CHEMISTRY AND DEVELOPING COUNTRIES

Edited by
D I Coomber, S S Langer
and J M Pratt

Chemistry and Developing Countries

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Thanks are due to our colleagues on the conference organising committee, whose enthusiasm and dedication led to a very successful meeting and subsequently to the production of this book: Dr G Thyagarajan until his return to India at the end of his term of office as Secretary of the Commonwealth Science Council, followed by Dr Raul Vicencio, also of the CSC; Mr Andrew Skinner and subsequently Dr Anne Wozencraft, representing the British Council; Mr Stuart Luxon; and our chairman Mr Dennis Chisman, who successfully ensured that momentum was maintained throughout the period leading up to the conference. We should also like to acknowledge the enthusiastic support of Dr U O'D (Neville) Trotz, the current Secretary of the Commonwealth Science Council.

We are particularly grateful to Helen Sharman OBE, also a chemist and a Member of The Royal Society of Chemistry, better known as the British astronaut on the Anglo-Soviet Juno Space Mission in 1991, both for allowing us to choose some of her own spectacular photographs that now grace the pages immediately preceding the two main chapters, and for introducing us to Christian Ripley at the National Remote Sensing Centre, who very kindly allowed us to use its magnificent picture of the Earth from Space taken from the Meteosat 2 satellite and which was used as the basis for the cover design.

Finally, this book would not have seen the light of day but for the patient typing of the manuscript by Vanessa Raffa, the Secretary of one of us (SSL). Her (possibly misguided!) enthusiasm in offering to help with this major project resulted in many long evenings slaving over a hot and highly complex desktop publishing system bent on challenging her every command!

Denys I Coomber and John M Pratt (conveners)

Stanley S Langer (Secretary to the organising committee)

October 1992

Preface

This report represents the main papers and the principal discussion points of the Conference on Chemistry and Developing Countries held in London in April 1991.

The Conference was arranged in conjunction with the British Council and the Commonwealth Science Council as part of the celebrations of the 150th Anniversary of the original Chemical Society, now known as the Royal Society of Chemistry. It was, in fact, the second such Conference on Chemistry and Developing Countries, the first having been held in the University of East Anglia, Norwich in 1984 on the occasion of the 50th Anniversary of the British Council, and in conjunction with the British Association for the Advancement of Science, whose Annual Meeting that year was held concurrently in Norwich.

The Director General of UNESCO, the Assistant Director General of the British Council, the President of IUPAC, the Chief Natural Resources Adviser to the UK Overseas Development Administration and a representative of the Commonwealth Secretary-General were among the keynote speakers at the opening of the Conference.

The Conference was concerned with two main concurrent themes - Chemistry for the Environment and Organising Science to Benefit the Third World. The overall and long-term aim of the Conference was to enhance the ability of scientists to contribute to the well-being of society - through new ideas, contacts, information and expertise - and generally to develop science and technology in order to increase the economic base of developing countries by stimulating wealth creation and job opportunities. Also, to use science more effectively in the safeguarding of health and the environment and the promotion of sustainable development.

The themes are so vitally important to the development of Third World countries that it is essential for effective follow-up action to be initiated without delay along the lines of the recommendations agreed at the Conference and detailed on pages 5-6. Such action is likely to involve the Commonwealth Science Council, with support from donor agencies and with professional coordination by The Royal Society of Chemistry.

D G Chisman

Contents

Resolutions and Recommendations of the Conference

The participants in the sessions on 'Organising Science to Benefit the Third World' at the Conference on 'Chemistry and Developing Countries', London, April 1991:

1. Wish to congratulate The Royal Society of Chemistry for its initiative in organising this pioneering conference on such an important and vital issue.

2. Strongly urge The Royal Society of Chemistry to:

    (a) take a more direct interest in the problems of the developing world, with particular reference to the development crisis in sub-Saharan Africa in the light of the recent World Bank Report and the proclamation by the UN of 1991-2000 as the Second Industrial Development Decade for Africa.

    (b) interact more strongly with UN and other donor agencies concerned with global development.

3. Request the Conference Organising Committee to take whatever steps it may consider most appropriate to promote action under the following headings, which would enhance the contribution of chemistry and chemists to development in the Third World:

    (a) Information and library services. Need to devote a proportion of aid funds for purchasing journals and text books, supporting the establishment of local/regional publishing houses, and accessing data-bases.

    (b) Equipment. Better organisation and coordination of procurement, maintenance, training and use, documentation, etc.

    (c) Small funds. Need for sources of relatively small funds to promote chemistry at the regional level, with particular reference to travel and conferences.

    (d) Science policy. Need for exchange of views and advice on developing a national science policy with particular reference to chemistry and chemical technology and on analysing, and providing possible remedies for, the 'swing from science'.

    (e) Brain drain. Scope for governments to make greater efforts to reduce the outflow by modifying educational systems and to attract back some of the most highly skilled expatriates.

    (f) University management. Need for exchange of views and advice on the state of universities and how to improve their effectiveness, in the light of the country's science and education policies.

(g) Availability of expertise. Mechanism needed to identify areas where crucial developments (in education or projects) are held up through lack of key staff and to facilitate necessary recruitment.

(h) Need to develop local Chemical Engineering Design Capability.

(i) Technology transfer. Need for impartial advice, training and organisation of multi-party meetings in the field of chemical technology transfer.

(j) Intellectual property (IP). Need for the developing countries to reassess their attitude towards IP rights in general and scope for chemists to take an increased interest in the field of patenting.

(k) Aid agencies. Need to coordinate the efforts of the various aid agencies and to disseminate information on their scope and area of operation so that aid reaches the target groups.

These resolutions and recommendations were drafted as the result of a working session of the regional representatives (see page v) together with a few others under the chairmanship of Dr Mohinder Singh of Malaysia and discussed at the final session of the Conference. Section 3 includes suggestions ranging from the tactical to the more strategic, while section 2 invites The Royal Society of Chemistry to undertake initiatives which, although lying within the stated aims of its Charter, obviously fall outside the Society's normal range of activities. Because of present constraints on funds and manpower, such initiatives could not readily be undertaken in the absence of new mechanisms for funding and implementation. They therefore raise the question whether The Royal Society of Chemistry should venture into other 'chartered', but uncharted, waters. The recommendations were discussed at a meeting of the Conference Organising Committee on 30 April and at the subsequent meeting of its parent body, The Royal Society of Chemistry's International Committee, on 20 May; both committees supported the idea that The Royal Society of Chemistry should endeavour to play an active role in this field and should explore methods of doing so. The next steps involve further discussions with the Commonwealth Science Council and with the OECD donor agencies, as well as within The Royal Society of Chemistry itself.

Edited by J M Pratt

Regional Representatives at the Conference

The following chemists were invited to attend the Conference to represent:

1. **Latin America**

   Dr Gerardo Burton, Department of Organic Chemistry, University of Buenos Aires, Argentina, nominated by the Federation of Latin American Chemical Societies.

2. **Caribbean**

   Professor G C Lalor, Pro-Vice-Chancellor of the University of the West Indies, Kingston, Jamaica, selected by the Organising Committee (unable to attend at the last moment).

3. **Western Africa**

   Professor E H Wright, Department of Chemistry, Fourah Bay College, Freetown, Sierra Leone, nominated by the 4th International Chemistry Conference in Africa, Malawi, 1989.

4. **Eastern and Southern Africa**

   Professor C C Mjojo, Department of Chemistry, Chancellor College, Zomba, Malawi, nominated by the 4th International Chemistry Conference in Africa, Malawi, 1989.

5. **Arab Countries**

   Professor S E Morsi, Secretary General, Supreme Council of Universities, Cairo University Campus, Cairo, Egypt, selected by the Organising Committee.

6. **Asia**

   Dr M Mohinder Singh, Director of Science and Technology, Ministry of Science, Technology and Environment, Kuala Lumpur, Malaysia, nominated by the 3rd Asian Chemical Congress, Brisbane, Australia, 1989 (see also paper 2.12).

Keynote Talk 1

Chemists: Sinners or Saviours

Andrew J Bennett
Overseas Development Administration (ODA)

The Challenge

The Challenge that faces both the developed and developing world is to achieve and sustain desirable economic development and change, and social change. This must be achieved in the real world and in an ever changing political, social, economic and physical climate and against the background of ever increasing population pressure on the finite resources of the world.

Recent events have shown that much of our development activities and the way in which we have managed and used the resources of the planet have caused environmental damage, degraded our resource base and polluted our air, water and land.

Sustainability

We must learn to manage our environment in a sustainable way. The concept of sustainable development has gained widespread recognition following the publication in 1987 of the Report of the World Commission on Environment and Development entitled 'Our Common Future'. The report concluded that it is possible to have development without destruction. It rejected the philosophy of 'zero growth' as the only way to protect our environment, and demonstrated that, with wise management and the use of appropriate technologies, it is possible to have economic growth and conserve natural resources; indeed they are both essential to each other and mutually reinforcing.

The report identifies that poverty forces many people to overdraw on the earth's ecological capital, creating a poverty trap - a vicious spiral of environmental degradation and further poverty. Poverty is both a cause and a symptom of environmental degradation. People are poor because they lack access to resources, do not possess the technologies and skills to manage them, or because they are prevented from doing so by ill health, civil strife, lack of investment capital or poor government policies. Poverty restricts the options available and access to technology; it breeds instability and encourages a short-term survival perspective. However, ignorance, greed and arrogance can also cause severe and lasting environmental damage. The poor are not the principle destroyers of the environment; they are often the product of inappropriate or inequitable development.

With the exception of recent events in the Gulf, most environmental problems are not deliberately caused - they result from an aggregation of the normal day-to-day actions of people going about their normal day-to-day activities. The problem is not always the absolute numbers of people but the rate of population growth which leads to the degradation of resources and urban pollution. The world's population had doubled since 1956. It now stands at over five billion: it could double by 2050. Every second there are three new mouths to feed and support. 94 % of these new people will live in developing countries and by 2015 some 50-75 % of them will live in an urban environment. This unprecedented rate of urban development carries with it some formidable challenges to infrastructure, employment creation, services and pollution control.

Translating the concept of sustainable development into practice - rhetoric into reality - requires an understanding and careful management of the complex interaction between people, their resources, the environment and their development objectives. The vital ingredients are:-

- a through knowledge of the extent, location and physical and chemical characteristics of our natural resources;

- the development and uptake of 'clean' systems and technologies to conserve and use efficiently these resources, minimise waste and avoid pollution;

- the full participation of communities in programmes of action through consultation at all stages, education, skills training and technology transfer;

- an interdisciplinary approach involving physical, natural and social scientists;

- the establishment of environmentally sound physical infrastructure, eg. roads, transport system, power supplies, water supplies, etc;

- formulation of policies and financial mechanisms that promote and support the wise and sustainable use of resources, facilitates technology transfer and uptake and discourages the polluter; and

- establish and strengthen the institutions needed in the public, private commercial and social sectors.

For renewable natural resources, the challenge is to develop management practices that conserve the resource and minimise waste while meeting the needs of the communities that depend on them. For the non-renewable resources (coal, oil, minerals, gas and fossil water), we must develop systems for their efficient exploitation, use and recycling, while seeking realistic and affordable alternatives that use renewable resources, eg. hydropower, solar and wind energy. For human resources it requires investment in education, health and training. There is no point if we preserve the environment if the world starves because we sacrifice food security.

The Risks

There is now a long list of threats to the environment at local, regional and global level. At global level, there are concerns over possible climate change, depletion of the ozone layer, deforestation, loss of biological diversity and potential widespread pollution caused by industrial accidents, wars, and careless disposal of hazardous substances. At a regional level, industrial pollution (eg. acid rain), water pollution, drought and desertification are important issues. At local level, industrial pollution, water and air quality, environmental health and amenity issues are causes for concern.

I cannot deal with all of these today. Some are local in cause and impact while, with others, the cause and impact are separated in distance and in time. Where the cycle is local and immediate, it is in people's own interest to act, provided they have the will and resources to do so, but in many cases one person's development becomes another's environmental threat, eg. the build-up of greenhouse gases in the atmosphere, the hole in the ozone layer and acid rain. To solve these problems requires collaboration and cooperation at national and international level - it highlights the interdependence of global society.

The Response

Environmental concern is now firmly on the agenda of Governments. In 1990 the British Government published a White Paper on the Environment entitled 'This Common Inheritance'. It is a comprehensive survey of all aspects of environmental concerns in the United Kingdom and internationally - from the street corner to the stratosphere, and from human health to endangered species. It recognises global interdependence and that it is in all our interests to help developing countries to tackle their local and global environmental problems through technology development and transfer, financial assistance and human resource development.

It accepts the need to adopt the precautionary principle where there is uncertainty and for the polluter to pay where there is a higher level of certainty that can be measured and monitored. People can be persuaded through better awareness, and peer group pressure, to change their consumer and polluter habits; their habits can be conditioned by market mechanisms, eg. through their pockets (taxation or incentives) and no regrets policies that do not increase inflation; if all else fails, their behaviour can be regulated by legislation. There are, I fear, no quick fixes.

We have a repairing lease on this planet and our actions must be based on 'good science, good economics and common sense'.

There is a good deal going on at the international level. The parties to the Montreal Protocol have agreed to phase out the production of ozone depleting substances by the year 2000 and created a special fund to help developing countries to comply, and to meet the incremental costs of doing so. A global environmental facility of $1,000 million was created last year to help developing countries tackle the range of global environmental issues they face. Britain's £40.3 million contribution to these facilities is separate from our aid budget for developing countries. It comes from a new and separate item of public expenditure, specifically for global environmental assistance.

There are negotiations in train for Conventions in Climate Change and the Convention of Biological Diversity and to prepare a Charter or Declaration of Principles on the sustainable use of the world's forest resources. Conventions on trade in, and disposal of, hazardous substance and the oceans exist already. In June 1992, in Brazil, there will be a United Nations Conference on Environment and Development - an 'Environmental Summit' - to review progress.

Role of and Priorities in Science and Technology

Science, and in particular chemistry, supports development; it provides solutions to problems and opens new opportunities; it produces new technologies for better resource management. All these can support sustainable development. The opportunities for applying science and technology to improve the way of life of masses of poor people have never been greater or more urgent. However, science and technology it not a 'cause célèbre'; it must be incorporated as an integral part of a country's economic and social development strategies in a way that it becomes a key factor in both private and public discussion making. The challenge is that the capacities of many developing countries to manage technological change are now highly differentiated, both within and between countries. Where the need is greatest the weakness is often most pronounced. The development and strengthening of this capacity must be a priority development issue for the 1990s.

Role of British Aid

Britain contributes to sustainable development overseas in many ways. Through its official aid programme (£1,600 million in 1989), participation in international initiatives, membership of numerous international institutions, eg. the UN agencies and development banks, the European Community and the Commonwealth. British industry, commerce, academia, learned societies, research institutions and non-governmental charities also play a major role. Britain has a wealth of institutions and organisations with overseas interests and experience.

Britain's role in promoting sustainable development cannot be considered in isolation; its policies and actions must be coordinated with and compliment the actions of developing countries. We can encourage governments to create supportive policies and appropriate economic and social climate, and develop the institutions needed to sustain development. We can fund ways to facilitate technology transfer since most technologies are developed and owned by the private sector. To abuse intellectual property rights would act as a severe disincentive to industry to invest in research and development.

Under the aid programme Britain provides financial assistance, goods and equipment, training and know-how. In our support for science, we pay particular attention to human resource development and institution strengthening because of the parlous state of the research institutions in many developing countries. Every year some 15,000 overseas students study in the UK under awards administered by the British Council - a large proportion of these come to study or carry out research on scientific issues. We support the British Royal Society International Fellowship Schemes and the activities of the Commonwealth Science Council.

We fund numerous link arrangements between British institutions and those of developing countries. Some of these links are focused on collaborative research to resolve specific problems. In 1989/90 we spent a total of £48 million on specific research projects at UK and research institutions overseas. However, most of our research activities are not focused on chemistry alone; they are aimed at solving problems or developing specific technologies and this requires an interdisciplinary approach. ODA recognised the need for strong S & T capacity in the management and implementation of the aid programme. We are well equipped with chemists; for example, our own scientific unit, the Natural Resources Institute, now based at Chatham, has 80 experienced chemists out of about 500 staff. They work on a wide range of issues from the synthesis and testing of pheromones, soil analysis, food quality, and measurement of pesticide residues; but they all work as members of interdisciplinary teams on pest control, soil management, food processing and environmental impact monitoring.

