and the scientific and engineering community were influenced by the results of the conference.

CHEMRAWN VII: Chemistry of the Atmosphere: Its Impact on Global Change. Baltimore, Maryland, USA; 2–6 December 1991.

CHEMRAWN VII was cosponsored and managed by the American Chemical Society in association with the U.S. National Academy of Sciences and the Third World Academy of Sciences (Trieste, Italy). The conference explored the international problem of atmospheric global change, particularly as generated by human activities. Descriptions of the conference were published in *Chemical and Engineering News* (Zurer, 1991) and in *Chemistry International*. USAID published the CHEMRAWN VII Perspectives and Recommendations volume.

P. S. Zurer. "CHEMRAWN Conference Tackles Threats to Atmosphere," *Chem. Eng. News*, pp. 21–22, December 23 (1991).

Chem. Int. **14**(4), 146–151 (1992).

J. W. Birks, J. G. Calvert, R. E. Sievers. *CHEMRAWN VII; The Chemistry of the Atmosphere, Its Impact on Global Change*, Agency for International Development, Bureau for Science Technology, Washington, DC (1992).

The Organizing Committee consisted of Robert Sievers (Chair), Robert M. Barkley, John W. Birks, Nyle Brady, Jack G. Calvert, Eldon E. Ferguson, Thomas E. Graedel, Rudolph Pariser, Cyril Ponnamperuma, Bryant Rossiter, William G. Schneider, and William E. Wilson.

Some 400 scientists attended the conference. Introductory remarks were made by Valentin A. Koptyug, Past President of IUPAC, and Sir John Meurig Thomas, Chairman of the CHEMRAWN Committee. D. Allan Bromley, Assistant to the President for Science and Technology, Office of Science and Technology Policy, Washington, DC, spoke on *An Approach to Global Climate Change: A U.S. Perspective*. Daniel A. Albritton, Director, NOAA Aeronomy Laboratory, Boulder, discussed *Atmospheric Chemistry and Global Change: the Scientists Viewpoint.* A. P. Mitra, former Director General, Council of Scientific and Industrial Research, India, spoke on *Global Environmental Change Overview: Developing Countries.* E. P. Blanchard, Vice Chairperson, DuPont, discussed *Control of Global Change: Industrial View*. George M. Hidy, Vice President, Electric Power Research Institute, spoke on *Control of Global Climate Alteration: Power Industry Perspective.* C. H. Krauch, Board of Directors of Hüls AG, Germany, discussed *Future Energy Sources and the Atmospheric Challenges for Research and Development.* Valentin A. Koptyug, Professor, Presidium of Academy of Sciences, Russia, spoke on *International Cooperation and Some Research Needs to Improve Our Understanding of the Chemistry of the Atmosphere.* Sir Crispin Tickell, Warden, Green College, Oxford, UK, discussed *Global Change and the Role of Governments.*

The Future Actions Committee consisted of: John Birks (Chair), Daniel L. Albritton, Fred Bernthal, Nyle Brady, Jack G. Calvert, Paul J. Crutzen, Anne H. Erlich, Keiichiro

Fuwa, Mary L. Good, Alan Hayes, Bruce W. Karrh, Mohamed Kassas, B. A. Koptyug, Carl H. Krauch, Gerard Megie, Mario J. Molina, Lubos, Nondek, Rudolph Pariser, Cyril Ponnamperuma, Maurits la Riviere, Bryant Rossiter, Harold I. Schiff, Robert E. Sievers, Wiaoyan Tang, Sir Crispin Tickell, and Dieter Wyrsch. The committee met during the conference and made the following recommendations:

- **With respect to all aspects of global change chemistry:**

1. Recognize that all atmospheric problems are interrelated and connected with biospheric processes so that an integrated, multidisciplinary approach must be taken for their solution.
2. Secure broad international agreement before undertaking major experiments aimed at mitigating global change that has regional or global consequences.
3. Research and develop the means for full social environmental costing of energy use.
4. Develop ecological balance sheets (lifecycle analyses) for comparison of different processes leading to similar end-products.
5. Apply incentives/disincentives to direct the huge innovative potential of public and, especially, private R&D organizations for the development of more energy-efficient industrial processes and more productive, but sustainable land-use.
6. Provide incentives/disincentives to accelerate development of alternative energy technologies, especially solar and safe nuclear subject to strict environmental safeguards.
7. Encourage corporations to continue the trend toward increased participation of environmental scientists in decision-making positions.
8. Forge a partnership between governments, industry, and academia in establishing global change research priorities and programs and in formulating responsible policy.

- **With respect to education:**

9. Foster the education and professional development of atmospheric chemists, worldwide, especially in developing countries.
10. Increase environmental literacy by encouraging environmental chemistry instruction as an important part of general education at all levels (elementary school through university).
11. Improve understanding of global change issues at the political level so that due account is taken of them in policymaking.
12. Transfer experience and skills in atmospheric chemistry and monitoring techniques to developing countries through a continuing program of training workshops such as the one held in conjunction with the CHEMRAWN VII conference.

- **With respect to global monitoring:**

13. Implement means of establishing adequate quality control in atmospheric measurements worldwide.
14. Encourage government and industry to cooperate with the atmospheric chemistry community in developing global inventories of emissions to the atmosphere.
15. Explore with industry the possibility of strengthening and expanding the existing international efforts to establish a high-quality global monitoring network in developing countries. Such networks will enhance our understanding of atmospheric chemistry and global change by:
    a. Establishing chemical sources and deposition patterns for acid precipitation.
    b. Obtaining trends and variability of troposphere ozone.
    c. Characterizing the global distribution of carbon monoxide and the oxides of nitrogen.
16. Monitor UV radiation and its effects on living organisms and their ecosystems, especially in the vicinity of the Antarctic.
17. Accelerate the development of both research and routine monitoring instruments.

- **With respect to stratospheric ozone depletion:**

18. Maintain a vigorous scientific research agenda.
19. Continue high-priority attention to developing new substitutes and replacements for chlorofluorocarbons (CFCs) and encourage increased emphasis on recycling and recovery of CFCs, hydrogen-containing chlorofluorocarbons (HCFCs), hydrogen-containing fluorocarbons (HFCs), and bromine-containing compounds.
20. Be advised that proposed new fleets of supersonic aircraft could result in large changes in stratospheric ozone concentrations and climate.

- **With respect to climate change:**

21. Promote international discussion in agreement about controlling future emissions of greenhouse gases.
22. Obtain a detailed understanding of the global carbon cycle.
23. Identify and quantify the sources and sinks of greenhouse gases and aerosols.
24. Assign high priority to understanding and quantifying the many feedbacks involved in climate change.
25. Quantify the effect of aerosols on climate, including both direct radiative effects and changes they induce in cloud albedo via their role as cloud condensation nuclei.
26. Utilize available proxy records of climate change (e.g., tree rings, ocean and lake sediments, ice cores, pollen records) to obtain a better understanding of the causes of climate change in the past and to validate climate models.