Role of Chemistry for the Environment

Chemistry can be sinner or saviour in its impact on the environment and sustainable development. Chemists can produce technologies and processes that pollute or purify. You will be aware that every reaction or process results not only in an intended product, but also numerous by-products. You will also be aware that altering the temperature or concentrations of even naturally occurring substances can have far-reaching effects on the rate and equilibrium point of a reaction. One definition of pollution is altering the natural composition and balance by changing the concentration of substance or adding a foreign substance to an environment. Chemists can not only identify and characterise those substances but also develop systems by which they can be removed, neutralised or even turned into useful products. In the North, they say 'where there's muck there's brass' - one community's pollution could be another's livelihood.

In the last 150 years, chemistry has made a major input to development. It has given us the means to increase productivity in the agricultural sector, through fertilizers and pesticides; to control and treat disease, through insecticides and antibiotics; fuels; new metals; transistors; plastics; food processes; water treatment and better refrigeration. However, at the same time, these advances have resulted in toxic wastes, dioxins, loss of wild life, carcinogens, greenhouse gases, acid rain, water pollution and a hole in the ozone layer. At the 'high tech' end of the spectrum, biotechnology and genetic engineering offers exciting prospects for environmentally sound or improved technologies, but the environmentalists are now equally concerned at the likely impact on ecosystems of the release of genetically modified organisms.

There are no free lunches as our experience with chloroflurocarbons has shown, the environmental impact of the release or escape of apparently benign substances can be unexpected even if the atmospheric chemists warned us. We all have a major role to play in limiting pollution; improving efficiency in our industrial processes and use of resources; recycling technologies; maintenance or restoration of soil fertility and developing new products and materials to sustain economic development and to improve the quality of life.

As chemists, you are well placed to be sinners or saviours, destroyers or conservers. But to reach your full positive potential, you will need to bond with other disciplines and to work with others in the UK and overseas. The needs are pressing, the agenda is long and the challenges are great, but we must establish priorities and make the best use of scarce resources.

Mr President, an important starting point must be networks for the exchange of information and ideas. This conference provides such an opportunity. The themes you have chosen are most timely and relevant and with your excellent panel of speakers you should have an interesting and highly productive meeting. I know that my Minister, Mrs Chalker, will be interested to learn of your conclusions.

Keynote Talk 2

IUPAC and its Role in Development

Yves P Jeannin
President, International Union of Pure and Applied Chemistry (IUPAC)

The Royal Society of Chemistry has chosen to organise a meeting on 'Chemistry and Developing Countries'. First let me congratulate your Society for this very timely initiative and, on behalf of the International Union of Pure and Applied Chemistry, express our thanks for the kind invitation to participate and to say a few words about the activities of IUPAC in this field.

When, before the first World War, the Chemical Societies of France, Germany, Italy, Russia, the United Kingdom and the United States decided to work together, they defined the following goals for their association:-

- to unify the rules of chemical nomenclature and the notation for physical constants;
- to organise a congress of pure chemistry;
- to standardise the formats for publications.

All those efforts were brought to an end by the First World War. In 1919 Sir William Pope, President of the Society of Chemical Industry, and Paul Kestner, President of the French Society of Industrial Chemistry, formed the International Union of Pure and Applied Chemistry. The first General Assembly was held in Rome in 1920 and the first President, elected on this occasion, was Charles Moureu. It is worth noting that the Union was founded by industrial chemists. The aims of IUPAC, as they are written today in our statutes, read as follows:-

- to promote continuing cooperation among the chemists of the member countries;
- to study topics of international importance to pure and applied chemistry which need regulation, standardisation or codification;
- to cooperate with other international organisations which deal with topics of a chemical nature;
- to contribute to the advancement of pure and applied chemistry in all aspects.

This spirit has not really changed since 1920. At first glance, it does not have much to do with developing countries. However, looking more carefully at our programmes shows that some of them are of great interest to those countries. Today we have 44 member countries; this already shows the interest of developing countries in IUPAC work. In addition, IUPAC defines several categories of chemist members who can participate in the work of its commissions, which constitute the productive core of the Union: Titular Members, Associate Members and National Representatives. The number of Titular and Associate Members is limited by statutes, and those members are co-opted on the basis of their expertise; this not a wide open door for chemists of developing countries and explains why the third category of member was set up. It allows chemists of all countries, including developing countries, to take an active part in the work of any Commission identified as being of interest to that country. The National Adhering Organisation nominates its chemist who then becomes a National Representative, once approval is given by the Chairman of that Commission. National Representatives have direct access to all the drafts of that Commission and they may make a personal input; they may also participate in the meetings of their Commission. Let me take the case of the Commission on Thermodynamics as a typical example. National Representatives come from Australia, China, Czechoslovakia, France, Hungary, India, Japan, Malaysia, New Zealand, Norway, South Africa, Poland, Turkey, USSR, USA and Yugoslavia. Thus, several developing countries are involved.

Another centre of interest for developing countries is provided by the CHEMRAWN conferences. CHEMRAWN means Chemical Research Applied to World Needs. Its purposes may be defined as follows: to identify human needs, to serve as an international forum and to serve as an international non-governmental source of advice for governments and agencies. Seven conferences have already been held and the interest of developing countries naturally depends on the topic under discussion. For instance, CHEMRAWN II was devoted to Chemistry and World Food Supplies; this attracted considerable attention and many attendees were from developing countries. Mrs Indira Gandhi, then Prime Minister of India, came to the opening ceremony and gave an address. A follow-up was organised in the form of two workshops held in Africa and in Sri Lanka. This conference was a considerable success and the CHEMRAWN Committee is thinking about repeating such a conference; the problems which were discussed then are still important now. CHEMRAWN V was also well attended by participants from developing countries; it dealt with Chemistry and Health, another major problem in the Third World. The subject of CHEMRAWN VII is Chemistry and the Atmosphere, and its impact on global changes. This concerns every country, developed and developing, not only because atmospheric problems are planet-wide, but also because some decisions taken at an international level, such as at the Montreal Conference attended by Heads of Governments, will entail drastic changes in some industrial practices. The financial resources of developing countries are, of course, not the same as those of highly industrialised ones and their problems will therefore be much more difficult to solve.

CHEMRAWN VIII is entitled 'Chemistry and Sustainable Development - Towards a Clean Environment, Zero Waste and Highest Energy Efficiency'. This is a vast problem for every country. The establishment of new industries in developing countries must take advantage of the latest concepts of sustainable development defined by the United Nations. The conference programme also calls for reports on recent progress in low-waste and non-waste technologies in all kinds of industries which use chemistry, such as ore processing, petrochemistry, the pulp and paper industry, electrochemical processes, etc. Waste as a raw material is another topic of wide interest. Effective channels for the dissemination of information on clean technologies have to be set up so that every country may know how to avoid pollution and how to recycle wastes. Finally, chemical methods for the elimination of large-scale environmental pollution and the rehabilitation of natural systems have to be made available to everyone and used everywhere. The part to be played by developing countries in CHEMRAWN VIII is an essential one.

IUPAC realises that chemistry is a science which cannot be managed without the relevant expertise. This is not a problem in highly industrialised countries, at least not in theory, but it is often the case in developing countries. IUPAC has taken care to provide opportunities for such countries to take advantage of its programmes. Let me give an example taken from the Division of Applied Chemistry. One of its Commissions is concerned with pesticides, and more generally with agrochemicals. I want to mention its project on the prediction of pesticide residues in crops by the optimum use of existing data. The project report makes a number of useful recommendations and suggestions. Pesticides are used all around the world. Their quality is important; their industrial synthesis is important because they may contain as byproducts molecules which are dangerous for animals and human beings; their mode of action is important; their proper use in fields is important; their fate, degradation and transformation in the environment are very important. In order to improve their handling, IUPAC organised a workshop in China. It was a great success and there are plans to hold another in South East Asia.

Another opportunity was provided by a workshop devoted to Safety in the Chemical Industry. This is a major problem, not only for industrialised countries, but also for developing countries. Risk assessment and risk reduction are a daily concern for the whole chemical industry. During this conference, it quickly became apparent that the teaching of the subject is rather poor everywhere. Altogether, 50 participants from 22 Third World countries had been invited. These people strongly expressed their needs in teaching at all levels, from the worker level to the chemical engineer level. They are indeed highly concerned, with the Bhopal accident as a constant reminder to them.

Another more recent approach of IUPAC is to establish programmes specifically to help developing countries. The first point to emphasise is that these programmes should be implemented with the active participation of chemists from those developing countries. For this purpose, the financial support of UNESCO is greatly appreciated and I would like to take advantage of the presence of Dr Federico Mayor, Director-General of UNESCO, to thank him very much and to hope that my presentation will convince him that more can be done by IUPAC with the support of UNESCO. The role of IUPAC does not specifically include helping developing countries, but we do feel it is a responsibility we must fulfil. IUPAC has the expertise in chemistry and feels that it must be offered.

A good example is given by the activities of our Committee on the Teaching of Chemistry, and I would like to make a special mention of our project on low-cost equipment for experimental chemistry. The provision of scientific equipment soon creates difficulties for the recipient because of maintenance problems. Thus, making such equipment with low-cost and locally available hardware solves both the equipment problem and the maintenance problem, since those who build a machine can easily maintain it. The second programme of that Committee was to prepare simple experiments based on such low-cost equipment. The Committee received many useful suggestions and proposals which were tested in several different countries and put together in a booklet. Puerto Rico, Brazil and India were particularly active in this area. The Committee also decided to pay attention to environmental chemistry. The aim is to create teaching units on energy and the environment which can be adapted to situations encountered in different countries. One such unit has been prepared and already tested in 15 countries. It deals with the burning of fuels and how chemistry can help to minimise waste of materials and energy. We have also organised meetings in various developing countries as a follow-up to our projects, especially in Africa, in order to show teachers what can be done with limited means in presenting experiments to young schoolboys.

Finally, I would like to mention what we call the Affiliate Scheme set up by IUPAC four years ago. Glenn Seaborg, a Nobel laureate, had the idea of an international chemical society. This is not the place to show how the proposal was modified over the years, but it ended up by offering individuals the possibility of involvement in IUPAC affairs. It is worth pointing out that chemists adhere through their own chemical societies. However, in some countries chemists are fairly, sometimes very, isolated and sometimes they do not even have a national chemical society. Nevertheless they can now adhere through any foreign chemical society. This scheme is an extremely good way to disseminate news from the international community of chemists through our journal Chemistry International, and an extremely efficient way to make ties between chemists from all around the world. Individual chemists may participate in the work of a Commission of their choice by correspondence. In 1990, IUPAC registered more than 7,500 affiliates from 82 different countries. Slightly less than 1,000 members came from developing countries. It is interesting to recognise that, whilst 82 countries are represented within IUPAC through this affiliate scheme, there are only 44 member countries. Quite clearly, there is a crucial need being expressed by many chemists from countries which are not Union members. It was precisely the aim of the affiliate scheme to provide to all those isolated chemists news about the world of chemistry and chemists, and to offer the possibility of dialogue within IUPAC.

As you can see, IUPAC tries to develop connections with developing countries. The last point I would like to make concerns the status of Observer that is given to those countries which hesitate to pay dues and to become a full active member, but which would like to know about our activities. Such Observers can attend the General Assembly, but they may not vote. At present, those countries are Bangladesh, Hong Kong, Indonesia, Malawi, Pakistan, Philippines, Singapore, Sri Lanka, Thailand and Tunisia. They have an opportunity to follow our activities which more and more take into consideration many kinds of problems related to chemistry in developing countries.

Keynote Talk 3

Chemistry, UNESCO and Development

Federico Mayor
Director-General, UNESCO

It is both a privilege and an honour for me to be here today to celebrate the 150th anniversary of The Royal Society of Chemistry. You have chosen vital issues for this anniversary - Chemistry for the Environment and Organising Science to Benefit the Third World. Chemistry has come a long way from alchemy and from the time when John Dryden could write of the 17th century amateur scientist:

> "... was everything by starts and nothing long:
> But in the course of one revolving moon
> Was chemist, fiddler, statesman and buffoon".

The advances since 1841 in the field of chemistry alone are surely beyond the wildest dreams of the founders of this Society. However, more important is our perceptual leap, first to an understanding of the direct role of chemistry in the development of society's capacity for agricultural and industrial development and, more recently, that of the need to develop new methods of farming and production which make development sustainable from the point of view of maintaining the earth's resources and mankind's equilibrium of nature.

That is why this understanding of the role of science as a whole and chemistry in particular, not only to the 'wealth of nations', but also to the survival and well-being of mankind as a species is so central to your concerns as a Society and to those of UNESCO. Your Society has a justifiably excellent reputation throughout the developing world. Graduates from British universities form local branches in many Third World countries and your Society does an enviable job keeping these highly trained professionals in the mainstream of international chemistry. I salute this commitment and hope that you will continue to encourage your members here in the United Kingdom to visit and help their counterparts in developing countries. I also hope that The Royal Society of Chemistry will continue its efforts to help develop national chemical societies that are self-sustainable in the poor countries so that local chemists can play a key role in promoting sustainable development in their national settings.

Since taking up my duties at UNESCO, I have underlined the concept of cooperation both between the sciences and the various socio-economic groups in today's world. To this end, my staff and I have sought to find mechanisms where scientists in developing countries could begin to develop and then to strengthen their national scientific capacities. I could share many examples of this with you, but I shall restrict myself to chemistry and explain UNESCO's methods of encouraging cooperation on an equal basis among countries rich and poor. These involve a considerable number of activities carried out in partnership with the scientific institutions of developing countries.

We have to begin at the beginning - at the basic level of local schooling. We have emphasised at UNESCO the fact that the availability of educational material is perhaps the most powerful and consistent determining factor in learning achievement. Inequality in access to such basic materials as appropriate textbooks and laboratory equipment is a major source of dramatic differentials in student achievement throughout the world. Worse still, the failure of many school systems to win women and girls to scientific careers is a shameful waste of enormous human resources.

With other UN organisations, particularly UNDP, UNESCO has set up operational projects in a number of Member States to develop a capacity at national and provincial levels for the production of teaching materials and equipment for schools. In this we take account of local needs and quite often dovetail the production of materials with in-service teacher training to up-grade science and mathematics instruction.

Teacher training of course hinges on university-level education. UNESCO has benefitted greatly in its higher education work from our close ties with ICSU and its component unions. Among the initiatives launched over the past few years is one recently reported upon at an ICSU meeting by Professor Sane of the University of Delhi and Professor Waddington of the University of York and Chairman, ICSU-CTS. These two professors from the world's South and North have been working together at obtaining and maintaining equipment for university chemistry teaching. With the support of UNESCO, IUPAC, the British Council, ICSU-CTS and the Commonwealth Foundation, this important initiative has resulted in five key achievements:

- to develop reliable, low-cost equipment produced locally and designed for easy assembly and maintenance;

- to find experiments appropriate to this equipment that can illustrate the principles and practice of modern chemistry;

- to transfer technical know-how to teachers through workshops, manuals and video tapes;

- to set up a production unit that can supply kits and assembled equipment;

- to encourage curriculum changes so as to ensure that the whole package enables a student to be better trained for a career in chemistry.

This project is thriving because it is based in India, a developing country with the infrastructure strong enough to carry such a project. I would like to stress that this is the type of cooperation we want to establish: South-North cooperation, not just transfer from developed to developing countries which we have witnessed for so long.

Other UNESCO initiatives which are worth mentioning here deal with computer software, audio-visual aids and local book publishing. These, together with the one on laboratory equipment which I have already mentioned, have, over the past two years been brought together under a programme for the development of university foundation courses in the basic sciences.

UNESCO best acts as catalyst and partner if existing networks are already gaining the support of professionals in their local settings. Thus, a strong network is usually composed of a number of neighbouring countries with a solid base in one outstanding institution. By creating a spirit of cooperation, and a framework through which outside assistance and support can be channelled, such 'growth points' can expand. UNESCO's assistance generally takes the form of analytical services - about 2,000 per year - which include literature searches, small research grants, support for research programmes and equipment, maintenance and repair. We have sponsored networks in every geographical region. In Asia, for example, the chemistry networks are grouped under the umbrella of the Asian Coordinating Group for Chemistry (ACGC) which also look after our new programme - Botany 2000. In turn, this innovative programming is working closely with UNESCO's African chemistry networks.

It is no coincidence that the main work of these groupings focuses on local natural resources. Indeed, natural products chemistry is certainly one of the most active groups. Herein lies UNESCO's in-built advantage in that many of the most interesting plants grow in the tropics. By studying their chemical composition we provide for the protection of genetic diversity in tropical regions because local managers see clearly that careful long-term study yields greater profits than destroying species in the short-term.

Chemists are involved in development. This is inevitable in driving any agricultural or industrial revolution. What is not inevitable, however, is that development, though profitable in the short-run, will be environmentally benign in the long-run. We in the industrialised countries have barely begun our own transition from the exploited environment to at least the concept of intelligent ecological management. Considerable debate continues on the all-important question of whether the need for economic progress can be properly met while satisfying the over-arching question of preserving the environment. Global change is certainly a troubling trend powered in part by the materials we wish to burn and by exponential demographic growth. Surely chemists, and particularly those in physical chemistry and biochemistry specialising on photosynthesis and biotechnology, have a vital role to play in finding new, cleaner and renewable energy sources.

Chemical scientists have always had a unique relationship with industry. The range of chemistry-based productive enterprises is enormous as is their scale and weight in the market forces which can, left to short-term thinking, threaten man's biosphere. Thus, chemists have a unique community responsibility among scientists, the business world and political decision-making. The chemist must be a watch tower - protector as well as provider - thinking of the long-term to maximise the benefits of products and innovations while avoiding adverse environment effects. The time has certainly come when chemists and their scientific colleagues must speak out in plain language and inform the public of the issues of survival involved in our productive and political processes.

The man and woman in the street cannot - at this time - make decisions or formulate opinions on things which are self-evident truths to specialists. Such sophisticated concepts as global warming or ozone-layer depletion must not remain buried in specialised journals when scientist and layman alike may yet one day be confronted with their own particular version of, for example, a dioxin disaster like "Love Canal" in the United States. The passion of conservationists may well be in vain unless the chemist provides the hard data soon enough and publicly enough. By speaking out, by exploring alternatives, chemistry becomes a community adviser and a source of viable economic and commercial solutions.

To get the hard data means training analytical chemists living and working throughout the world and particularly in developing countries. In our UNESCO programmes, we have once again mobilised the network principle to promote just this kind of training. The specifically local nature of many environmental problems requires the presence of local chemists who can use, in their settings, the great wealth of existing chemical knowledge. To this end, UNESCO is directing its efforts towards university-level chemistry education. Besides organising a world-wide programme on university chemistry teaching, we have also encouraged undergraduate training explicitly linked to the actual milieu within which the graduate chemist will work. This, of course, also involves UNESCO's insistence on promoting university-industry cooperation for local benefit. Two examples of this are the Amazonia project, forging partnerships between universities, research institutes and business throughout the Amazonian region for sustainable economic development, and the Blue Danube project linking universities, governments and business to clean up and nurture that important river valley.

UNESCO is not alone in such networks. Such NGOs as ICSU and the International Council of Rectors of Universities are involved in those I have just cited. In the ACGC group, the Federation of Asian Chemical Societies plays a large role as do the Swedish and Australian international aid agencies. Furthermore, in all that involves the environment, notably the preparation of the United Nations Conference on Environment and Development scheduled for 1992 in Rio de Janeiro, UNESCO works in close collaboration with its UN system partners and , in particular, with the United Nations Environment Programme.

Similarly, you may recall that just over a year ago UNESCO brought together the United Nations Development Programme, UNICEF and the World Bank in co-sponsoring the Conference on World Education for All held in Jomtien, Thailand. This was part of making International Literacy Year more than a poster and a stamp, but the launching point of a genuine resolve by the world community and above all by governments, to confront illiteracy and the lack of access to education in a concerted and dynamic way. This has resulted in increased priorities in World Bank lending and UNDP project assistance. After all, neither science nor chemistry can advance when basic education - including an all-important introduction to the sciences - is denied to so many children, particularly in those least developed countries that most need trained scientists and technicians.

The Royal Society of Chemistry was born in this country four years after Queen Victoria ascended the throne. My organisation was founded in London some 105 years later. Yet our common heritage and common goal are clear. Chemistry and indeed, science and all knowledge, depend fundamentally on what the small band of Victorian reformers treasured -free enquiry and the need to see things as they are and not through the lens of received wisdom or traditional prejudice. UNESCO was founded on the self-same burgeoning democratic and liberal traditions but this time against the background of a war that pitted democracy against forces of blind rage and unreason. No scientist in 1841 and no scientist now would ever deny that knowledge is universal and that the pursuit of knowledge can only take place in freedom. On a larger scale, when we speak of emerging world orders in the present circumstances of a winding down of the cold war, it is important to transcend increasingly old fashioned questions of national military security to confront the security threat to all of us on the planet caused by man's interaction with nature. With black snow falling in the Himalayas, with burning oil wells creating a lethal microclimate in Kuwait, it should be clear that war is also an environmental problem. The answer, I believe, is a greater reliance on multilateral forms of world conflict resolution and, most of all, on a better ability to understand others living in different cultural and social settings. Ultimately, for science, for chemistry and for world peace, much of the answer lies in the active meaning of the words freedom and democracy.

Chapter 1 Chemistry and the Environment

1.1 Introduction

Denys Coomber
formerly Laboratory of the Government Chemist

Theme 1 of the Conference covered problems of pollution on land and in the air and water. Speakers came from every continent though the representation was inevitably thinly spread and, for instance, there was only one speaker from Africa and there were complaints that small countries, eg. the West Indies, were not represented. The papers presented are listed below and extended summaries are given in 1.2 to 1.11. While no formal resolutions were passed at the sessions, points raised by speakers and in the discussion session are included in the following. The importance of chemistry in dealing with environmental problems is in all papers.

Professor Peter J Peterson (1.2) gave the opening paper on endemic diseases caused by natural pollution: deficiencies in essential trace elements (pollution in a negative sense) or an excess of a toxic element. Extensive analytical programmes are needed in this field. In the case of fluorosis, he emphasises the need for work on low cost defluoridation processes.

Professor Dilip Biswas (1.3) described the problems of land pollution following human activities. While this was based on Indian experience these would be similar in any heavily populated developing country especially in a tropical climate.

Dr J G Kretzschmar (1.4) and Professor Tania Tavares (1.5) spoke on air pollution in cities in Mexico and Brazil in which motor vehicle exhausts were the main culprit. Professor Tavares made the point that when analytical measurements were made over a period of time, improvements in methods could bias conclusions drawn from trends in such measurements. This could be corrected by a suitable use of standards.

Dr David Mage (1.6) dealt with the difficult determinations involved in assessing the amounts of pollutants actually taken in by people in the Human Exposure Locations Assessment (GEMS) programmes in which emphasis on correct sampling and calculation is as important as the analysis.

Dr Deborah Chapman (1.7) gave an account of the GEMS/WATER global water quality monitoring and assessment programme. Chemical data is essential for water quality assessment and chemical techniques need to be simple so that they can be used on a global scale.

Dr Jerome Nriagu's paper (1.9) was concerned with the increasing levels of metal pollution to which African populations were exposed. Many factors were responsible for the special vulnerability of Africans to toxic metals: their particular lifestyles, their low nutritional status, the dusty conditions throughout Africa leading to the spreading of metal contamination. He referred to foreign companies which were able to carry on operations, eg. mineral exploitation, which would not be permitted in their own countries.

Professor Wang Ju-Si (1.10) spoke on the most serious environmental problem in China-water pollution. She gave a case history of the rapid development of a petrochemical industry in Beijing which threatened to overwhelm the water treatment plants in the city and of the major role played by chemistry and chemists in saving the situation. A serious water problem was also the subject of Dr Handa's lecture (1.8), in which he dealt with the Ganga Action Plan and the study made by the National Environmental Engineering Research Institute to design effective measures for water quality management of the Ganga river.

Dr Barry Noller (1.11) described a Commonwealth Science Council initiative in the Asia-Pacific region in which the most urgent programmes needing the application of chemical research were chosen by the participants. A similar idea could with advantage be adopted in many other developing countries. He compared the component projects in this initiative with those to be discussed at a UN Conference on Environment and Development (UNCED) in Brazil in 1992. In considering environmental analytical techniques, Dr Noller emphasised the importance of field methods being essentially simple and avoiding hazardous chemicals so that they can be widely used (cf. Dr Chapman).

1.2 Environmental Chemistry of Endemic Diseases

Peter Peterson
King's College London

Introduction

Human health, especially in rural populations in developing countries, can be seriously affected by parasitic diseases, communicable diseases as well as nutritional diseases. Parasitic disease such as malaria with one to two million deaths per year, 300 million infected, and two billion at risk, and schistosomiasis with 200 million affected, and around 500 million at risk are widely reported and studied (1). Communicable diseases, including water borne diarrhoeal diseases, seriously affect people with around five million deaths in young children each year and are again well recognised (2). Nutritional diseases on the other hand have in recent years not received the same publicity, yet many serious consequences result. It has been estimated that around 800 million people are seriously malnourished, 800 to 900 million are anaemic with an iron deficiency and around seven million have vitamin A deficiency (2).

Vitamin deficiencies, together with iodine deficient goitre, the selenium responsive Keshan and Kaschin-Beck diseases and those where excess levels of fluoride, arsenic or selenium seriously affect health are referred to as 'endemic diseases'. They are not, however, restricted to individual countries but the term is used to distinguish diseases with a chemical aetiology from biologically mediated communicable or parasitic diseases.

In this report, emphasis will be placed on endemic fluorosis, iodine deficient goitre, Keshan and Kaschin-Beck diseases.

Fluorides and Fluorosis

The intake of excess concentrations of fluorides, whether from drinking water, ingestion of food or inhalation of high fluoride smoke or dusts, gives rise to fluorosis in animals and humans. Plants too are affected but will not be discussed here.

Dental fluorosis, the mottling of teeth at relatively low concentrations of fluoride, occurs on all continents and is widespread (3). It usually arises from drinking well waters containing elevated concentrations of fluoride ions. No accurate data exist on the total numbers of people affected but a recent report suggests the numbers exceed 80 million and could be as high as 100 million (4). In China, some 85 million people are at risk from high fluoride levels and 38 million people are reported to have dental fluorosis, while in India the number affected is around 25 million.

High fluoride concentrations in soils, rocks and waters, particularly well waters, occur throughout the world. High fluoride levels and hence dental fluorosis, where exposure to fluoride exceeds approximately 1.5 to 2 mg l^{-1}, is often thought of as being a disease of tropical climates. Accordingly, the disease extends in geographical belts extending from Turkey into the eastern Mediterranean and into Africa, particularly the east coast nations, and down to South Africa. Other belts extend from Turkey across to India, China, Korea and Japan. Dental fluorosis also occurs in South America, including Bolivia, Argentina and Equador. In earlier years, dental fluorosis was recorded at locations in the temperate countries across Europe and the Americas.

Traditionally, fluorosis is considered to arise from drinking high fluoride surface, shallow- and deep-well waters although drinking special high fluoride teas and intake of high fluoride salt in some South East Asian countries can markedly increase the intake. In parts of China 'brick tea' contains up to 600 mg kg^{-1} giving rise to a concentration in solution of 3 mg l^{-1}. High fluoride salts typical of China, Thailand, Myanmar and Vietnam can give rise to a daily intake of 4-5 mg fluoride. Inhalation of high fluoride smoke from coal combustion provides another major exposure route.

The incidence of dental fluorosis varies enormously depending on exposure and nutritional status in particular. In Thailand at one location, up to 92% of the subjects examined showed dental fluorosis where the water contained 1.0-1.6 mg l^{-1} fluoride (5). Not surprisingly, incidence of dental fluorosis varies throughout China, but is recorded in all 28 provinces, autonomous regions and municipalities of the country except Shanghai (6). Fluorosis distributions have been mapped in detail in China based on the exposure route, ie. deep-well water, shallow-well water, high fluoride coal smoke, etc. Less detailed maps have also been produced for other parts of the world, particularly for affected states in India.

Dental fluorosis is particularly widespread in people from many regions of the Rift Valley throughout the east coast of Africa. In Kenya, for example, fluorosis is a health problem of major concern. Nair and Gitonga (7) have estimated that around 10 million people are potentially at risk, but further data is required to ascertain annual variations in concentrations and the contribution of fluoride in drinking water to total exposure.

Skeletal fluorosis, where osteoscherosis, ligamentous and tendinous calcification and extreme bone deformity result, is also global in scope. In China, some two million people and in India, approximately one million people, suffer from this incapacitating disease. Although normally considered as a disease of the elderly due to continuous fluoride exposure over long periods of time, skeletal fluorosis has been reported in locations also in children particularly in Tanzania. Skeletal fluorosis would normally be considered at fluoride concentrations above approximately 10 mg l^{-1} in water, but nutritional level, calcium intake, etc, modify human response. Skeletal fluorosis incidence, as with dental fluorosis, varies markedly from location to location.

Although fluorosis is well known as an endemic disease throughout the world, the numbers affected would appear to be increasing due to population growth, particularly in Africa. Despite the use of alternative low fluoride waters in parts of China and India the disease is still serious.

The development of extensive low cost defluoridation techniques is still required for areas where alternative sources of low fluoride water are unavailable. Extensive work is necessary to understand the aetiology of the disease, its exposure routes and to reduce the incidence of both dental and skeletal fluorosis around the world.

Iodine Deficient Goitre

Iodine deficient goitre, despite being a well recognised endemic disease, still affects over 150 million people around the world from a population exposed to low iodine of around 800 million to 1 billion people (8). Endemic goitre occurs on all continents and in many countries, particularly throughout the Third World. Iceland is one of the few countries where goitre has not been described. It is thus a disease of serious proportions although the iodization of salt has reduced the incidence of goitre in the developed world to relatively low numbers. More than 43 million people in South East Asia suffer mental and physical impairment due to iodine deficiency (9). Under severe iodine deficiency, ie. less than 20 $\mu g\ day^{-1}$, cretinism results. It has been estimated that over 3 million people suffer of iodine deficient cretinism. The incidence of cretinism varies in China between 0.01 to 1.09% of the groups surveyed.

High iodine levels cause thyrotoxicosis and hence iodine-induced goitre due to reduced thyroid uptake of iodine although this situation is much less common than iodine-deficient goitre. High-iodine goitre is typical of coastal areas in China and Japan where intakes of seaweeds or vegetables pickled in kelp salt are consumed (10). This contrasts with the iodine-deficient goitre which is greatest in areas of high mountains and plateaus, especially those far from the influence of the maritime atmosphere with its elevated levels of iodine.

The critical intake band is around 50-100 μg I day^{-1}, with water as a source accounting for 10-20% of the exposure. For children, adolescents and pregnant women, the daily intake should exceed 150 $\mu g\ day^{-1}$. Concentrations of iodine in urine or in head hair are ready monitors of iodine exposure. Values of around 0.5 ± 0.25 μg I g^{-1} hair can be found in iodine-deficient areas compared with 'normal' values of around 1 ± 0.2 μg I g^{-1} hair (11).

'Normal' soils range around 5-10 μg I g^{-1} d.w. with plant values less than 1 μg I g^{-1} d.w. (12). Data from a range of countries shows that the incidence of endemic goitre is light around 1 μg I g^{-1} d.w. soil, but becomes serious with an incidence of approximately 40% when the vaue is around 0.4 μg I g^{-1} soil. The exact relationship varies with the other exposure routes of iodine including total diet and water iodine intakes.