- **With respect to oxidant formation and acid precipitation in the troposphere:**

27. Establish regional networks for the early detection of “cleaner” air resulting from emissions control strategies.

28. Elucidate how local emissions influence regional and global scale chemistry.
29. Encourage research to achieve better understanding of acidification processes, including dry deposition and cloud-mediated acidification in natural ecosystems and their interactions with other human influences.
30. Strongly enhance research efforts to increase scientific knowledge of tropical atmospheric chemistry, including biotic interactions.

Immediate results from CHEMRAWN VII

- Copies of the Perspectives and Recommendations volume were distributed to U.S. legislators.
- CHEMRAWN VII was an important financial success, thus being able to generate a significant research program in support of its future actions recommendations. A CHEMRAWN-sponsored campaign in the Amazon Basin in Peru was successfully completed in July 1996 by use of novel, high-flying kites and blimps. Over forty vertical concentration profiles for atmospheric gases were measured, including ozone, carbon dioxide, NO(x), methane, and some 30 volatile organic compounds. The calculation of fluxes in these profiles was carried out. The expedition involved cooperation between CIRES and the University of Colorado, the University of Piura, NOAA, PETROPERU, and DuPont with major funding support provided by Dreyfus Foundation. A successful bonus of this research was the development of light-weight, portable instruments for the measurement of the various atmospheric gases. A number of valuable scientific publications primarily by Prof. John Birks and coworkers at the University of Colorado have resulted from this research. Prof. Birks served as Chair of the Future Actions Committee (FAC).
- The FAC worked with the CHEMRAWN XIV FAC to fund requests for support. In 2002, after the two FACs were combined, they made grants to support the atmospheric chemistry contribution to the Malta I conference (Frontiers of Chemical Sciences: Research and Education in the Middle East), CHEMRAWN XV, and CHEMRAWN XVII. Funding was later employed to support the future actions recommended by CHEMRAWN XIV.

Long-term results

CHEMRAWN VII is a case in point where the very top leaders from industry, academia, and government came together in a cause they deemed important to societies and governments and were personally willing to place the Recommendations and Perspectives into the hands of their constituencies.

Consider the following: The first person to be approached as Chairman of the Organizing Committee of CHEMRAWN VII was Dr. Walter Orr Roberts, Director of the Center for Atmospheric Research at Boulder Colorado. Dr. Roberts was recognized worldwide as the “Dean of Atmospheric Research,” the preeminent scientist in the field. He immediately accepted the chairmanship and began to contact other world-class scientists in the field to join with him. Unfortunately, he was stricken with serious illness and the responsibility of the Chair went to the very able Dr. Robert Sievers, Director of CIRES. Nonetheless, the pattern had been set and Dr. Roberts considered CHEMRAWN VII the “capstone” of his career. Others, to mention just a few, who participated in the

conference included the executive vice president of DuPont, the science advisor to the President of the United States, an Ambassador to the United Nations from Great Britain, a Nobel Laureate, and two scientific participants who would shortly receive the Nobel Prize in chemistry.

Like previous conferences, especially CHEMRAWN II, great emphasis was placed on the participation of approximately 30 young and upcoming scientists from developing nations. In addition to participating in CHEMRAWN VII, they attended a contiguous workshop on environmental measurements appropriate to their own countries. If history repeats itself, many of these participants will not only serve the environmental needs of their countries but will also become future ministers and government leaders.

As mentioned earlier, the Perspectives and Recommendations were widely distributed and played a specific role in developing the environmental policies of the United States and no doubt other countries as well. Later, CHEMRAWN XIV: Towards Environmentally Benign Products and Processes would become a direct outgrowth of CHEMRAWN VII.

CHEMRAWN VIII: Chemistry and Sustainable Development: Towards a Clean Environment, Zero Waste and Highest Energy Efficiency. Moscow, Russia; September 1992.

CHEMRAWN VIII was organized in Moscow during a time of profound economic and political change. The conference was covered in articles in *Chemistry International*.

Conference objectives, *Chem. Int.* **14**(3), 88–89 (1992).

M. Freemantle. "Chemistry and Sustainable Development", *Chem. Int*. **15**(2), 41–47 (1993).

One hundred and fifty scientists, including 50 from outside Russia, attended CHEMRAWN VIII. The conference emphasized certain goals set by the United Nations Conference on Environment and Development (UNCED) and had the following objectives:

- Analyze the current state-of-the-art and define the requirements for the development of industry based on chemical processes in the framework of a sustainable development strategy.
- Help in the dissemination of information on clean technologies, using waste as a raw material.
- Recognize scientific achievements that could lead to revolutionary techniques in chemical production, pollution prevention, and waste recycling and use, and stimulate international collaboration.
- Elucidate strategic recommendations for policy and decision-makers. The development of the branches of industry, which have the most perceptible impact on the environment and on the health of the population.

Program
CHEMRAWN VIII grouped some 44 plenary lectures and a number of contributed posters into four sessions on the following themes:

- Policy and strategy of adopting sustainable development practices.
- Goals for chemistry and the chemical branches of industry in moving toward sustainable development and cleaner chemical technologies.
- Recent practices and technological achievements of the chemical branches of industry.
- New approaches to waste treatment and elimination of large-scale environmental pollution.

In his plenary lecture, Kirill M. Dyumayev (Deputy Minister of Science, Higher Education, Technical Policy of Russia) spoke on *Achievements and Problems in the Chemical Industry of Russia*. Dyumayev noted the technical standards of the Russian chemical industry did not meet modern international requirements, and that much equipment had become outdated. On the other hand, he pointed out that Russia is a

country rich in chemical raw materials and energy, which was moving to a market economy. Scientists, businesspeople, and policymakers would be needed to develop an open and independent economic structure. Lectures followed on *Efficient Use of Energy in the Chemical Industry* (Kunio Yoshida, Japan); *Pollution Reduction at a Major U.S. Chemical Manufacturing Company* (Alan M. Ford, USA); *UNIDO's Activity and Transfer of Cleaner Chemical Technologies* (Archalus Tchneknavorian-Asenbauer, Austria); *Cleaner Production, an Opportunity for Industry* (Jean Kryger, France); *Using Technology Alliances to Lead to Sustainable Development* (James D. Molzon, USA); *Membranes as a Means for Solution of the Environmental Problems in Chemical Production* (N. Plate, Russia); *Catalysis and New Technologies for Sustainable Development* (Kirill Zamaraev, Russia); and *Environmentally Safer Processes, Opportunities for Catalysis and Process Research* (Leo Manzer, USA). Additional papers were presented on best practices in agrochemicals, aluminum, and other ferrous metals; recycling of polymers; and pulp and paper industries. The final conference session was entitled *New Approaches to Waste Treatment and Elimination of Large-Scale Environmental Pollution*.

A Perspectives and Recommendations volume was not published, but CHEMRAWN VIII effectively presaged the highly influential CHEMRAWN XIV: Environmentally Benign Products and Processes.

CHEMRAWN IX: The Role of Advanced Materials in Sustainable Development. Seoul, Korea; 1–6 September 1996.