The incidence of goitre is still high in Asia despite many attempts at increasing iodine intake via iodinated products, injection of iodinated oils, etc. In China alone, goitre occurs in 28 provinces,autonomous regions and municipalities, except Shanghai. Based on surveys of 213 million people, the incidence has been calculated to be 19.8 million. In India the number affected is 40 million while serious incidences of the disease occurs throughout Asia and South East Asia particularly (13).

As with the incidence of fluorosis, iodine-deficient goitre occurrences have been carefully studied and mapped throughout China (14) and more generally on the global scale (8).

Keshan Disease

The endemic cardiomyopathy, Keshan Disease, named after Keshan County, Heilongjiang Province, has been reported since the early 1930s from many areas of China and extends into Inner Mongolia and the Democratic People's Republic of Korea (North Korea) (14). Early stone tablets describe characteristic symptoms from different areas of China. The disease has been reported in 15 provinces and in 309 counties in a belt from south-west to north-east China. The criteria for diagnosing Keshan Disease include acute or chronic cardiac insufficiency, heart enlargement, 'gallop rhythm', arrhythmia and ECG changes. Histopathologically, it is characterised by multifocal necrosis and fibrous replacement of the myocardium. The disease effects children usually under 10 years of age and women of child-bearing age living in rural areas, but the incidence rate among age classes varies between adjacent counties. Pronounced annual fluctuations of disease incidence have been noted throughout China (14, 15).

Acute and subacute incidence of Keshan Disease and the resultant death rate varies between villages, counties and provinces as well as with the year of occurrence. The disease was especially prevalent around the years 1960 and 1970 (14, 15). Overall, the death rate has decreased over a 20-year period in North China from 40.25% to 12.97% (average 21.03%) (16). An incidence rate of up to 11% in susceptible age groups and a fatality rate of up to 80% has been reported in earlier times although the disease incidence has declined markedly in recent years (14).

Epidemiological studies have shown that the disease occurs in low selenium environments, resulting in a low dietary intake. Approximately, 15 $\mu g\ d^{-1}$ is the critical dietary intake value (17) and can be compared with a median intake of 74 $\mu g\ d^{-1}$ for some U.S citizens (18) and up to 210 $\mu g\ d^{-1}$ in Japan for example (19). Selenium concentrations in water, soil and crops from Keshan Disease areas are low and have been mapped across the country. Selenium in top soils from, for example, the 'deficient' red-brown earths, purplish soils and drab earths contain 0.09, 0.06 and 0.08 $\mu g\ g^{-1}$ respectively , giving rise to a concentration in rice and maize of around 0.017 and 0.014 $\mu g\ g^{-1}$. Rice and maize from a non-disease area contains approximately 0.07 and 0.05 $\mu g\ g^{-1}$ respectively.

It is of interest that the selenium concentration in rain water when measured at intervals from the coast near Changle to Yengshou in the interior in a north-east direction, following the prevailing wind, actually increased from 0.18 ng ml^{-1} to 0.43 ng ml^{-1} (20). Selenium concentrations in soil on the other hand , show an inverse relationship with that in rain. Indeed, experiments on the microbial volatilisation of selenium from Chinese soils show that higher rates occur on the low selenium soils rather than on the 'normal' soils, thus perhaps helping to explain significant selenium loss from soils already geochemically low in the element (21). At peak loss it was calculated that up to 0.07 g yr^{-1} mu^{-1} selenium could be lost (1 mu equals approximately one-sixth of an acre). Selenium in hair is a useful biological indicator of selenium status. Selenium concentrations in hair for individuals from a Keshan Disease purplish soil area averages 0.123 µg g-1 (n = 492) compared with 0.366 µg g^{-1} (n = 183) from a non-disease area, north-west brown desert soil (22).

Hair selenium concentrations in individuals from Keshan Disease areas in Kalaqin Qi, Inner Mongolia where selenium was sprayed over crops increased during the trials. Control hair from Keshan Disease patients was approximately 0.160 µg g^{-1} compared with hair from people in the selenium sprayed area of 0.3 to 0.5 µg g^{-1}. Selenium intake for staple foods from the control areas was 6.7 µg d^{-1} compared with non-affected areas of 18.1 µg d^{-1} and 63.4 µg d^{-1} from the sprayed areas.

Preventative trials, especially with sodium selenite tablets, selenized salt or selenium-supplemented fertilizers and hence supplemented crops, have been carried out throughout China over a number of years.

The results clearly show that selenium supplementation has a protective effect; the longer the period of supplementation the greater the benefit. Based on a large number of supplementation trials throughout China and Inner Mongolia, it is now accepted that the major aetiological factor in Keshan Disease is a deficiency of selenium.

Kaschin-Beck Disease

140 years have elapsed since Kaschin-Beck Disease was reported by I M Urenskii from the Transbaikalia region, Urov River area of east Siberia. The disease was named after two Russian scientists who were involved in its early description although it is often referred to as Urov Disease in Russia. Historical records referring to the joint deformations and dwarfism show that it has been known for over 300 years at least in Shaanxi Province, China.

The disease occurs in 15 provinces and 303 counties of China including the Tibetan autonomous region extending into North Korea, Inner Mongolia, Japan and Russia (14). The distribution of the disease is mostly contiguous, but some discrete areas occur. Likewise, some 'health islands' occur within disease affected areas. Some two million people exhibit clinical symptoms of the disease and around thirty million live in affected areas in China alone. The disease incidence fluctuates annually and in recent times new disease areas are still being reported.

The basic pathological change with the disease, commencing mainly in children of five to thirteen years, is the multiple degeneration and necrosis of articular cartilage and the growth plate which results in permanent disabilities. In severely affected areas, children two to three years of age are affected, while in lightly affected areas, new cases occur after ten years of age.

Kaschin-Beck Disease (deformans endemica) is regarded as an endemic, chronic high-incidence and degenerative osteoarthrosis whose aetiology is still incompletely understood (14). In Russia, it was proposed that a strontium-calcium imbalance was implicated in the disease as well as high phosphate and manganese contents (23), although further studies are not definitive.

In recent years, three theories have been advanced to account for the disease in China. One theory implicates mycotoxins in contaminated grain produced by the fungus *Fusarium oxysporum*. The mycotoxin theory, although popular for a time, seems now to receive less support although a higher incidence of fungal contaminated grain was reported from disease areas than from non-disease areas.

An implication that well water is involved in the aetiology of the disease is the second theory based on a decrease in the disease incidence following the provision of alternative sources. For example, a change from shallow well water for affected villages in two areas in Jilin Province, to deep well water reduced the humic acid level to a value similar to non-disease areas. This was accompanied by a high recovery rate and the absence of new cases in previously affected villages (24). Likewise, a change from shallow well water to deep well water in Linyou County, Shaanxi Province, decreased the disease incidence over a two-year period until no new cases occurred, whilst in affected villages still supplied with shallow well water, the incidence of Kaschin-Beck Disease actually increased (25). In this latter trial, the authors considered that the increase in selenium content of the well water from 0.08-0.09 ng ml^{-1} to 1.16-1.38 ng ml^{-1} was the responsible factor rather than a decrease in humic acids.

Other studies have implicated humic acids in the aetiology of the disease though the effect may be an indirect one as humic acids bind selenite and reduce the available selenium in water.

The thirds and most widely supported theory to explain the aetiology of Kaschin-Beck Disease involves an imbalance of chemical elements in the ecological environment, especially a deficiency of selenium (26). Evidence for this view comes from the occurrence of the disease on low selenium soils in China and thus, there is a comparable but not identical distribution as with Keshan Disease.

Tan Jianan et al consider that values of selenium in hair of $<0.120\ \mu g\ g^{-1}$ are characteristic of Kashin-Beck Disease areas, while $>0.2\ \mu g\ g^{-1}$ indicate disease free areas.

Since Kaschin-Beck Disease occurs on low selenium soils, many selenium supplementation trials, both large and small scale, have been reported over the years from the most severely affected counties. Recent trials have been monitored by an X-ray examination of hand-bone development as well as using hair and blood as indicators of the selenium status. In one study involving 437,000 three- to six-year old children from seven endemic counties in Heilongjiang Province, sodium selenite was given orally as tablets (0.5 mg once per week) for three successive years, and the disease followed by X-ray examination (27). The detection rate decreased following treatment from 40.82% to 8.66%.

In another study involving 1,000 children in 20 severely affected endemic areas in Yungshou County, Shaanxi Province lasting from 1980-1987, the X-ray positive detection rate dropped from 63.6% to 21.9% following selenium supplementation (28). Selenium-enriched yeast has also been shown to exert a protective effect in a study of 180 five- to fifteen-year old children in Fengning County, Hebei Province.

Conclusions

Despite the intensification of human health concerns and interventions around the world, serious nutritional diseases still occur on a large scale, incapacitating hundreds of millions of people. Supplementation trials with iodine and selenium illustrate their relationship with goitre and Keshan Disease respectively, but the chemical aetiology of Kaschin-Beck Disease, despite being selenium responsive, is still uncertain. Greater emphasis needs to be placed on epidemiological surveys of such diseases. At the excess level, endemic fluorosis is a disease which is global in scope although alternative water sources and blending of waters have virtually eliminated the disease from western Europe and North America. In a number of developing countries, however, endemic fluorosis is increasing in line with increases in populations principally exposed to high-fluoride waters. Low cost defluroridation processes are still urgently required for locations where alternative water sources are unavailable. Such environmentally-related diseases will continue to assume global prominence over the next decade despite improvements in health care in some countries.

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The Author

New Zealand citizen. BSc, MSc (New Zealand), PhD (London). Principal Programmes Officer U N Environmental Programme, Global Environmental Monitor System. Director of Monitoring and Assessment Research Centre. Responsible for UNEP/WHO cooperation in environmental monitoring assessment. Interested in environmental toxicology, particularly in Asia.

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1.3 Land Pollution from Human Activities

Dilip Biswas
Ministry of the Environment and Forests, New Delhi, India

Introduction

Land is a basic natural resource that holds the key for our survival and sustainable development. It provides us with the essential life support systems and it has to meet our growing demands for food, fodder, energy, settlements and industries. With the progressive pressure of human activities, land is being increasingly subjected to pollution and degradation in various forms.

Land is used (and often misused) as a receptacle of pollutants from various human activities which include:-

(a) Municipal wastes,

(b) Industrial wastes,

(c) Agrochemicals and irrigation,

(d) Mining and quarrying.

This paper outlines the nature and extent of land pollution and associated problems attributable to municipal wastes, industrial wastes and pesticides. The possibilities of land treatment for waste management are also discussed. The references are based on Indian experience which is, by and large, typical of developing countries.

Municipal Wastes

It is estimated that in India, municipal solid wastes are produced at an average rate of 0.33 kg per capita per day. From an urban population of about 185 million, this is of the order of 22.35 million tons per year. To this has to be added the large volume of sewage generated from a sizeable population which is not served with sewage systems.

Municipal wastes containing sewage and solid refuse are often discharged on land without adequate treatment. In many places, solid wastes are disposed of in open dumps or land-fills in low lying areas. In addition, industrial wastes containing hazardous substances are often disposed of at such sites, adding to the pollution problem.

In a land-fill, biochemical decay of organic material results in evolution of gases and liquids. Liquid products and extruded moisture tend to flow due to differential head. The dissolved material moves out due to concentration gradient. Among the major products of biodegradation are methane, carbon dioxide, organic chemicals of high BOD (and COD) and nitrates. Thus, the organic constituents and moisture in the wastes becomes a major source of land pollution and ground water contamination.

Several constituents are removed from or added to the percolating effluent depending on the characteristics of pollutants and the nature of soil strata through which infiltration takes place. The time lag between pollution of the land surface and its percolation to the ground water depends on a number of factors. These include the reactions in the topsoil and vadose zone (unsaturated layer), soil moisture, specific gravity and viscosity effects.

Compared to the flow on the land surface, movement of leachates containing pollutants from the topsoil to the ground water system is relatively slow. Hence the impact on the ground water quality often remains undetected until it is too late for remedial action.

Industrial Wastes

Land disposal of industrial wastes without requisite treatment continues to be a common practice for a number of industries. Solid wastes are mostly discharged into open dumps or land-fills which, as in the case of municipal wastes, are sources of land pollution and eventually ground water contamination. The effluents are either discharged into pits or passed through unlined channels to the nearby low lying areas. In some cases, industrial effluents are discharged into public sewers, where they mix with sewage and finally end up in the agricultural fields.

Some pollutants are attenuated by soil and the vadose zone, while a part of the wastes enters the ground water system through leaching. Thus, it is not uncommon to find high concentrations of some trace elements associated with industries in the ground water at a considerable distance from the industrial sites.

In India, systematic studies to monitor ground water pollution from industrial sources have been carried out at only a few places and for selected pollutants. However, even from the limited studies so far conducted, the seriousness of ground water pollution is evident. High concentrations of chromium, nickel, lead, copper and zinc in ground water have been observed near industrial areas. Iron and manganese concentrations exceeding 1,000 mg per litre, much higher than background values, indicate a direct relationship with the industrial sources. These pollutants, when discharged on land, react with soil and vadose zones forming stable complexes which lead to their attenuation. The fact that these pollutants are detected in ground waters in concentrations much above background values indicates that the process of attenuation has been supersaturated. Unless preventive measures are taken the problem of ground water pollution will assume alarming proportions.

Pesticides

Over the years, several hundreds of pesticides have been introduced for agriculture and public health purposes. The use of chemical pesticides in agriculture commenced in India around 1948-49. The manufacture of BHC and DDT started during 1952-53 and since then there has been a steady increase in the use of chemical pesticides. However, in recent years there has been a shift in favour of organophosphorus and carbamate formulations and due to growing concern about the persistence and adverse effects of DDT it has been decided to restrict its use to public health programmes.

The behaviour of pesticides applied on soil depends upon many factors such as absorption, leaching, volatilisation, run-off, uptake by soil organisms, microbial and chemical degradation and photolysis.

Pesticides in soil, whether introduced directly or indirectly, may persist and alter the structure and function of non-target organisms. Persistence of these chemicals depends on their nature, temperature, humidity and light and on the activities of soil micro-organisms which break down the chemicals rendering them less harmful. Most of the literature regarding persistence of pesticides is based on work in temperate regions where the half-life of most organochlorine pesticides varies from one to several years. In India, studies have shown that the half-life varies from three to nine months due to the high temperature and humid conditions.

Though the average consumption of pesticides in India is as low as 6.4 grams per hectare, the total consumption in terms of active ingredients is more than 80,000 tons per year. Notwithstanding the favourable climate for breakdown of chemicals, accumulation of pesticide residues has been reported in soil, water, fruits and vegetables and even human tissues.

It is estimated that of the total pesticides applied to crops, less than 0.1% reaches the target pests and more than 99% moves into the environment and in the food chain. It has also been noticed that a number of pests developed resistance on exposure to certain pesticides over an extended period. It thus becomes necessary to synthesise new pesticides creating further pollution problems. While insecticides and other invertebraticides such as nematicides and molluscides have a direct effect, herbicides and fungicides influence the soil faunal populations by affecting their food materials.

Inadequate Date Base

Most of the studies on the effect of land pollution have dealt with soil micro-organisms and insecticides. The available information on the population structure of soil organisms is not sufficient for prediction of models of pollution impacts. There is a need for further investigations on the effect of various pollutants, not only on the structure of the faunal populations, but also on how their functions affect the ecosystem. Pesticide and fertiliser combinations may exert synergistic and interactive effects on the ecosystems which are not yet well studied. The concept of integrated pest management reducing dependence on chemical pesticides also needs further investigation and large scale trials.

Information on the effect of industrial effluents and heavy metals on soil populations is scarce and scattered. Limited information is available on the effect of municipal wastes on the qualitive and quantitive composition of soil fauna.

Pollutants interact with a host of soil organisms. Termites, earth worms and other deep burrowing forms play an important role in the functioning of the ecosystems. Systematic studies on the effect of land pollution on such organisms may lead to useful findings as well as ways of mitigating land degradation.

Land Treatment for Waste Management

While indiscriminate discharge of wastes on land is of serious environmental concern, it needs to be recognised that land is the best available sink for ultimate disposal of wastes. This is particularly relevant in a developing country where it is unlikely that all wastes would be given the fullest treatment at source before disposal.