M. C. Chon. *Chem. Int*. **19**(3), 127 (1997).

An assessment of the conference is on file on IUPAC's CHEMRAWN Web site at <http://www.iupac.org/standing/chemrawn/conferences.html>.

The six-day conference was held in Seoul, Republic of Korea, 1–6 September 1996. Eighteen countries were represented by 355 participants, of whom 237 were from the Republic of Korea itself. There were 72 lecturers. Dr. Min Che Chon, Conference Chairman, led the 23-person organizing committee. Dr. Y. B. Chae, Vice Chair, chaired the 24-person Future Actions Committee.

Conference goals: As Prof. Chon stated in his opening address: "The need for sustainable development arose from the realization that there is a limit of the supply of natural resources and that development and production can cause serious environmental problems. At this point, sustainable development is no longer just an option, but imperative."

Thus, the goals of the conference were to:

- Evaluate (a), the state of current production technologies of advanced materials and (b) environmental impacts of the application of advanced materials in the fields of energy, communications, transportation, and construction.
- Clarify the role of technology and reduce the ecological load imposed by developing advanced, ecologically sound materials, and the means of their application.
- Elaborate strategies for selection of and search for optimal eco-friendly combinations of materials as well as processes and combinations of processes for advanced materials in the fields of energy, communications, transportation, and construction involving a number of different industries.
- Formulate criteria for estimation of environmental acceptability (sustainability) of current technologies for the production of materials.
- Search for effective ways of international cooperation and information exchange in the fields of materials-designed production and use.

The conference consisted of sessions on communication, transportation, construction, and energy, in which academics, industrialists, and scientists examined and analyzed production technologies and their current impact on the environment. Sir John Meurig Thomas of the Royal Institute of Great Britain and Peterhouse, University of Cambridge, UK, spoke on *Needs and Seeds for Revolutionary Technology Towards Sustainable Society*; Prof. C. N. R. Rao of the Advanced Scientific Research and Indian Institute of Science, lectured on *The Impact of New Emerging Areas of Solid-State Science on the Development of Advanced Materials: Three Case Studies*; and President Charles O. Holliday of DuPont Asia-Pacific, spoke on *Policy and Practical Issues in Sustainable Development: An Industrial Perspective on Opportunities and Responsibilities*.

President Chunk Wook Suh of Korea Mobile Telecommunication lectured on *Wireless Telecommunications in Korea*; Vice President Sang Bok Hong of Pohang Steel Corporation discussed *The Korean Steel Industry and Development*. Other highly placed industrial executives presented issues in materials science for electric power generation and distribution for the Korean semiconductor industry and for the automobile industry. The technical papers were summarized in an excellent Proceedings volume, which was widely distributed.

The Perspectives and Recommendations volume, which was prepared and distributed through the IUPAC Secretariat, identified the following seven key findings and six recommendations for future action.

Key findings

- There is a need for increased understanding and use of lifecycle assessments in making decisions on materials and technologies supporting the objectives of sustainable development.
- Ways to recycle complex manufactured goods containing advanced materials need to be developed. Designing such goods for recycling may be a top priority.
- The importance of conservation and development of adequate water supplies for agriculture and human consumption cannot be underestimated. Shortages will be the source of major conflicts in the future.
- There are opportunities in the upgrading of locally available materials with small amounts of other materials or processing technologies from outside the region.
- The opportunities to improve many traditional materials (steel, cement, etc.) are consistent with the goals of sustainable development.
- A number of advances in energy production can contribute to sustainable development.
- Catalysis research offers the potential for routes to sustainable production techniques.

Recommended future actions

- A “materials for sustainable development” R&D agenda should be created to guide national funding agencies.
- The Future Actions Committee (FAC) supports the need to contribute to the ready transfer of environmental technologies across industries, nations, and public/private sectors; to increase the focus from control and remediation technologies to avoidance and resource conservation.
- Intellectual property rights should be protected in a way that acts as an important driver for the introduction of advanced materials and process technologies that can further sustainable development, rather than as a hindrance to increased collaboration for sustainable development.
- A program of technical education related to sustainable development should be included in future CHEMRAWN conferences.
- Experts must define (in writing) the needs and opportunities in advanced materials to build a better awareness among the public of the contributions of chemistry and advanced materials to our society and to sustainable development.

- When awards are given, special recognition should go to advances in developing materials that contribute to sustainable development.

Conference outcomes

A great strength of CHEMRAWN IX was that it brought a number of key academics together with executives from such companies as AT&T, Korea Mobile Telecom, Bell Laboratories, the Russian Academy of Sciences, Samsung Semiconductors, Hitachi Ltd., Pohang Iron and Steel Co. (Korea), NKK Corp. (Japan), Chichibu Onoda Cement Corporation (Japan), Angarsk Electrochemical Co. (Russia), Chiyoda Corporation (Japan), General Motors Research and Development Center (USA), Daimler-Benz Aerospace Airbus GMBH (Germany), and Ecomaterials Researching Group of China. Some 84% of the conference's $326,000 budget came from industrial contributions, principally from petrochemical companies.

CHEMRAWN IX was part of a new emphasis on sustainable use materials that accompanied significant industrial development in the Republic of Korea. The conference accompanied the establishment by UNIDO and the Ministry of Science and Technology of the Republic of Korea of the International Center for Materials Evaluation Technology (ICMET) in Taejon, Korea. ICMET's mission is "to develop international guidelines, codes of practice, standards on testing and characterization for new materials and to bridge the gap between developed and developing countries in this important area of materials science and technology."

CHEMRAWN IX was organized around specific fields of endeavor rather than the usual chemistry sectors. It was therefore possible to classify the discussion of advanced materials in terms of the development of specific consumer markets. This industrial rather than academic emphasis was probably encouraged by the fact that 30% of the papers were presented by industry. The approach was fruitful in attracting the attention of scientists and support of industrial representatives.

The CHEMRAWN IX organizing committee produced an excellent conference. As noted above, the FAC developed useful recommendations, documented in a Proceedings volume accompanied by published Perspectives and Recommendations. While economic difficulties in the host nation in ensuing years prevented the FAC from further activities, the conference successfully underscored the importance of sustainable development for production of materials. This theme was later developed further by the organizers of CHEMRAWN XIV. Another important area, the availability of water for sustainable development, was the basis of the program for CHEMRAWN XV: Chemistry for Water.

Future Actions Committee: Y. B. Chae (*Chair*, Korea); Parry Norling (*Vice Chair*, USA); Y. S. Sohn (*Vice Chair*, Korea); C. R. Choe (Korea); M. C. Chon (Korea); E. Dowdeswell (UNEP); J. Economy (USA); A. Hayes (UK); S.-D. Jang (Korea); J.-I. Jin (Korea); V. A. Koptyug (Russia); F.A. Kuznetsov (Russia); H. Lee (Korea); H.-D. Li (China); R. P. Martin (France); P. Moyna (Uruguay); J. Nishizawa (Japan); R. Pariser (USA); S. J. Park (Korea); W.-H. Park (Korea); C. N. R. Rao (India); K. Taylor (USA);

A. Tcheknavorian-Asenbauer (Austria); J. M. Thomas (UK); P. Varadarajan (India); F. Wang (China); V. Zharov (UNESCO)

International Advisory Committee: C. N. R. Rao (*Chair*, India); A. J. Bard (USA); R. P. H. Chang (USA); M. C. Chon (Korea); M. Doyama (Japan); M. Dröscher (Germany); J. Economy (USA); A. Hayes (UK); M. Jiang (China); V. A. Koptyug (Russia); F. A. Kuznetsov (Russia); Y. T. Lee (Taipei); H.-D. Lee (China); E. Matijevic (USA); R. Metsalaar (Netherlands); S. Nagakura (Japan); J. Nishizawa (Japan); R. Pariser (USA); P. Siffert (France); F. Wang (China); G. Wegner (Germany); D. S. Yan (China); V. Zharov (UNESCO).

CHEMRAWN X: The Globalization of Chemical Education—Preparing Chemical Scientists and Engineers for Transnational Industries. Budapest, Hungary; Washington DC, USA and Honolulu, Hawaii, USA; August–December 2000.

A description of CHEMRAWN X is given on the IUPAC Web site, listed as Project 021/13/93.

IUPAC's CHEMRAWN Committee first considered the idea of a conference on chemical education in the mid-to-late 1990s. Because chemical education has so many dimensions, organizers felt that a single overarching conference would be inappropriately limited and might duplicate the work of many other meetings. Nevertheless, the globalization of chemical education was identified as a new phenomenon which presented a special need, i.e., how best to prepare chemical scientists and engineers for work in the new multinational environment—*industry*. The CHEMRAWN Committee was surveyed to identify important issues and also to determine the best conference format. Organizers considered alternatives of holding a major funded conference; a virtual conference; and regional CHEMRAWN conferences; including an educational component in all CHEMRAWN conferences; and a series of mini-CHEMRAWN meetings that were "piggybacked" on larger meetings.

With CHEMRAWN X: The Globalization of Chemical Education, the CHEMRAWN Committee experimented by holding a series of mini-CHEMRAWNs—full-day sessions on Chemical Education to Meet World Needs, as part of larger conferences. Compared with other CHEMRAWN conferences, the $6000 budget, which was provided by IUPAC, was very small. The first event, which involved members of IUPAC committees on industry (COCI) and education (CTC), took place at the 16th International Conference on Chemical Education, Budapest, in August 2000; the second at the American Chemical Society meeting, Washington, DC, August 2000; and the third at PACIFICHEM, Honolulu, December 2000. CHEMRAWN X concluded with a Future Actions discussion as part of CHEMRAWN, COCI, and CTC committee meetings at the Brisbane IUPAC General Assembly in 2001.

An outline of the important issues as considered at the CHEMRAWN X mini-meetings is presented on the IUPAC Web site <http://www.iupac.org/standing/chemrawn/conferences.html>.

Speakers and their topics at the Washington meeting were: Mary L. Good, *Multinational Chemical Employment: Educational Needs*; Anthony K. Smith, *International Student and Teacher Exchange*; Edel Wasserman, *Preparation for Industrial Research*; Morton Z. Hoffman, *Molecular Science: New Curriculum Pathways for World Needs*; Paul H. L. Walter, *Africa: A Unique Opportunity*; Edmund J. Collier, *National Security Education Program*; Janet Osteryoung, *We Are Prepared for the 1960s*; Parry Norling, *Industry Expectations: Chemical Education for Researchers*; Scott Lockledge, *Improving the Nation's K-12 Science Education*; John P. Ferraris, *Preparing Problem Solvers for the Chemical Industry: DChem Program*; N. P. Tarasova, *Education for Sustainable Development: From Slogans to Action*; J. Boggs, *The Two Faces of Undergraduate Study*

Abroad; P. Norling and J. Kopytowski, *Industry Expectations in Regard to Chemical Education Standards*; N Mohamed and Z. Ismail, *Perception of Students Difficulties in First-Year Chemistry*"; P. Norling and J. A. Miller, *Preparation for Industrial Research.*

The speakers identified the following issues and questions:

- Industry expectations seem to differ from country to country. Are the differences real?
- Can chemical education earned in one part of the world be used at another?
- Does graduate education need to be tailored for those going into industrial research?
- How does industry make its needs known?
- Can the time to a degree be "contained"?
- How should universities instill the desire for continual learning?

After the conference, some 40 companies around the world were approached with questions regarding the growth rate in new employment for Ph.D. chemists; whether there is a need for a balance in specialized versus broad chemical education; the general need for orientation of new employees; and the need for industry/academic interaction. Thirteen companies responded, including Air Products (USA), BASF (Germany), Cantalabria IFC (Spain), Degussa (Germany), Eastman Chemical (USA), Honam Petrochemical (Korea), LG Petrochemicals (Korea), Mitsubishi Chemicals (Japan), Nippon Sholubai (Japan), Rohm & Haas (USA), S Corporation (Korea), Union Carbide (USA), and Witco (USA). Among these companies, sales vary from $40 million to $28.5 billion annually while R&D expenditures fall between $300,000 and $1.4 billion per year. The number of Ph.D. employees varies from 5 to 2000. The companies listed their needs for employees educated as follows: 20% broadly based, 40% specialized, and 40% highly specialized, with concentration in the fields of process chemistry and process technology, biomedical technology, computational and combinatorial chemistry, organometallic chemistry, surface chemistry, photo-related chemistry, material sciences, electronics materials, and nanotechnology.

The CHEMRAWN X experiment defined many of the issues that are currently being addressed by the chemical education community. In the process, it attained many objectives and benefits of a major CHEMRAWN conference, but with greater flexibility, less organizational effort, broader involvement, continuing discussions, and minimal cost. The degree of industrial involvement in the post-conference survey activity was particularly gratifying and meaningful. Overall, this "piggyback" model may be a useful direction for some CHEMRAWN conferences in the future, with the caveat that such small-budget conferences are not likely to generate surplus funds for use by a Future Actions Committee.

CHEMRAWN XI: Latin American Symposium on Environmental Analytical Chemistry. Montevideo, Uruguay; 15–20 March 1998.

Conference assessment (pdf file, 146 kB) July 2001, IUPAC Web site

Conference report (pdf file, 399 kB) *Chem. Int*. **20**(4), 99–102 (1998).

Invited lectures published in *Pure Appl. Chem*. **70**(12), 2259–2336 (1998).

CHEMRAWN XI was organized by Prof. Patrick Moyna and coworkers at the Facultad de Química, Universidad de la República de Montevideo, and chaired by Dr. Folke Ingman of the Royal Institute of Technology, Stockholm, Sweden. Two hundred and sixty-one persons attended the conference, of whom 135 were locally based. Thirteen regional countries and eight nonregional countries were represented. One hundred and ninety-five papers were given in the general areas of analytical aspects of urban agrarian pollution; methodologies for effluent and emission control; treatment and final disposition of liquid effluents and solid residues; remediation by chemical and related methods; prevention and environmentally benign processes; and related topics.