Controlled application of wastes on land can help in achieving a desired degree of treatment through the physical, chemical and biological processes within the plant-soil-water matrix. Partially treated waste water can be further treated though land application and land can serve as a 'living filter' comprising interaction of soil, vegetal cover and soil micro-organisms.

Depending on the methods of application and percolation, the land treatment of wastes may be of three types, viz. slow rate systems, rapid infiltration systems and overland flow systems.

To ensure safety in land treatment of waters it is essential to ascertain the background concentration of pollutants, the fate of pollutants added to the land and the risks involved in terms of assimilative capacities and acceptable limits. Decisions have to be guided by a clear understanding of the reaction processes and transport phenomena within and among the various sinks, namely living systems, soil, water and air. Pilot projects undertaken in selected areas have shown encouraging results from which it is possible to establish cost effective approaches for waste management through land treatment.

Conclusions

1. Land is a major recipient of pollution, but our knowledge of soil pollution interaction is far from adequate.

2. Land can serve as a 'living filter' as it provides a degree of waste treatment due to a combination of chemical, physical and biological processes in the soil. There is thus a need for better understanding of the processes and pollutant transport phenomena in the soil.

3. Sporadic studies made so far have shown promising possibilities for coupling the conventional pollution control activities (control at source and end-of-pipe treatment devices) with that of land treatment of wastes. This is particularly important where land treatment may be a cheaper and more effective means for prevention and control of pollution.

Discussion

Mr M L Richardson asked why the paper particularly refers to land treatment of wastes while it would be preferable to control at source. The speaker replied that control at source is, no doubt, the preferred option. However, with the given technologies of pollution control it is not possible to have foolproof treatment of wastes at source. Hence, part of it is unavoidably disposed of on land and the land can provide further treatment to such wastes. Since pollution control technologies are energy intensive, land treatment could be a cost-effective means particularly in developing countries. However, this does not mean indiscriminate disposal of the wastes.

Professor S Z Haider asked whether speciation of different chemicals had been done in the studies on land treatment of wastes. The speaker said that characteristics of different chemicals and soil-pollutant interaction studies were the basic pre-requisite for determining the methods for land treatment and so this had been the initial approach.

The Author

Bachelor of Chemical Engineering (Jadavpur University, Calcutta), 1963. Master of Technology in Food and Biochemical Engineering (Jadavpur), 1965. MSc in Agricultural Engineering (Louisiana University, USA 1969). 1969-1976 Professor Indian Agricultural Research Institute (New Delhi). Joined Government service in 1976 as Member-Secretary of the National Committee on Environmental Planning. Currently adviser in the Ministry of Environment and Forests, New Delhi. Areas of interest include soil conservation, waste management and non-conventional energy sources.

1.4 Urban Air Pollution: Problems and Trends in Latin America

J G Kretzschmar
Flemish Institute for Technology Research, Belgium

Introduction

The total population of Latin America approximates 450 million. The annual increase of 2.3% exceeds that in Europe, North America and Russia though it is lower than in Africa (2.8%).

While population densities are moderate or low, 40 per km^2 in Mexico and 11 per km^2 in Argentina, the degree of urbanisation is high. This is 70% of the total population in Peru, Mexico and Brazil and reaches 85% in Argentina, Chile, Uruguay and Venezuela. In 1985 twelve Latin American cities had populations exceeding 2.5 million, and four of the world's largest conurbations are Latin America; Mexico City, Buenos Aires, São Paulo and Rio de Janeiro. Annual growth rates are high and by the year 2000 populations may reach 26 million in Mexico City and 24 million in São Paulo.

Total energy consumption and specific consumption by fuel type and by sector or socio-economic activity are important facts in air pollution. The per capita consumption of commercial energy approximates 30 GJ, low compared with a world-wide average of 60 GJ. Coal, the most polluting fuel, represents only 6%, liquid fuels 65%, gas 20% and primary electricity (mainly hydroelectric) 9% of commercial energy production. The major contribution to air pollution comes from liquid fossil fuels especially when used in motor transport. Latin America has 60% of the automobiles in all developing countries and annual growth rates are high, eg. 11% in Brazil compared with 2% in the USA.

A high degree of urbanisation, heavy motor traffic, with high vehicle emission rates due to poor technology and maintenance and low quality fuels combined with adverse meteorological conditions (sunlight, inversion, stagnation) mean that pollution problems are unavoidable. This will be illustrated by considering the metropolitan areas of Mexico City and São Paulo.

Air Quality Guidelines and Standards

National Air Quality Standards in the cities under investigation are summarised in Table 1 together with the corresponding guidelines of the WHO.

Table 1. National Air Quality Standards and WHO Guidelines (in μg/m³)

Pollutant	t_{av}	Brazil	Mexico	WHO
SO_2	24h	365	350	100-150*
	AAM	80	-	40-60
SPM	24h	240	275	150-230*
	AAM	-	-	60-90
	AGM	80	-	-
Inh. Part. (<10 μm)	24h	150	150	-
	AAM	50	-	-
Smoke	24h	150	-	100-150*
	AAM	60	-	40-60
CO	1h	40.000	-	30.000
	8h	10.000	15.000	10.000
O_3	1h	160	220	150-200
NO_2	1h	320	400	400
	24h	-	-	150
	AAM	100	-	-
$HC-CH_4$	1h	-	160	-
Pb	3m	-	1.5	-
	AAM	-	-	0.5-1.0

t_{av}: Averaging time

AAM: Annual Arithmetic Mean

AGM: Annual Geometric Mean

* : 98th-percentile of daily averages for 1 year

SPM: Suspended particle matter

Air Pollution in Mexico City

The Metropolitan Area of Mexico City (MAMC) is situated in the Mexican Basin at an average altitude of about 2240 m. It covers an area of some 2500 km^2 surrounded by high mountains. Two valley channels, located in the North East and North West tend to funnel (contaminated) air to the centre and the South West of the city.

The local climate is subtropical with high average monthly temperatures around 15°C (12°C as lowest in January, 17°C as highest in May). Precipitation mainly occurs in the period June - September and totals 725 mm on a yearly basis. Due to the particular geographical characteristics and the light winds, ventilation is poor with a high frequency of surface as well as upper air inversions during winter time (on average 25 days/month in the period November - May).

The population approaches 20 million with an annual growth rate over 3%. The population density is almost 7000/km^2 in the centre to some 500/ km^2 in the least populated zones.

MAMC is the political, administrative and economic centre of Mexico with one third of the country's GDP, some 30,000 industries and 3 million motor vehicles moving slowly, responsible for 44% of the total energy consumption in MAMC and continuously loading the stagnant air with soot, SO_2, NO_2, CO, hydrocarbons and lead.

Air pollution monitoring in Mexico City began in the 1950s and by 1972, a 17-stations manual network for SPM (Hi-Vol) and SO_2 was functioning on a daily basis. In 1985 an automatic network with 25 stations for SO_2, CO, O_3, NO_x and hydrocarbons (HC) became operational as well. Despite this long history information is still incomplete.

In the late sixties and early seventies annual average SO_2 levels were in the range 40 - 190 mg/m^3, with daily maxima occasionally as high as 500 - 900 mg/m^3. Over the years the situation has not improved much and average SO_2 levels (50 - 160 mg/m^3) are still above WHO guidelines (Table 1).

Average SPM levels (Hi-vol gravimetric determination) were between 60 and 150 mg/m^3 by the end of the sixties and yearly average levels are now 150 mg/m^3 with daily maxima exceeding the 1000 mg/m^3 level.

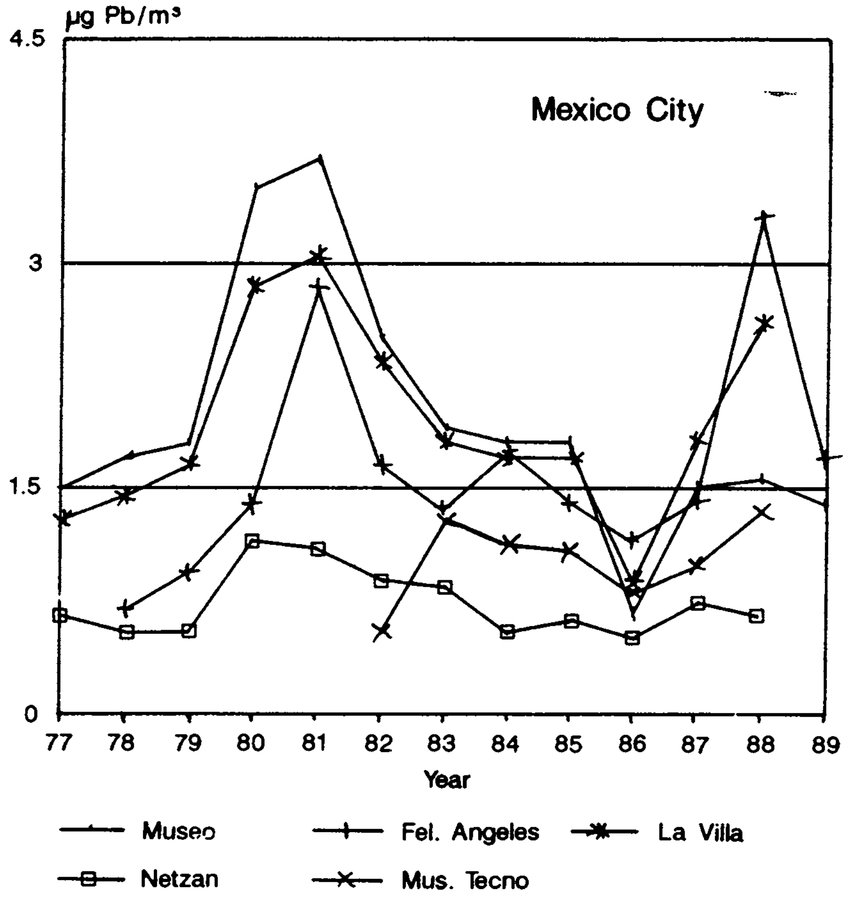
While the lead content of gasoline has officially been lowered from 3.5 ml/gallon before 1981 to 0.64 in 1986, lead-free gasoline is still not available locally. Consequently average lead levels are still too high though some overall improvement has been noted over past years as illustrated by Figure 1.

Ozone is undoubtedly Mexico City's air pollution problem number one, especially in the SW region. Hourly levels exceed 160 mg O_3/m^3 a couple of times (on the average 4 hours) during 70% or more of the days. Hourly peak values have been reported reaching 700 mg O_3/m^3. Recent reports (1) show a deterioration since 1986/87 when gasoline was reformulated with a lower lead content.

CO levels have been reported as surprisingly low (1) despite the extremely advance local conditions. However, a systematic overview of the actual CO measurements in Mexico City seems hard to find. The same applies to nitrogen oxides.

In conclusion it can be stated that the MAMC has very serious air pollution problems, mainly linked to local motor traffic.

Figure 1. Average Lead Levels in Mexico City



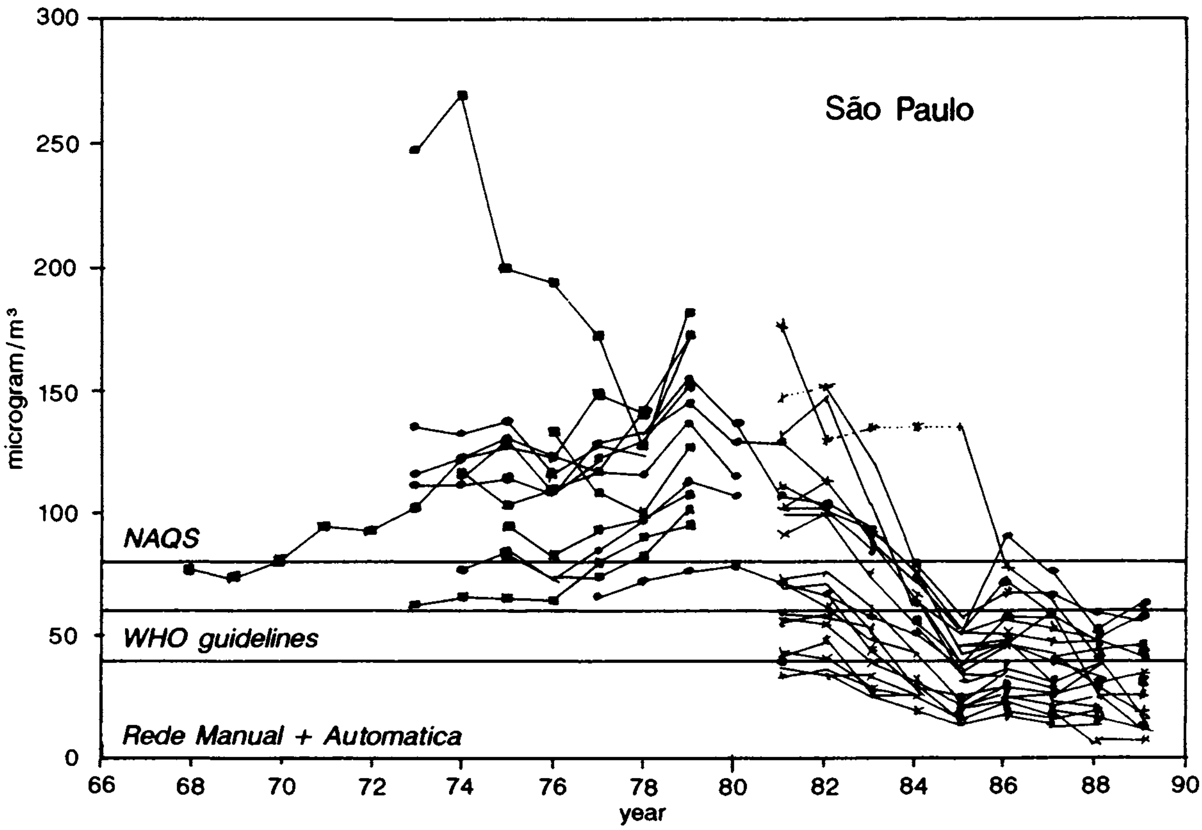
Air Pollution in São Paulo

The economically most important region in Brazil is the so-called Greater São Paulo Area (GSPA). The total area is close to 8000 km^2 with a complicated topography dominated by 650 m to 1200 m high hills. Some 5000 km^2 of GSPA is urbanised. The total population is approximately 17 million and continues to increase.

The local climate can be summarised as a dry winter (minimum temperature 8°C) followed by a wet summer (maximum temperature 30°C). In winter time subsidence inversions frequently occur with 'unfavourable dispersion conditions' 50% of the time. With almost 4 million motor vehicles major air pollution problems are a likely risk.

Air pollution monitoring started in 1968 with the measurement of the daily average SO_2 and smoke levels at one site. In 1981 CETESB (2) started a telemetric monitoring network with 25 fixed sites. SO_2 pollution showed an increase in the 1970s, a significant decrease in 1980-85 and a stationary situation afterwards (figure 2a). NAQS levels were met at all sites by the end of the 1980s and all average SO2 levels were within WHO guidelines.