The overall strategic question of the conference was: *What is the role and potential of chemistry and, in particular, analytical chemistry in the prevention, treatment, and remediation of environmental pollution?*

Specific conference goals were to:

- Identify the state of the environment in Latin America.
- Identify the potential of local laboratories to ensure the local expertise, instrumentation, and methodologies to carry out proper analysis of polluted samples.
- Identify the potential for monitoring of effluents.
- Identify the potential of international cooperation in development of the research program.

In addition to plenary sessions, the conference included poster and oral presentations on five themes: (1) analytical aspects of monitoring rural and urban contamination; (2) methodologies for control of effluents and emissions; (3) final treatment and disposition of liquid effluents and solid residues; (4) environmental remediation and restoration using chemical and biological techniques; and (5) prevention of contamination and installation of non-contaminating processes.

The Future Actions Committee, chaired by Dr. Folke Ingman, based its recommendations on the following conclusions arrived at during the conference:

- The state of the environment in Latin America is deteriorating rapidly as heavy pollution of watercourses, land degradation, and soil and air contamination continues.

- Urgent action requires reliable information. Although many sources of pollution are obvious and should be addressed without delay, a more systematic approach needs to be implemented.
- Research laboratories are prepared to take responsibility for data collection. The analytical chemistry community, including RAQAL (Red de Analisis Químico Ambiental en America Latin) stands ready to work on sampling strategies and methodology for quality control of analytical results
- Natural regions for monitoring exist. Water monitoring needs to take into account the natural borders for waters, the drainage basins, and catchments. Activities should be organized around catchment areas. Meteorological conditions define areas that influence each other heavily through airborne pollution.
- Experience from elsewhere in the world is relevant. Conferees encouraged implementation of best practices learned in studies of the Baltic Sea, the Gulf of Thailand, the Rhine River on the European continent, and the Great Lakes district in North America.

Conference recommendations

- Monitoring programs are urgently called for. Scientists at the conference concluded that it is urgent that laboratories in the region address the question of large-scale monitoring programs to survey the environment
- Regional cooperation is needed. An international monitoring program is necessary since pollutants do not recognize national borders
- Quality and interdisciplinarity are essential. A successful monitoring program will have to rely on cooperation between many fields of science, including chemistry, biology, ecology, medicine, geography, and hydrology.
- A strategy is needed for optimal results. A monitoring program will need to develop a proper sampling strategy not only for toxic chemicals but also for nontoxic substances that may be present in amounts that degrade the environment. Biological monitoring must include a search for specific ecological endpoints in the flora and fauna, as well as in humans.
- Water quality is the most urgent priority. Clean water for everyone is a prerequisite for the health of the population. The environmental status of water must be considered in devising treatment plans and water management for urban areas industry and agriculture.
- Monitoring of air quality also is needed. Meteorological competence is essential for such a program. Increased vehicular traffic in the big cities is a special concern for air quality. It is now being recognized that indoor air pollution is an important factor in human health
- A change is needed in the position of scientists in the region. Scientists must be included in the decision-making process. Also, stress must be placed on educating a generation of chemists capable of working independently, developing and validating needed analytical techniques, establishing and running regional networks, and raising needed financial support.

Specific activities recommended

- IUPAC should construct a DAC/DCE (Division of Analytical Chemistry/Division of Chemistry and the Environment) Web site.
- IUPAC should set up regional training programs involving RAQAL and IAEAC (International Association of Environmental Analytical Chemistry).
- A series of spin-off meetings should be organized, centering on regions in Latin America that have a natural coherence, such as the Rio de la Plata Basin, Mexico, Central America, the Caribbean, the Amazonian and the Orinoco basins.
- The Uruguayan National Chemical Group should become an IUPAC Observer Organization.
- A monitoring program should be instituted for the Rio de la Plata drainage basin.
- IUPAC should provide methodological support for spin-off conferences.

CHEMRAWN XI covered the important area of chemical activities in environmental protection in a region where national and regional authorities are challenged to prevent further environmental deterioration. The general findings and proposals of the FAC represent an excellent record of the present situation and a series of valuable proposals for further action. CHEMRAWN XI was an excellent example of a regionally focused CHEMRAWN conference that was useful for participants and a model for other regions.

International Scientific Committee: Damià Barceló (Spain); Tomás Bense (Uruguay); Walter Benson (USA); Ida De Gergori (Chile); Wilson F. Jardim (Brazil); Ayrton F. Martins (Brazil); Patrick Moyna (Uruguay); Alfredo Sanz-Medel (Uruguay); Joseph Tarradellas (Switzerland); Osvaldo Troccoli (Argentina); Rene Van Grieken (Belgium).

CHEMRAWN XII: Chemistry, Sustainable Agriculture and Human Well-Being in sub-Saharan Africa is scheduled to be held in Stellenbosch, South Africa, 3–6 December 2007.

A multitude of political, economic, and scientific efforts will be required to solve Africa's hunger crisis, in which at least 38 million people in sub-Saharan Africa are suffering exceptional food shortages. The following are the objectives of CHEMRAWN XII:

- Highlight the role of chemistry in agriculture and recent advances in the chemical aspects of soil fertility and management, pest management, post-harvest technology, biotechnology, and high-value agricultural products.
- Identify constraints to scientific sustainable agriculture in the region in the areas of policy and knowledge gaps.
- Provide examples of successful research in chemistry that are relevant to agriculture.
- Develop strategies to transfer low-cost technologies that have worked elsewhere.
- Promote other strategic issues relevant to the quest for sustainable agriculture (e.g., private sector participation, training and involvement of young African chemists in agriculture-related research, gender issues, etc.).

Professor Ikenna Onyido (Nigeria) described the vision for CHEMRAWN XII in the March–April (2003) issue of *Chemistry International*. Two pre-conference workshops were held: the first at the International Congress on Chemistry in Africa, August 2004, in Arusha, Tanzania and the second during the Annual Congress of the Chemical Society of Ethiopia in February 2006 in Addis Ababa.

Project: 2001-086-1-021. <http://www.iupac.org/projects/2001/2001-086-1-021.html>.

I. Onyido. *Chem. Int.* **25**(2) (2003).

I. Onyido. *Chem. Int.* **27**, 8–10 (2005).

At the first of these workshops, 34 participants came from 12 African countries as well as Sweden, the United Kingdom, the Netherlands, and Bangladesh to participate in discussions organized by Prof. Onyido and Stanley Langer (Royal Society of Chemistry, UK) on Soil Fertility and African Food Supplies at the August 2004 International Congress on Chemistry in Africa in Arusha, Tanzania. Workshop goals were to:

- Articulate the issues that concern chemistry and chemists in the drive for sustainable agriculture in sub-Saharan Africa, as well as systematize views on the way forward.
- Gather information on existing or planned projects and conferences on food and nutrition in Africa and seek ways of ensuring that CHEMRAWN XII is in concert and cooperation with such efforts.
- Brainstorm on how to galvanize professional, financial, and political support in Africa and beyond for the project.

- Enlist the interest, support, and participation of top African chemists in the project.

Professor Gbolagade B. Ayoola (University of Agriculture, Makurdi, Nigeria) opened the workshop with a keynote paper surveying the nature and dimensions of the food question and identifying the role of scientific agriculture in addressing the food problem in sub-Saharan Africa. Professor Ayoola ascribed the root causes of the food problem to (1) poverty, (2) aberrant and conflicting policies by national and global bodies, and (3) lack of access to food that is available. Contributing causes are subsistence food production using outmoded methods, a focus on exportable cash crops rather than sustainable agriculture, limited interface with industry, poor nutrition for the farmers, and the widespread HIV/AIDS epidemic. Professor Ayoola urged the adoption of advanced technology and the development of markets as methodologies superior to simple *ad hoc* food aid.

The second half of the workshop discussed how chemists and chemistry might contribute to food security and sustainable agriculture in Africa. Professors Saka (Malawi), Bukuru (Burundi), Jondiko (Kenya), Keriko (Kenya), and Bashir (Sudan) recommended that chemists should:

- Carry out soil fertility studies leading to the formulation of fertilizers for different soil types and the utilization of organic matter and wastes for the production of fertilizers.
- Develop more effective disease and pest control management, including biopesticides.
- Research better post-harvest handling methods and food fortification.
- Exploit non-traditional plants for indigenous fruits and vegetables.
- Produce fertilizers and pesticides from natural sources.
- Find ways to promote the efficient use of water and reduce transpiration rates of crop plants.
- Research chemically induced germination of seeds.
- Develop chemistry based food conservation technologies.
- Optimize agri-waste processing (e.g., from rice and wheat husks, maize storers, fruit peels, etc.) to produce raw materials for animal feed and fertilizers.
- Conduct studies on soils and mechanisms for the release of bound phosphate through the addition of indigenous materials such as organic matter.
- Investigate how to use natural products as pesticides, fertilizers, and food preservatives.
- Improve the animal feed industry through research on alternatives, concentrates, and vitamins.
- Develop a biotechnological approach to breeding for resistance to diseases and drought.

Professor M. Akerblom (Sweden) noted that chemistry can address the food question in Africa by encouraging effective use of currently available materials. Especially important will be the development of better food preservation practices to minimize spoilage, and research on how to improve nutritional value. Participants praised the workshop as a laudable precursor to a full CHEMRAWN XII conference.

Over 100 people attended from many African countries and beyond attended the second workshop. This was organized by Stanley Langer on “An Overview of the Food Problem in Africa and the Scientific Options for Ameliorisation”, held during the Annual Congress of the Chemical Society of Ethiopia in February 2006 in Addis Ababa. The main goals of the workshop were essentially the same as those indicated above from the Arusha workshop.

Professor Leopoldt Van Huyssteen (University of Stellenbosch, South Africa) opened the workshop with a keynote paper entitled *A Systems Perspective on the Role of Science in Agricultural Production*. This raised many important issues and clearly pointed out the interdisciplinary nature of the problem. Food affordability is a growing problem in the developing world, and the use of new technology is essential. Whilst there is a great need for a vast increase in the supply of clean water, the amount of waste water is growing. Van Huyssteen highlighted the contributions of chemistry to soil stability, nutrient balance, water purity, crop protection, ripeness of fruit, and pest control. Removal of the traditional disciplinary boundaries in established universities was essential if the problem under discussion had any hope of being solved.

During the subsequent discussion, it was pointed out that farmers dislike spending money and so the need for new technology would have to be especially persuasive. Above all, science has to support indigenous knowledge. The use of traditional methods needs to be supplemented with new science. There was discussion on the perceived poor image of genetically modified food and other ways of increasing yields. Socio-political issues were also considered.

The two workshops would form the basis for the program of the full CHEMRAWN XII conference to be held in December 2007.

CHEMRAWN XIII: Chemistry for Clean Energy.
Organizers: Prof. F. Kuznetsov and Dr. S. Sivaram have proposed an analysis of the clean energy needs in developing countries.

IUPAC Project #2001-087-1-021.

The CHEMRAWN Committee, recognizing that the need for energy is growing significantly in both the developed and developing worlds, approved the organization of CHEMRAWN XIII: Chemistry for Cleaner Energy in 1998. It was known at the time that large investments are being made in liquid natural gas, compressed natural gas, petroleum products and gas, coal bed methanation, gas hydrates, nuclear, solar, wind, hydroelectric energy and fuel cell electrochemical energy generation. Issues related to transportation, such as large centralized generating facilities vs. small localized plants, will be considered at the conference. More recent issues involve development of new, sustainable energy sources such as fuel from biomass. This project was delayed but it continues in the planning stages.

CHEMRAWN XIV: Toward Environmentally Benign Products and Processes.
University of Colorado, Boulder, Colorado, USA; 9–13 June 2001.

S. K. Ritter. "Green Chemistry", *Chem. Eng. News*, pp. 27–34, July 16 (2001).

Report of the Future Actions Committee:
<http://www.iupac.org/standing/chemrawn/crXIVfac.html>
<http://www.iupac.org/publications/ci/2002/2401/news-green.html>

Selected lectures published in *Pure and Applied Chemistry*:
<http://www.iupac.org/publications/pac/2001/7308/index.html>

In June 2001, some 200 scientists and policymakers from more than 30 countries met in Boulder, Colorado to discuss the new field of green chemistry. The purpose of CHEMRAWN XIV was "to assess the current state-of-the-art in Green Chemistry and discuss the role of chemical research and science policy in advancing global environmental protection and sustainable development". The Green Chemistry Institute and the American Chemical Society worked with the CHEMRAWN Committee to produce this significant event encompassing all aspects and types of chemical processes including synthesis, analysis, monitoring, separations, and reaction conditions that reduce impacts on human health, energy consumption, and the environment. This theme was built on the initial effort of the IUPAC Working Party on "Synthetic Pathways and Processes on Green Chemistry" promoted by the Physical Organic Division. The general chair of the conference was Dr. Michael Fitzpatrick, President and Chief Operating Officer of Rohm and Haas. There were 80 contributed papers, an extensive poster session, and an educational pre-conference workshop. Over $400,000 was raised in support of CHEMRAWN XIV, including a substantial contribution of matching funds from the American Chemical Society.

Topics covered by the conference included product lifecycle impacts (from raw materials to recovery and reuse); emerging biotechnology alternatives such as enzyme-catalyzed reactions; environmentally benign agricultural practices; alternative reaction and separations media such as supercritical CO_2 and ionic liquids; green chemistry education; and establishing national green chemistry programs. A major purpose of the conference was to identify the economic and social issues and scientific gaps that need to be addressed for sustainable development. The Future Actions Committee (FAC), chaired by Paul T. Anastas, then of the White House Office of Science and Technology Policy (OSTP), delivered the following important findings:

- Green chemistry and enabling approaches result in the protection of human health and the environment and help preserve sustainability in a manner that is both economically profitable and increases competitiveness.
- The incorporation of green chemistry into the training of current and potential science students increases the effectiveness of recruitment and retention efforts in this crucial field.