Figure 2a. Yearly SO_2 Average in Manual and Automatic Network

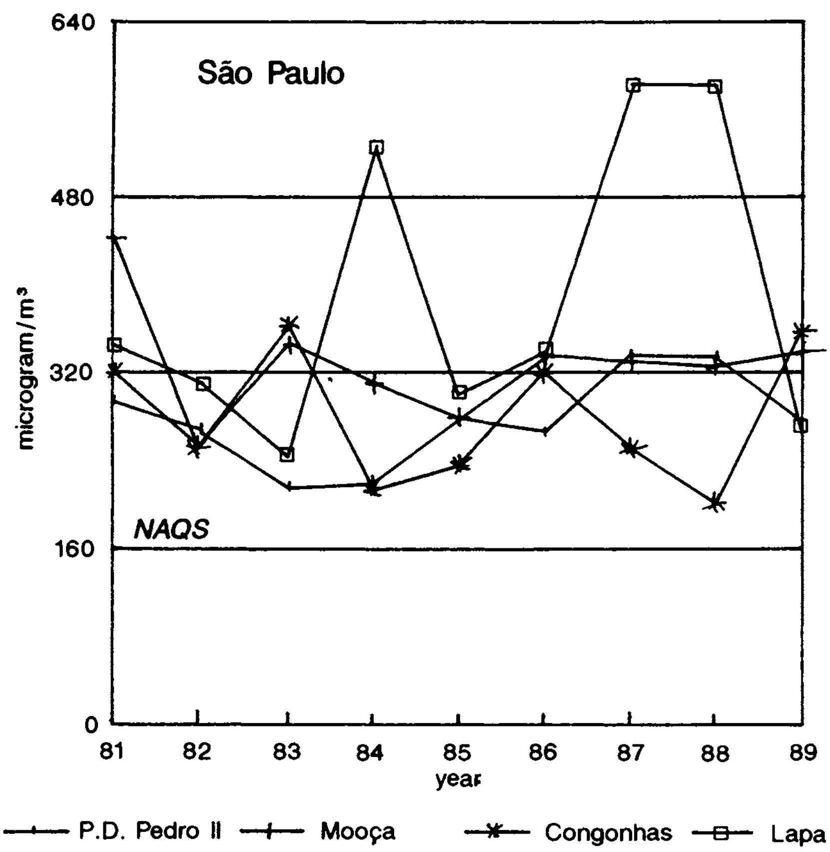


Measurements of Suspended Particle Matter (SPM) showed only a minor downward trend over six years. Major efforts to reduce ambient smoke levels have been less successful than for SO_2. WHO guidelines and NAQS standards are frequently exceeded at certain sites, particularly in winter. The enormous fleet of badly maintained diesels is the most probable cause of this problem.

The CO situation in São Paulo is really worrying and no improvement has been noticed over the past years. WHO guidelines and NAQS standards are exceeded in 4 out of 5 monitoring sites. In order to address this problem, and other traffic related problems such as NO_x, HC and O_3, the National Environmental Council enacted on 6 May 1969 an automobile emission control programme under which emission limits become progressively more stringent.

Nitrogen oxides, volatile organic compounds, high ambient temperature and intense solar radiation are ideal for ozone production at ground level. All these conditions are frequently met in São Paulo. The seriousness of the problem is illustrated in Figure 2b.

Figure 2b. Maximum Hourly Ozone Levels in Four Different Sites



The results of systematic monitoring of the daily lead levels at different sites show figures below WHO guidelines (Table 2). This reduction with time has occurred despite the rapid increase in vehicle numbers from 1.5 million in 1976 to over 4 million in 1990. The National Alcohol Programme launched in 1975 to reduce oil imports has been responsible for this by the introduction of gasohol (gasoline with 13 to 22% anhydrous ethanol) and the introduction of alcohol-based Otto engines; by 1990 more than 90% of the new cars will have alcohol-based engines.

Table 2. Three Monthly Average Pb-Levels (μg Pb/M³) in São Paulo

Site	1978	1983	1987
1	0.8-1.4		
2	0.9-1.2		
3		0.1-0.3	0.2-0.4
4		0.2-0.6	0.1-0.4
5		0.1-0.2	0.1-0.2
6	0.8-1.6	0.2-0.4	0.4-0.5

Acknowledgement

Collecting and analysing air pollution data for Latin America has been a slowly moving process over the past years. Although still incomplete, the first results are beginning to emerge. To a large extent this is due to the information obtained from many different local agencies and individuals and the help and support from the Monitoring and Assessment Centre (MARC) in London, the World Health Organisation (WHO) in Geneva and the United Nations Environmental Programme (UNEP) in Nairobi.

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The Author

Doctor in Applied Science, KU Leuvan, Belgium (1969) Hon. Research associate (1970) University College, London. Esro-Nasa Post-Doctoral research fellow (1970-71) University of California. 1965-72 KU Leuvan, Research Assistant, Electronics, 1972-83 Nuclear Energy Research Centre, MOL, 1984-85 Janssen Pharmaceutica, Beerse, Automation Manager, 1985-89 Project Manager at MOL, 1990 - Programme Manager 'Energy, Raw Materials and Environment' Nuclear Research Centre MOL. Temporary adviser WHO, Geneva. Visiting Professor International Institute for Hydraulic and Environmental Engineering, Delft, The Netherlands. Research Prize 1988 Royal Institute of Flemish Engineers.

1.5 Air Pollution Problems in Brazil

Tania Tavares
Federal University of Bahia, Brazil

Brazil faces air pollution problems of a regional and global nature. On regional terms, problems of industrial and urban origin exist only in a very localised way although serious in many cases. The town of Cubatáo, considered the most polluted area in the world until recently, suffered landslides over the town due to the destruction of slope vegetation, with loss of life. Identification of cause/effect relations on vegetation damage is needed. The city of São Paulo (9.7 million inhabitants) is one of the most polluted areas of the world due to motor traffic. With a 14.2% growth per decade, the atmospheric conditions of São Paulo would be worse if alcohol had not substituted about half of the otherwise gasoline fuel, eliminating lead use and reducing about 20% of carbon monoxide and hydrocarbon emissions. However, in 1989, due to the low world price of oil and the more attractive world price of sugar making ethanol production less economical, Brazilian ethanol fuel production was insufficient. Ethanol was substituted with methanol from natural gas but this increased aldehyde emission leading to enhancement of ozone. The acid formation resulting from the aldehyde affected the works of art in the museum (the greatest Baroque centre in the world).

On the global basis, the Brazilian atmospheric emissions of the greenhouse gas CO_2 have increased by 3,118% in the last twenty seven years. Although the increase in CO_2 emissions due to fossil fuel burning accounts for 318% of the total, the Brazilian per capita emission is low (0.38 tons C per capita), corresponding to 4.53% of the USA emission in 1982 and 33.5% of the world's per capita emission. The low per capita CO_2 emission in Brazil is due to extensive hydroelectric power, 85% in 1984 and 94% in 1989. However, most of the large-scale low-cost hydroelectric capacity is already being utilised and further expansion will involve high investment and high ecological cost. Alcohol use as fuel prevents an additional 12.5% of the present CO_2 emission (13 x 10^6 m^3/year ethanol used in automobiles, replacing the combustion of 10.8 x 10^6 m^3/year of gasoline). The remaining increase is due to forest burning which accounts for about 6.1% of the present estimated world emission of 5.5 x 10^9 tons C/year. Many uncertainties are involved in this estimation, mainly the following: biomass density on C uptake from recovering forest, grasslands and soil, annual deforestation, fraction of unburnt phytomass, inorganic carbon which is left over and in the soil, and depletion of soil organic carbon.

Many measures have been taken to avoid forest burning in the last two years. Farmers are discouraged from clearing forests for cattle ranching by removal of tax concessions. There are also limits on timber exports.

Illegal forest burning is being detected by remote sensing via satellite and heavy fines are imposed. As a result, the clearance and burning of the Amazon forest has slowed down significantly. However, Brazil is pressed by the increase of its population and has an urgent need for development which will cause a substantial increase in energy demand and use of natural resources. Additionally Brazil has foreign debts amounting to more than US $120 billions. Constraints on usage of natural resources because of global environmental effects will hardly be accepted by the politicians and the population. Brazil has been pressed by the developed countries to preserve its nature and as a result the Government announced in April 1989 an ambitious new environmental programme. There is, however, a nationwide feeling that the developed countries have already destroyed their forests in the past and are presently responsible for the greater part of C emissions.

Brazilian emissions of non-natural greenhouse gases (CFCs) are insignificant and those of natural ones (N_2O and methane) are not estimated. There is a great need for research in many aspects of this problem.

The Author

Professor of Analytical Chemistry and Director of the Environmental Interdisciplinary Centre of the Federal University of Bahia, Brazil.

1.6 The WHO/UNEP Global Environment Monitoring Systems (GEMS) Programmes for Measuring Human Exposure to Air Pollutants

David Mage
World Health Organisation, Geneva, Switzerland

The WHO/UNEP GEMS Programme recognises that ambient (outdoor) air quality data, although useful for many other purposes such as control and trends, does not reflect human exposures to air pollution. People spend of the order of 90% of their time indoors where the presence of pollutant sources and sinks can enhance or mitigate the outdoor pollutant effect.

It is necessary to determine the amounts of pollutants people actually take in. WHO/UNEP GEMS is encouraging the conjoint approach of measuring personal exposures to air pollutants (through all media) along with ambient air quality as an appropriate tool for definition and solution of air pollution problems. This is the GEMS/HEAL (Human Exposure Assessment Location) programme in developed and developing countries. The member countries are Brazil, China, Germany, Hungary, India, Japan, Mexico, Russia, Sweden, Thailand, USA and Yugoslavia. The measurements are difficult to carry out as people vary widely in their ventilation rates. Measurements include the use of monitors in situ, indoors and outdoors and personal, analysis of duplicate meals etc.

Preliminary results have been obtained of lead and cadmium levels in a number of cities. Lead levels have decreased over time as a result of the decreased use of lead in motor fuel. However, cadmium levels have remained constant due to the fact that the cadmium is all derived from food.

Future determinations on eg. mercury, fluorine, will depend on which items are chosen by collaborating countries.

1.7 Water Quality Assessment Around the World: The Role of Chemistry with Particular Reference to Brazil and Malaysia

Deborah Chapman
Environment Consultant, Kinsale, Republic of Ireland

Introduction

Access to water of adequate quality is essential for human health, food production and sustainable development. Every human use of water (whether for drinking, irrigation of crops, industrial processes or recreation) has a minimum acceptable quality. This quality can be described in terms of physical, chemical or biological properties.

Physical properties, such as temperature and turbidity, are often easy and cheap to measure but rarely give sufficient information on water quality when measured alone. It is important to understand the physical properties of a water body as an aid to interpretation of chemical or biological information. Chemical properties, such as major ions and dissolved elements, describe basic water quality, and when combined with measurements of metals and organic chemicals can give some insight into man's impact on a water body. Chemical measurements can be made using techniques with a wide range of complexity and sophistication. Most of the variables required for the determination of basic water quality can be undertaken by relatively cheap and simple methods.

Biological properties can be described by studying the individual species, or whole communities, present in a water body. These methods indicate changes in water quality arising from combined impacts on a water body (natural and/or man-made), but rarely indicate the precise cause of a change in quality. They can be cheap to perform but are usually based on a knowledge of regional flora and fauna. Therefore, any particular method cannot be used around the world without local adaptation.

The assessment of water quality is an evaluation of the characteristics of the water in relation to defined objectives. Typical objectives include: (i) determination of suitability for specific uses, eg. drinking water or irrigation, (ii) determination of the impact of human activities, eg. industrial discharges, (iii) determination of trends in water quality, (iv) determination of natural water quality, ie. unaffected by man and (v) determination of fluxes of pollutants, nutrients and suspended solids from river basins to coastal waters and oceans. Monitoring is the activity which gathers the necessary information and data to enable assessments to be made.

Global Water Quality Monitoring and Assessment

Many large rivers and lakes cross international boundaries. The increasing use of such water bodies for waste disposal in recent decades has necessitated the expansion of water quality monitoring and assessment activities from a local to an international scale. Consequently the need for global information on water quality has become more urgent. The Global Environment Monitoring System (GEMS), which is a component of the United Nations Environment Programme (UNEP), began collecting water quality data on a global scale in 1978 as part of the GEMS/WATER programme. This programme, implemented by the World Health Organisation (WHO) and supported by UNEP, UNESCO (United Nations Educational, Scientific and Cultural Organisation) and WMO (World Meteorological Organisation), also aimed to promote and establish water quality monitoring in the developing regions of the world through training and support.

Countries participating in the GEMS/WATER programme carry out as many of the defined chemical measurements as they are able, at selected sites from important water bodies. There are relatively few stations in any one country. Brazil currently has twelve stations, all situated on the eastern side of the country. Malaysia, which is a relatively small country, currently has seven river stations. GEMS/WATER sites are often already in use as part of the nation's own water quality monitoring programmes. A list of the basic measurements required to be made at all sites is given in table 1. The results of the monitoring are submitted to the WHO Collaborating Centre on Surface and Ground Water Quality at the National Water Research Institute (NWRI), Burlington, Ontario, Canada where they are stored in the GEMS/WATER computer database. These data indicate that most developing countries participating in the programme can make the basic chemical measurements using techniques recommended in the 'GEMS/WATER Operational Guide' (1). However, few developing countries regularly submit results obtained using techniques such as Atomic Absorption Spectroscopy (AAS) which are recommended for the detection of metals. This led to problems in using the data available in the GEMS/WATER database when the first global assessment of surface water quality was undertaken by GEMS in 1989, ten years after the programme began. However, by using additional published material the global assessment (2,3) was able to identify nine principal water quality problems which are either widespread around the globe or emerging as possible future global issues. These were:

1. Organic matter pollution: Principally arising from domestic wastewater and affecting developed and developing countries.

2. Accelerated nutrient enrichment: Arising largely from the widespread use of phosphorus in detergents and affecting mainly lakes from all regions of the world.

3. Salinisation: Often associated with poor irrigation practice or excessive irrigation.

4. Nitrate enrichment: A problem mainly for developed countries, especially in regions of high nitrate fertiliser use on agricultural land. It is particularly a problem where groundwaters used as drinking water sources become contaminated. High nitrate levels present a health risk to bottle-fed infants.

Table 1. Basic Variables to be monitored at all GEMS/WATER Monitoring Stations

Variables	Rivers	Lakes and Reservoirs	Groundwaters
Water discharge/level	*	*	*
Total suspended solids	*		
Transparency	*		
Temperature	*	*	*
pH	*	*	*
Electrical Conductivity	*	*	*
Dissolved Oxygen	*	*	*
Calcium	*	*	*
Magnesium	*	*	*
Sodium	*	*	*
Potassium	*	*	*
Chloride	*	*	*
Sulphate	*	*	*
Alkalinity	*	*	*
Nitrate plus nitrite	*	*	*
Ammonia	*	*	*
Total Phosphorus, unfiltered	*	*	
Total Phosphorus, dissolved	*	*	
Silica, reactive	*	*	
Chlorophyll a	*	*	
Fluoride			*

5. Pesticide contamination: Pesticides are used all over the world with different levels of control applied to their use. Many pesticides end up in surface water and a few have been detected in groundwaters. They are harmful to the aquatic environment and can present a human health risk to water users when in high concentrations.

6. Suspended particulate matter: Deforestation and changing agricultural practices are making large areas around the world susceptible to soil erosion. The soil is washed into rivers, increasing their suspended matter load.

7. Metal contamination: This currently affects some of the major rivers in the developed world and is a growing problem in newly industrialising regions. The contamination arises from such sources as industrial waste discharges and mining operations.

8. Acid precipitation: Acidification of surface waters, particularly lakes, is occurring in areas of the world where susceptible waters are affected by acid depositions resulting largely from the burning of fossil fuels. The problem is thought to be extending to some developing regions of the world.

9. Synthetic organic micropollutants: These are man-made chemicals not normally occurring in the environment and their potential environmental effects, transformations and persistence are usually not adequately known or understood. Detecting such chemicals can be technically difficult and expensive, and most are not routinely included in monitoring activities.

One of the conclusions reached by the group of experts considering the global assessment of water quality was that the GEMS/WATER programme should be reviewed and possibly revised. This has been undertaken and the new programme took effect in 1990 (4). A greater emphasis has been placed on the assessment activities of the programme and many new stations have been selected to fulfil the revised objectives. These objectives are:

A. To provide water quality assessments:

   (i) to define the status of water quality,

   (ii) to identify and quantify trends in water quality,

   (iii) to define the causes of observed conditions and trends,

   (iv) to identify the types of problems that occur in specific geographical areas,

   (v) to provide the information and assessment in a form that resource management and regulatory agencies can use to evaluate management alternatives and make necessary decisions.

B. To provide information on the fluxes of toxic chemicals, nutrients and other pollutants for the world's major river basins to the continent/ocean interfaces.

C. To strengthen national water quality monitoring networks in developing countries, including the improvement of analytical capabilities and data quality assurance.

The revised global network consists of:

Baseline stations (total 46) away from sources of direct pollution and human activity. These stations provide information on background levels of water quality and the global transport of pollutants.

Trend stations (total 250) which represent human impact and are, therefore, located in areas with multiple or specific impacts on water quality.

Global river flux stations (total 67) which are located downstream, on major rivers with large drainage basins in order to determine fluxes of organic and inorganic contaminants, nutrients, etc. to the continent/ocean interface.

To aid in future assessment of GEMS and other water quality data, NWRI has developed microcomputer-based software for the statistical treatment, synthesis and presentation of the data. The software package is known as RAISON (Regional Analysis by Intelligent Systems on a Microcomputer) and integrates the use of maps with tabulated and graphically presented data. Hence it is possible to illustrate on one page the trends in water quality variables at selected sites, superimposed on a map showing the locations of the chosen sites. Many forms of graphical presentation are possible, including methods which indicate the statistical variability of the data sets. When GEMS/WATER data are examined in this way it is possible to observe differences in water quality for geographical regions, observe variability in monitoring results for single sites and to make comparisons of national data with global averages. However, when examining the graphical presentation of data from single sites, caution must be applied in their interpretation. The accuracy and reliability of the analytical measurements may not be known without further reference to the results of analytical quality control programmes carried out as part of the GEMS/WATER programme or by the individual laboratories themselves. This can be illustrated by the measurements for total mercury concentrations using AAS at a GEMS station in Brazil (Rib. Serra Asul-Fraz Sobradinho). During 1986 and 1987, values as high as 8.00 $\mu g\ l^{-1}$ were recorded in the GEMS database for this station. However, the maximum value for mercury recorded from all global stations submitting data to the GEMS database from 1982 to 1984 was only 0.5$\mu g\ l^{-1}$. This suggests that the results from the station in Brazil are abnormally high and should be investigated further to determine the cause, which could be due to analytical difficulties or severe environmental problems.

Approaches to Water Quality Monitoring and Assessment in Developing Countries: Brazil and Malaysia

Many developing countries have now initiated their own national water quality monitoring programmes. Chemical monitoring, combined with some physical measurements, provides the best method of obtaining regular assessment of the impact of development on countries' water resources. The facilities for advanced analysis of trace quantities of metal or organic chemical pollutants are often not available for regular monitoring.

Nevertheless, more simple chemical measurements can be used to monitor the changes in overall quality of regional water resources as can be illustrated by reference to Brazil and Malaysia.

These two countries are very different in size. The total land area of Brazil is 8,457 x 10^3 km^2 and of Malaysia is 329 x 10^3 km^2(5). Whereas Malaysia has a national monitoring programme designed and administered by the Department of Environment in Kuala Lumpur, water quality monitoring in Brazil is conducted by state agencies. Only a few Brazilian states have extensive programmes and make the results widely available.

In the rapidly industrialising state of São Paulo, Brazil, chemical measurements are used to produce a Water Quality Index for river stations. The index is based on the measurements of pH, Biochemical Oxygen Demand (BOD), total nitrogen, total phosphate, temperature, turbidity, total residue, dissolved oxygen and faecal coliforms (ie. bacteria associated with human faeces). The results of these analyses at any site are used to calculate an index value between 0 and 100 (see ref. 6 for details of the calculation of the index). A value between 80 and 100 indicates excellent water quality, between 52 and 79 indicates good, between 37 and 51 adequate, between 20 and 36 inadequate for conventional water treatment and between 0 and 19 totally inadequate water quality. These five categories are used to produce a colour map each year with five different colours indicating the stretches of rivers conforming to the five levels of water quality. This method of data analysis and presentation has the advantage that it clearly illustrates the changes in river water quality from year to year and the extent of the river systems which can be classed as excellent or inadequate. No expert knowledge is required to understand the presentation, making the approach particularly suitable for informing managers, policy makers and the general public.

In the 'Environment Quality Report' of 1988, the Malaysian Department of Environment analysed the sources of complaints about water pollution. This showed that 51% of the complaints related to effluents high in organic matter, such as those from the rubber and palm oil industries and animal husbandry. Since 1978 the Malaysian government has been carrying out extensive water quality monitoring. According to the 1988 report, 3009 samples were collected from 575 sites on 87 major rivers. The assessment of river quality is based on five main measurements: BOD, COD (Chemical Oxygen Demand), suspended solids, ammoniacal nitrogen and pH. Metals and nutrients are also studied at selected locations. The choice of measurements reflects the nature of the principle pollution problems and the difficulty involved in analysing other variables. In 1988 over 2,000 analyses were undertaken for variables such as suspended solids, conductivity and BOD, whereas less than 1,000 were made on any of the common heavy metals and less than 300 for organic chemicals such as pesticides. The results are compared with standards for water quality set by the government. Assessment is principally based on the examination of regional variations in water quality, the status of the rivers eg. whether polluted rivers are deteriorating or improving and trends in individual rivers. Over the period 1985-88, river water quality has improved in general but the situation with respect to suspended solids in polluted rivers has deteriorated. Further details of the assessments are available in the annual 'Environment Quality Reports' published by the Department of Environment, Kuala Lumpur.

Conclusions

Chemical monitoring plays a major role in the GEMS/WATER global water quality monitoring and assessment programme. Simple chemical techniques provide the means for determining basic water quality and a basis for monitoring systems in developing countries. Chemical data are an essential component of water quality management and can be used, for example through water quality indices, to present the results of water quality assessments in a readily understood and attractive form.

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The Author

BSc (1st Class Hons) in Environmental Biology, Chelsea College, University of London 1978. PhD in Limnology, Royal Holloway College, University of London 1981. 1981-83 St Thomas's Hospital London; Cancer Research 1983-86 Department of Zoology, University of London: Marine pollution research. 1986-90 The GEMS Monitoring and Assessment Research Centre (MARC), King's College, London: Deputy Director 1988-90. Freelance Environment Consultant, Kinsale, Republic of Ireland, principally engaged over the last nine months as a temporary adviser to WHO and UNESCO in relation to the GEMS/WATER programme.

1.8 Water Pollution Problems in the Indian Subcontinent with Special Reference to the Ganga Action Plan

B K Handa
National Environmental Engineering Research Institute, Nagpur, India

The river Ganga has for years been subjected to tremendous pressures. Most of its water in the upper reaches is diverted to canals, and untreated domestic and industrial wastewaters are dumped into the river at several places. It is estimated that 900 million litres of sewage is discharged into the river every day and this accounts for 75% of the total pollution reaching the river. The residues of pesticides and insecticides used in agriculture also contribute non-point pollution in the river.

Recognising the magnitude of the problem and realising the importance of water quality as a principle element of river management, the Government of India established the Central Ganga Authority in 1985 for planning and execution of a timebound programme to prevent pollution of the river. The Ganga Action Plan (GAP) is being implemented through R and D inputs in the areas of water quality monitoring and modelling, wastewater treatment and environmental impact assessment provided by several research and academic institutions, the Council of Scientific and Industrial Research laboratories, public health engineering departments, consulting firms and international and bilateral funding agencies.

The National Environmental Engineering Research Institute (NEERI) is engaged in a 36 month study, which commenced in December 1988, on the assessment of the impact of the Ganga Action Plan on public health carried out under the joint sponsorship of the Ganga Project Directorate and the Indian Council of Medical Research, and in collaboration with the All-India Institute of Hygiene and Public Health, Calcutta. The study aims at evaluation of the benefits of the project vis-à-vis the costs, and identification of corrective/supplementary measures, if deemed necessary. The cities of Varanasi and Nabadwip were chosen as project sites in view of their religious and cultural significance. The study will also help in designing cost-effective strategies for similar water quality management programmes in future.

Yet another significant contribution of NEERI to GAP relates to the ranking of technology option for wastewater management. A ranking system, based on the criteria of environmental, health and aesthetic risks, annualised cost, operation and maintenance cost, land requirement and system reliability developed by the Institute, has been used to identify the most appropriate and cost effective wastewater treatment systems for two towns in Bihar, viz. Munger and Bhagalpur. There were several feasible options - activated sludge, percolating filter, design flow, stabilisation pond and aerated lagoon - chosen to meet effluent standards. The study identified a stabilisation pond as the most cost-effective system for Munger in spite of its high land requirement. For Bhagalpur, the most appropriate option was the aerated lagoon.

1.9 Growing Health Hazard from Toxic Metals in the African Environment

Jerome Nriagu
National Water Research Institute, Ontario, Canada

Introduction

Any concern for environmental quality is subservient to job creation and the provision of food and shelter in most African communities. By necessity, most of the limited medical resources are devoted to preventive primary health care aimed at combating high rates of infant and maternal mortality, endemic communicable diseases and malnutrition. Environmental health is generally associated with affluence and misguided industrial operations in the developed countries and as such is believed to be a non-issue in Africa. In a recent review paper, I have shown that the ambient concentrations of trace metals and metalloids in some environmental compartments of Africa are comparable to, and often exceed, the levels being found in the developed countries (1). As the metal contamination continues to rise sharply, environmental metal poisoning will likely become another major public health burden on the African population.

Contamination of the African Environment with Toxic Metals

Practically every metal known to mankind is being discharged in one form or the other somewhere in Africa. The continent is richly endowed with mineral resources (Table 1), the mining and smelting of which have become the principle anthropogenic sources of toxic metals. To derive foreign currency, the metal deposits are exploited for short-term economic benefits with little regard for long-term environmental consequences. Regulations on emissions are lax and rarely enforced and the pollution control devices are often not repaired or replaced when they break down. With few exceptions, the mining and smelting centres of Africa are marked by severe environmental contamination with toxic metals and serious impairments of health in non-occupationally exposed people have been reported (1).

In addition to mining and smelting of ore minerals, other important sources of metal pollution include (a) transportation vehicles especially automobiles; (b) fossil fuel combustion to generate energy; (c) burning of fuel wood, agricultural waste and forest/savanna biomass; (d) litter which seems to be everywhere in the urban areas; (e) fertilisers with high Cd content; (f) municipal and industrial sewage and wastewaters; (g) manure derived from household wastes; (h) the spray of metallic fungicides and mulluscicides (see Nriagu, 1991 for details). With emissions from so many sources, the concentrations of trace metals in many ecosystems of the continent have reached unprecedented levels.

Table 1. Mineral Resources of the African Countries

Country	Mineral Resource
Algeria	Lead, zinc, mercury, iron ore, uranium, oil
Angola	Gold, iron ore, oil
Botswana	Copper, nickel, coal
Burkina Faso	Manganese, gold, copper, bauxite, uranium
Burundi	Nickel, gold, copper, platinum
Ethiopia	Gold, platinum, copper
Gabon	Manganese, iron ore, uranium
Ghana	Gold, bauxite, manganese
Guinea	Gold, bauxite, iron ore
Madagascar	Manganese
Mali	Bauxite, iron ore, gold, manganese
Mauritania	Copper, iron ore
Morocco	Lead, manganese, phosphate
Namibia	Copper, lead, zinc, uranium
Nigeria	Tin, columbite, iron ore, coal, oil
Rwanda	Tin
Somalia	Uranium
South Africa	Gold, platinium, coal, iron ore, chromium, manganese
Sudan	Copper, chromium, industrial metals
Tunisia	Lead, zinc, iron ore, oil, phosphate
Uganda	Copper, cobalt
Zaire	Copper, cobalt, zinc, manganese, tin, gold, silver, bauxite, coal, oil
Zambia	Copper, zinc, lead, cobalt, coal
Zimbabwe	Gold, copper, chromium, nickel, tin

The airborne concentrations of Pb in the congested central districts of Cairo average 4.9 $\mu g\ m^{-3}$ in summer and about 3.0 $\mu g\ m^{-3}$ year round (2); these ambient values exceed the 1.5 $\mu g\ m^{-3}$ threshold recommended for the protection of public health (3). From the monthly average dust concentrations at street level in Ibadan (Nigeria) reported to be 48-76 mg m^{-3} (4), the airborne Pb concentrations are estimated to be well over 4.5 $\mu g\ m^{-3}$ The high atmospheric Pb levels in Cairo, Ibadan, Lagos and many other cities of Africa can be attributed to traffic congestion, high dust loads in the air, narrow streets, arrested air flows, lack of rainfall and helter-skelter development and siting of industries.

Studies using biomonitors such as mosses, lichens and tree barks generally find levels of trace metal pollution in urban areas of Africa that are similar to those in cities of the developed countries (5-8). The reported high flux of Pb into the Gulf of Guinea of over 1000 $\mu g\ m^{-2} yr^{-1}$ (9) provides a dramatic illustration of the high intensity of Pb emissions from natural and anthropogenic sources in West Africa. Indeed, elevated levels of Pb in roadside ecosystems have been documented in many rural and urban areas of Africa (1). The Pb contents of roadside dusts exceed 7000 $\mu g\ g^{-1}$ and average 770-1820 $\mu g\ g^{-1}$ in many parts of the city of Lagos, Nigeria (10). In Nairobi, Kenya, the soil Pb concentrations exceed 4000 $\mu g\ g^{-1}$ in the industrial areas and 2000 $\mu g\ g^{-1}$ in the city centre (11). The traffic density may be lower but the African cities are much more dusty, dirty and congested, resulting in the accelerated build-up of lead in urban ecosystems.

The high concentrations of trace metals that may have been reported in surface waters of Africa are most likely due to sample contamination. The sediments however provide strong evidence of toxic metal pollution in many aquatic ecosystems. The trace metal concentrations in the River Niger delta sediments (12) are often much higher than the values observed upstream (13). The Hg, Zn and Pb concentrations in Ebrie Lagoon sediments, Ivory Coast, reach values which are 30-, 6- and 20-fold higher than those of uncontaminated sediments in the same region (14). The Cd, Cu, Ni, Pb and Zn contents of Lagos Lagoon sediments of 6.2, 7.5, 113, 178 and 46 $\mu g\ g^{-1}$ (15) are several times higher than those of uncontaminated sediments in the country. Downstream from Cairo, the Cd, Cu, Cr, Zn and Pb concentrations in finegrained (<2μm) sediments of River Nile have been shown to be 18, 13, 8, 8 and 5 times higher than those in sediments upstream of the city (16).

The synoptic review above points to the fact that African ecosystems are far from being free of toxic metal pollution. In fact, the levels of pollution in the cities are comparable to, and sometimes exceed, those of urban areas of developed nations. Marked increases in the release of toxic metals into the environment can be expected in future. The exploding population in the continent will entail larger demand for metallic goods and products. The rapid and unplanned urban growth will be accompanied by increased traffic, energy consumption, and industries in undesirable locations. With limited financial resources, pollution-prone cottage industries are encouraged while lax or ineffectual environmental controls entice the multinational companies to locate their polluting industries in these countries. The expected net result will likely be a sharp rise in the flow of toxic metals into the African environment.

Human Exposure

The exposure of African populations to increasing levels of pollutant metals in their environment represents a hitherto unrecognised health hazard. The narrow streets and overcrowding in urban areas, the helter-skelter location of pollution-prone industries, the open type of home designs, the vibrant outdoor lifestyle, the endemic dusty environment, the prevalence of contaminated dusts, both indoor and outdoor, poor nutrition and health, poor hygienic practices and the preponderance of children and pregnant women (the two groups at most risk) can combine to increase the level of exposure and susceptibility to lead and other metal poisoning. In addition to living conditions and lifestyle, cultural practices can also influence the exposure to toxic metals in terms of religious beliefs, medical treatment, food habits and beauty practices. Heavy metals for instance are featured in the *materia medica* of traditional African medicine. Preparations of lead sulfide in various organic bases are used in most parts of the continent as an eye salve or cosmetic under such names as kohl, tiro, tanjere, etc. (17). Elevated blood lead levels and even chronic lead poisoning have been associated with such an exposure route. Even some of the medicinal plants are known to be bioaccumulators of toxic metals (18).

One of the important sources of environmental mercury pollution in Africa is the widespread use of medicated soaps and skin-bleaching creams and potions that typically contain 5-15% of an amino mercuric halide as the active ingredient (1). These products have also been implicated as a major cause of nephrotic syndrome among the sophisticated young African women. One study at the Kenyatta National Hospital, Nairobi found that about 70% of student nurses used the mercurial skin toner and that the levels of Hg in urine and several tissues were correlated with the use of these products (Table 2). Since the absorption of Hg through intact skin is very slow, most of the Hg is probably transferred into the body by food handling and hand to mouth activity. Since personal hygiene is often limited by the scarcity of water, food handling and hand to mouth activity (and a lot of people eat with their fingers) must be regarded as a particularly important route of exposure for many contaminants. Other notable adventitious routes of metal exposure in African communities include earthenware vessels improperly glazed in primitive potteries and the ubiquitous cottage industries which sometimes result in severe contamination of the home environment.