- Research investments are needed by both government and industry beyond current "pilot program" levels to empower and enable the development and utilization of green chemistry technologies by the broad spectrum of private-sector interests.
- Many technologies that meet green chemistry objectives already exist and offer immediate opportunities to reduce environmental burdens and enhance economic performance.
- Markets for next-generation, innovative environmental technologies such as green chemistry need to be developed through international engagement and commercial promotion.
- Incentives are necessary to catalyze the implementation of green chemistry innovations by industry to overcome economic and technical barriers, especially for small and medium-sized enterprises.

The FAC went on to recommend the following key action items:

- National centers for green chemistry should be established or expanded, then linked to form a worldwide network.
- Basic research funding in green chemistry needs to be significantly increased.
- Educational initiative funding in green chemistry is needed to focus on curriculum materials development, fellowships, faculty training centers, and recruitment and retention activities.
- Increased incentives are needed for initial implementation of green chemistry technology by industry to offset any existing investment, policy, and regulatory barriers that may exist.
- A market development project for green chemistry and next-generation environmental technology is needed to build market position for commercial opportunities in international trade.
- International scientist exchange programs should be established, and research collaboration funding should be provided. Informational outreach must be undertaken to educate industry, public, and environmental groups of the benefits of green chemistry.

Outcomes

The highly successful CHEMRAWN XIV conference helped to build enthusiasm and foster activities worldwide supporting environmentally benign products and processes, as follows:

- Following a recommendation by a special task force of the American Chemical Society, the (formerly independent) Green Chemistry Institute (GCI) was incorporated into the American Chemical Society. GCI activities, which strongly support the goals of CHEMRAWN XIV, include establishment of 23 Green Chemistry chapters worldwide; a role in administrating the annual Green Chemistry Presidential Challenge Awards; an active program of publications and presentations promoting the principles of green chemistry; sponsorship of research fellowships and academic exchanges; development of green chemistry educational materials; administration of the Kenneth G. Hancock and Joseph Breen Awards in green

chemistry; organization of conferences and symposia, as well as online publication of a list of green chemistry events being held worldwide. For further information about GCI programs, see the Web site: <http://www.chemistry.org/portal/a/c/s/1/acsdisplay.html?DOC=greenchemistryinstitute\index.html>

- The FAC, chaired by Dr. Dennis Hjeresen of Los Alamos National Laboratory, met together with the CHEMRAWN VII FAC and eventually the two committees fused. Funds remaining from the conferences have been employed by the FAC to support green chemistry and CHEMRAWN-related projects including: green chemistry workshops in India and Thailand; participation of environmental chemistry representatives at the conference Frontiers of Chemical Science: Research and Education in the Middle East; contribution of $10,000 to assist the CHEMRAWN XV: Chemistry for Water conference and a contribution of $10,000 to assist CHEMRAWN XVII, the forthcoming greenhouse gas conference.
- Green chemistry has become an important feature in chemistry curricula worldwide.
- A journal of green chemistry has been founded by the Royal Society of Chemistry.
- Numerous green chemistry awards are presented worldwide
- Numerous green chemistry processes and products have been identified and implemented; in the United States, some have been recognized through Presidential Green Chemistry Awards presented each year by the Environmental Protection Agency working together with the American Chemical Society.

CHEMRAWN XV: Chemistry for Water. Maison de la Chimie, Paris, France; 21–23 June 2004.

IUPAC Project #2001-007-1-021.

Preliminary conference report: A. Smith. *Chem. Int.* **26**(5) (2004).

M. Freemantle. *Chem. Eng. News*, pp. 25–30, July 19 (2004),

The CHEMRAWN XV conference, which received the high patronage of the President of the French Republic, Jacques Chirac, brought speakers and attendees from five continents to discuss new chemistry and chemical engineering developments facilitating availability of drinking water. Five main areas for development considered at the conference were: (1) separations science (e.g., development of new membranes for water purification); (2) seawater desalination; (3) disinfection science involving, for example, biodegradable chemicals or new techniques for elimination of bio-film fouling of water supply pipes; (4) analytical science (e.g., developing biomarkers to track certain pollutants or computational techniques to model water and effluent flow or minimize usage and waste); (5) situations in a variety of developing countries (e.g., arsenic in Bangladesh and Chile, fluoride in Africa).

The French Minister of Foreign Trade, François Loos, was a keynote speaker. Plenary addresses included: *IUPAC and Safe Water Supply*, Dr. Leiv K. Sydnes, President of IUPAC; *Water, A Major Challenge for the 21st Century*, Dr. Koïchiro Matsuura, Director-General, UNESCO; *The World-Wide Water Problem*, Dr. William J. Cosgrove, President of the World Water Council; *Water and Civilisation in the 21st Century*, Prof. Vladislav V. Goncharuk, Ukraine; *Innovative Processes and Chemicals for Saving Water*, Dr. Utz Tillman, Senior Vice President of BASF; *Chemistry, Water and Health*, Prof. Yves Levi, Pharmacy University of Paris; *Green Chemistry and Water Resources Management*, Dr. Dennis L. Hjeresen, Los Alamos National Laboratory; *Increased Role of Plastics in Substructures*, Jean Bernard Lartigue, President of Total Petrochemicals; *What do the Professionals in Water Expect from the Chemical Industry*, Dr. Bill Roe, COO of Nalco; *The Problem of Pipe Materials for the Transport of Drinking Water*, Dr. Pascal Soukatchoff, Saint Gobain Pont-à-Mousson Co.; *Un Instrument de Mobilisation des Moyens: Le Réseau RIT Eau*, Dr. Jean-Marc Usseglio, SOGREAH; *The State and the Future of Water Desalination*, Jean-Marie Rovel, International Desalination Association; *Chemistry and the Environment: Challenges for Coastal Environments*, Jean-Francois Minster, IFREMER; *A Vision of Water Treatments and Distribution*, Nasri Chami, Anjou-Recherche; and *La Chimie au Service de la Production des Sources d'Eau Douce sous-Marines*, Pierre Becker, Nymphea Water Co. A series of workshops enabled the more than 200 delegates to share their results and views on specific problems in analytical sciences and technologies for water; chemistry, agriculture, soil, and water; chemistry, industry, and water; water treatments and supply; chemistry in specific uses of water; and case studies.

Subsequent actions

- A Future Actions Committee report is in preparation.
- S. Ahuja and J. Malin developed a project on arsenic remediation from groundwater in Bangladesh in connection with CHEMRAWN XV. With support from IUPAC and ACS, they visited Bangladesh in March 2004 and reported on their findings at CHEMRAWN XV. Together with Prof. Mosihuzzaman of the University of Dhaka, they organized a workshop on solutions to the arsenic problem. The event was held in December 2005 in Dhaka, Bangladesh with support from IUPAC, the U.S. National Science Foundation, the Bangladesh Academy of Sciences, the Chemical Society of Bangladesh, and other agencies.
- Dr. Hemda Garelick of the University of Middlesex, UK and coworkers are employing multivariant analysis to compare technologies for arsenic remediation. She reported on the group's progress at the December 2005 meeting in Dhaka.
- Dr. Ahuja organized a symposium at the 2006 Spring ACS National Meeting in Atlanta on arsenic pollution and remediation.

CHEMRAWN XVI: Innovation and the Chemical Industry was held at the IUPAC Congress and General Assembly in Ottawa, Canada; August 2003.

IUPAC Project #2003-003-1-021, carried out in collaboration with the Committee on Chemical Industry.

J. A. Kopytowski. "Innovation in the Chemical Industry", *Chem. Int.* **26**(5) (2004).

Description

At the one-day forum, 16 papers were presented. Four were delivered by invitees and twelve were presented by CHEMRAWN Committee members representing industry and academia. Overall, 27 people participated in the event. Michael Droescher, co-organizer of the conference, has published a book on innovation in the chemical industry.

As Prof. Kopytowski indicated in his summary of the conference, "The goal of CHEMRAWN XVI was to examine the innovation process in the chemical industry; specifically to look at techniques for more efficient development of new products and processes, and approaches to overcoming the significant barriers encountered in these efforts. One indication that this initiative was timely and well-oriented is the recent establishment in the United States of the National Innovation Initiative, which was created by the Council on Competitiveness. The management of technology has become crucial for further development."

Professor Kopytowski noted the following challenges to the innovative process in industry:

- Introduction of biotechnology into many processes and its presumed environmental impact may require large capital expenditures and/or changes to existing statutes.
- Automation of the chemical processes used in the chemical industry is decreasing employment in that sector.
- R&D is being concentrated in large multinational chemical companies. Although small and medium-size chemical companies employ 90% of workers, they tend to perform relatively little R&D, and, in this sense, they are excluded from the innovation process.
- A lack of jobs for scientists has discouraged young people from entering scientific careers.
- Government attitudes and funding patterns need to be examined. For example, funding sometimes is mistakenly politicized; rules and regulations suppress the innovation process; and developing countries allocate only a meager 0.1 to 0.4% of their already small GDP to national R&D.

Immediately after the Forum, a joint meeting of the IUPAC Committee on Chemistry and Industry (COCI) and CHEMRAWN was held to discuss the results. Participants identified the following "internal deficiencies", which need to be addressed to sustain the innovation process:

- The academic community is oriented toward the “discovery” phase of the innovation process but is less willing to concentrate on implementation. The academic sector may be somewhat insular in selecting research projects.
- The scientific community seems uninterested in addressing certain important social and economic problems.
- Concentration of R&D activities in large companies may be inhibiting the creative process.
- Process engineering, which is crucial to the implementation of innovative ideas, is underfunded and funds are decreasing. While it is acknowledged that costs of instrumentation are driving up the unit cost of R&D, examples given in the forum showed that sharing of equipment and finding new uses for it increases research productivity.

The proceedings of the meeting have been compiled and will be published in *Pure and Applied Chemistry.*

CHEMRAWN XVII Greenhouse Gases Mitigation and Utilization, organized jointly with the 9th International Conference on Carbon Dioxide Utilization, is scheduled to be held 8–12 July 2007 at Queen's University in Kingston, Ontario, Canada. Topics to be covered include the carbon balance, greenhouse gas mitigation strategies, utilization of carbon dioxide, and policy formulation. The organizing committee is chaired by Nicolas Cudre-Mauroux (DuPont), while Philip Jessop and Peter Tans are co-chairs of the scientific program committee. Information on the conference will be available at the conference Web site <www.chem.queensu.ca/greenhouse/>.

CONCLUSION

Over 28 years, CHEMRAWN conferences have addressed subjects of specific importance to society. Because they are designed to illuminate what the chemical sciences and engineering community can do to serve world needs, they have often served as leading indicators of what will soon occur in the chemical enterprise. From CHEMRAWNs I and XIV, which were large, multinational events, to CHEMRAWNs X and XVI, examples of smaller, more intimately organized symposia, CHEMRAWN conferences have taken the lead over three decades in identifying new approaches. The CHEMRAWN Committee believes that the CHEMRAWN process will continue in the future to draw upon the creativity and flexibility of the chemical community.

Education, innovation, materials and energy, environment, and food supplies have been important themes for CHEMRAWN conferences. Two special conferences, numbered X and XVI, respectively, considered the educational needs of industrial chemists and the process of industrial innovation. Four CHEMRAWN conferences, numbered I, III, VI, and IX, dealt with chemistry's role in creating new materials and the tradeoffs with energy supplies. Seven conferences, numbered IV, VII, VIII, XI, XIV, XV, and the planned XVII, discussed and planned activities contributing to the global theme of chemistry in the environment. Significant efforts have been made to inform and engage governments and policymakers and to improve world leaders' understanding of the technological processes which they govern.

Just as CHEMRAWN has the ability to attract outstanding scientists and important decision-makers to its causes, so also the ability to attract funding to CHEMRAWN activities speaks of its value to governments and society. Depending on the conference format, budgets have varied from over $300,000 to less than $10,000. Participants' and speakers' travel costs, a major expense in CHEMRAWN meetings, have sometimes been met using in-kind resources. The least costly conferences, CHEMRAWNs X, XVI, and the two recent CHEMRAWN XII workshops were events "piggybacked" onto other meetings.

The availability of sufficient funds to support the activities of Future Actions Committees was a major advantage enjoyed by the larger conferences. A second advantage is that, while the quality of scientific works and recommendations produced seems independent of the size of the conference, the larger conferences have been more likely to attract participation by government representatives and national leaders. Not all CHEMRAWN conferences have returned a financial surplus, but several large independent meetings (CHEMRAWNs I, II, VII, and XIV) had substantial surpluses even after expending after-conference funds on Future Actions Committee activities, distributing publications, and supporting developing country scientists. Donors encouraged the organizers to keep excess funds, providing they were devoted exclusively to promote future CHEMRAWN activities—such was the value they saw in CHEMRAWN.

It is said that "imitation is the sincerest form of flattery." Innovative concepts such as Future Actions Committees and the production of published Perspectives and

Recommendations, which were pioneered by CHEMRAWN, have been adopted in many other instances. We expect that CHEMRAWN will continue to do credit to the International Union of Pure and Applied Chemistry by finding new ways to fulfill world needs and identifying innovative new chemical processes and products to benefit humankind.

Acknowledgments
On behalf of IUPAC, the CHEMRAWN Committee gratefully acknowledges many hours of volunteer work that have been donated by committee members, conference organizers and participants, and generous support totaling nearly $3,000,000 from industrial and private donors, the NGO community, governments, and academia.

John M. Malin
Chair, CHEMRAWN Committee
2004–2007