Contaminated dusts and soils represent a major source of lead exposure in African children, especially in crowed urban areas. Soil Pb intake by infants (1-4 years old) has been estimated to be 0.5-7.5 μg per kg body weight per day (1). When the daily intakes from air inhalation (0.02-1.0 μg Pb kg^{-1} body weight) and foods (0.3-1.8 μg Pb kg^{-1} are also taken into account, it is clear that many children in African cites are being exposed to Pb levels that may exceed the WHO recommended Pb intake tolerance of 7μg kg^{-1} day^{-1} from all sources (21). In fact, it has been suggested that 10-30% of the children in some urban areas of Africa may already be suffering from lead poisoning (1). Chronic lead poisoning which induces depression, behavioral and neurological disorders in children, hypertension in adult males and negative pregnancy outcomes in females, remains one of the unrecognised public health issues in contemporary Africa.

Table 2. Effects of Skin Bleaching Creams on Mercury Levels in Urine and Body Tissues*

Tissue or body fluid	Group A	Group B	Group C
Urine	109 μg/l	6 μg/l	2 μg/l
Scalp hair	2108 μg/g	137 μg/g	11 μg/g
Pubic hair	335 μg/g	25 μg/g	18 μg/g
Fingernails	165 μg/g	62 μg/g	9.7 μg/g

* Group A subjects were using mercurial skin bleaching creams at the time of the study; Group B subjects had used such creams but had stopped using them at the time of the study; Group C subjects had never used any mercury-containing skin toners. Urine samples were from healthy female nurses while the tissue samples were obtained from patients with nephrotic syndrome (19, 20).

The Pb concentrations in body fluids and tissues point to a silent epidemic of environmental lead poisoning in Africa. The blood lead (Pb-B) concentrations in urban and rural residents of Egypt of 170-360 and 140-250 μg l^{-1} respectively (22) suggest that a large number of people have Pb-B above the CDC recommended medical intervention threshold value of 250 μg l^{-1}. The Pb content in hair of adult males in Khartoum, Sudan have been showed to be significantly higher than those of Britons, Germans and Saudi Arabians (23). A recent study of trace metal concentrations in human milk from six countries found the highest values for As, Cd, Cr and Hg in Nigeria or Zaire (24). Unfortunately, few systematic studies of the Pb-B distribution in African children has actually been reported. It is hoped that the present report on a silent epidemic of childhood lead poisoning will stimulate such an overdue investigation.

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The Author

1965 BSc (Hons) University of Ibadan, Nigeria, 1967 MS, University of Wisconsin, Madison. 1970 PhD University of Toronto, 1987 DSc (meritorious) University of Ibadan, 1970- Research Scientist, Environment Canada, 1985- Adjunct Professor, University of Waterloo, Canada, 1992 Visiting Professor, School of Public Health, University of Michigan, Ann Arbor, 1984 Editor 'Science of the Total Environment' (Elsevier) and of 'Advances in Environment Science and Technology' (Wiley), Founding Editor 'Heavy Metals in the Environment' (Elsevier). Rigler Medal of the Canadian Society of Limnologists 1988.

1.10 Water Pollution Monitory Assessment and Control - A Case Study for Solving Water Pollution in a Petrochemical Industrial Area

Wang Ju-Si
Chinese Academy of Sciences, Beijing, China

Water pollution is a most serious environmental problem in China. The amount of wastewater is increasing year by year and reached 36.8 billion M^3 in 1988. Water treatment techniques and facilities have lagged far behind the growth of industrial development and city construction. Only 25% of industrial wastewater and less than 3% of domestic sewage was treated. Even for factories in which wastewater treatment facilities have been built, drainage may still not reach the standard of wastewater discharge. This situation often happens in those industries such as chemical, petrochemical and pesticide production, coal gasification, dyeing and printing, etc.

This paper considers how to solve water pollution problems in a petrochemical industrial area.

Problems Arising

A petrochemical corporation located in the southwest of Beijing was built in 1967 and gradually extended to become one of the biggest enterprises in China. The corporation has one refinery, four chemical factories, a rubber plant, a chemical fibre carpet plant and two power stations. About 120,000 M^3 of wastewater is produced each day, 75% from industrial waste and 25% from domestic waste. Three wastewater treatment plants were built during the 1970s and these accept and treat highly contaminated industrial wastewater (30% of total industrial wastewater in this area). These treatment plants have played an important role in water pollution control, but the situation has deteriorated since the early 1980s. Treatment efficiency decreased year by year, the outlet water of the plants still had high CODs and a high level of pollutants and was over the national standards of wastewater discharge. Water pollution became serious in this area. Surface water and ground water became polluted in different degrees, even the water reservoir which accepted water from the three wastewater treatment plants became a heavily contaminated water pond. Crops and vegetables which were irrigated with the water from the reservoir were polluted and could not be used as food. In order to solve the pollution problems, the corporation invited many experts from research institutes and universities to discuss and study ways of improving the environment in this area, and a number of projects were introduced between 1985 and 1988.

Here as an example we show how to improve the effect of one wastewater treatment plant which accepts and treats the wastewater from four factories. The projects followed the following procedure: investigation, assessment, proposal, design and practice.

Investigation, Research and Proposal

1. Sources of pollution were investigated and major sources identified. Measures for pollution control and suitable techniques for wastewater treatment from pollution sources were studied. Some special techniques were developed depending on the chemical properties of the pollutants in the wastewater so as to be very effective and economical.

2. Based on a diagram of the wastewater drainage system, the degree of pollution in each drainage line was assessed and major pollutant points needing control were identified.

3. The factor which had the most effect on the running of the wastewater treatment plant was the lack of any pretreatment inside the production factories. Sometimes as a result of an emergency in the production system, a large quantity of chemicals was discharged into the wastewater system. This caused a high concentration of chemicals to build up in the entrance to the wastewater treatment plant giving the plant a big 'shock'. So the wastewater system became overloaded and could not be restored for a long time.

   It was suggested that pretreatment measures and facilities, such as oil separation tanks, wastewater storage tanks, etc. must be built inside the production factories.

4. Wastewater characterisation and analysis, pollutant identification and quantitative determinations were made. This was done for each pollution source, the effluent from each factory and the inlet and outlet of the wastewater treatment plant. More than a hundred organic pollutants were determined in wastewater. Major pollutants in the effluent of each factory were identified. Some of them had to be given more attention since they either appeared at very high concentration or were very toxic.

5. The biodegradation properties of wastewater and major pollutants discharged from each factory were studied. They could be described by their BOD curves and judged by the ratio of BOD to COD. Biodegradation studies of some major pollutants appearing in wastewater such as phenol, m-cresol, terephthalic acid, acetic acid, etc. were also undertaken. A ratio of BOD/COD of less than 0.2 usually means the compound is undegradable by aeration, higher then 0.4 means it is easily degraded. The ratio can vary with concentration of pollutant. The relation of biodegradation with concentration was obtained for each compound.

   Based on the results of wastewater analysis, the biodegradation study of wastewater and major pollutants and the amount of wastewater discharged from each factory, the permitted concentration of pollutants in the effluent from each factory was decided and a standard for the entrance water of the wastewater treatment plant was set. This regulation protected the plant from 'shock' due to high pollutant concentration of entrance water and was very important in maintaining good running of the treatment plant.

6. A survey of the working status of the wastewater treatment plant and the investigation of problems in management and operation indicated some shortcomings in treatment facilities and management. A plan of renovation and extension of the plant was suggested. It was also suggested that a fair amount of domestic sewage should be introduced into the wastewater treatment plant to modify the entrance water quality and to supply enough nitrogen and phosphorus nutrition for the aeration treatment tank.

7. Strengthening management and emphasising education was important for water pollution control. The administration of environmental protection should be further improved and a set of regulations should be perfected. Reward and penalty is necessary for the unit or persons doing good or bad work for environmental protection.

   Increasing environmental awareness is the basic guarantee of environmental protection. Strengthening education is vital, not only for the leaders and cadres responsible for environmental protection work, but also for every employee.

Practice

Based on the investigation and research work, a series of projects were put into practice:

1. Treatment facilities were built at pollution sources, and high concentrations of wastewater was thus controlled.

2. Pretreatment facilities, oil separators, wastewater storage tanks and neutralisation equipment were built in some production factories. The concentration, amount and pH value of wastewater discharged from each factory became stable so that the entrance water of the treatment plant also stabilised.

3. The engineering of the renovation and extension of the wastewater treatment plant was completed in 1987. New aeration and sedimentation tanks were constructed, filtration tanks were extended so that the capacity of the treatment plant was increased from 1200 M^3/hr to 1800 M^3/hr, domestic sewage was introduced so that it constituted about 45% of the total entrance water quantity. In addition a set of facilities for sludge digestion and concentration, mechanical dewatering of concentrated sludge as well as a sludge combustor were all built. Meanwhile, management and regulation was strengthened and the operation of the treatment plant was greatly improved.

As a result of the whole work described above and carried out in the 1980s, the water pollution situation has greatly improved. The quality of the outlet water of the treatment plant improved and the water reservoir became clean and fish could live happily.

Conclusion

Water pollution control is a hard task and needs the contribution of the whole society. Control and treatment at the source of pollution is the first thing. Solving water pollution problems needs science and technology as well as policy, law, regulation and management, etc. However, chemistry plays an important role and environmental protection cannot be done without it.

The Author

1964 graduated from Department of Chemistry Beijing University, 1964-75 Research Assistant, Institute of Chemistry, Chinese Academy of Sciences, 1975-86 Research Assistant Institute of Environmental Chemistry, Chinese Academy of Sciences, 1986 - Associate Professor, Research Centre for Environmental Sciences, Chinese Academy of Sciences. 1981-82 Visiting Scholar, Department of Chemistry, Queens College of the City University of New York, 1982-83 Visiting Scholar of Department of Pharmaceutical Chemistry, University of California. Research activities in industrial wastewater treatment and water reuse, biology for wastewater treatment, analysis and identification of environmental pollutants and their degradation products.

1.11 Priorities for Environmental Chemistry in the Asia-Pacific Region

Barry Noller
Federation of Asian Chemical Societies, Darwin, Australia

The large population centres of the Asia-Pacific region now heavily impinge on the region's environment. This impact by Man is immense and, coupled with the limited availability of resources, requires that priorities be set in order to apply adequate controls to manage and preserve such resources. However, such control requires an understanding of pollution processes in the environment before their control can be made adequately. Environmental chemistry plays a key role in the understanding of the pathways and fates of chemicals in the environment (1).

In order to set the kind of priorities described, an initiative led by the Commonwealth Science Council was developed through a process of peer review of proposals from various countries to identify where regional research effort was really needed as distinct from issues of prime interest to the global environment where significant effort may already be applied - eg. global warming and sea-level rise induced by an increase in atmospheric carbon dioxide concentration. Seven components were identified and form Project CREN (Chemical Research and Environmental Needs) (2). These are:

1. Atmospheric acidification.
2. Environmental (chemical) impact of fertiliser use.
3. Gaseous emissions from agricultural sources.
4. Pesticide residues.
5. Chemical transport processes and sediments in rivers.
6. Air Pollution modelling
7. Environmental analytical techniques.

Each component covers a problem area of regional significance. A parallel example of environmental chemistry concerning the complete control of uranium mining at a tropical location in a World Heritage National Park in the Northern Territory, Australia, shows how to pursue development and yet protect the natural environment. Environmental chemistry is seen to play an important role in achieving sustainable development.

Atmospheric Acidification

This component considers the composition and acidity of rainwater in the region taking into account the impact of sulphur, nitrogen and organic acids and their inventories.

The phenomenon of acid rain is now well described in the Northern Hemisphere. Recent observations have shown that large variations in the acidity of rainwater from region to region exist in the tropics. Over continental Australia, rainwater with pH in the range of 8.6 - 4.8 has been observed. Over India, the pH values are most often above 6.9 and similar high values are found at some stations in China. The acidity in tropical rainwater can be partially or completely neutralised by ammonia and alkaline soil dusts entrained in rain. Calcareous material, probably from central Asian deserts, appear to play a major role in determining the pH of rainwater over the Asian continent. Large scale perterbations of the S and N cycles have resulted in significant changes in the Northern Hemisphere. It is therefore of great interest to examine air pollution in industrialised regions and acidification in the tropics.

This project seeks to cooperate with other agencies (3) in producing and circulating reliable deposition data.

Another interesting possibility is the application of the Malaysian Watch Acid Rain Project in other countries. Secondary schools throughout Malaysia collected rainwater during the inter-monsoon period and measured pH using indicator strips. The data was analysed and a contour map of the country compiled (4).

Environmental Impact of Fertilizers

This component considers the effect of fertiliser and fertiliser factory wastes on water quality and utilization of urea factory ammoniated waste water for agricultural use. The project will focus on Bangladesh initiality, being typical of a country requiring urea fertilizer production to assist with an enormous food production requirement.

Bangladesh has five large urea plants in operation with more being planned,. Urea manufacture is based on the reaction of natural gas, air and steam. The process releases pollutants including ammonia. A seminar on the protection of the environment of fertilizer industries and a workshop on environmental chemistry priorities in Bangladesh (5) identified the areas of importance in fertilizer impact. In view of the fact that Bangladesh is covered by a vast surface water area almost throughout the year, water pollution is the most acute problem.

Gaseous Emissions from Agricultural Sources

This component considers trace gas emissions from agricultural wastes and will investigate methane, nitrous oxide and other trace atmospheric gaseous emissions, including those from animal husbandry. Global warming from the increase in greenhouse gases has become a major scientific and political issue during the past decade (6). Methane, nitric oxide and CFCs, although individually less abundant than carbon dioxide, together produce a comparable greenhouse effect.

The major sources of methane include rice paddy fields, enteric fermentation, biomass burning, land fills, coal mining, natural gas flaring, automobiles, swamps, oceans, etc. Of these the increase in emissions from paddy fields and ruminants are closely linked with increasing food production needed to meet growing populations. Research is needed to assess methane emission from cattle (including buffalo and camel) and estimates are scanty on methane from tropical forests and estuaries (mangroves). Less information is available for nitrous oxide than for methane.

Pesticide Residues

This component seeks to identify problem areas with residues in food, soil and water. Though less developed than others in Project CREN it is none the less important. At a meeting held in New Delhi in January 1991, the pesticide programme was discussed and considered to comprise the following:

(i) selection of pesticides of most significance;

(ii) identification of resource people from different countries with a view to preparing a toxicological atlas (ie. one exists for India) giving details of production, amounts of pesticides used and levels in water and foods;

(iii) study of bacteria which degrade organo-chlorine pesticides;

(iv) identifying training centres;

(v) development of appropriate pesticides.

The handling and fate of pesticides has been discussed by McEwan (7). Chemicals may be applied directly to animals to control external parasites or they may be incorporated in feeds or remain in feeds from a use during growth or storage. Plants may be treated at any stage of growth or for storage or transport. Soils may be treated pre-planting and during plant growth for weed or pest control. Formulations and modes of application vary widely. The organo-chlorine pesticides are still the most important pesticide residues in the environment and in animals. DDT remains in use in India for the control of malaria. Due to a wide range of factors it is not possible to be precise about half-lives of pesticides.

Chemical Transport Processes and Sediments

This component deals with the role of sedimentation in the pollution of rivers and oceans in the region by metals, hydrocarbons and pesticides. The parts of the region considered are both from largely populated areas and pristine coastal upstreams and coral reefs of the Indian and Pacific Oceans. Papua New Guinea (PNG) will be a prime site for study.

Water is a major carrier of particulates which can be transported from a disposal site usually in insoluble form but for certain species in dissolved states (8). It is therefore important to understand the phenomena responsible for retarding chemical fluxes and those which are, in contrast, capable of increasing species mobility in order to select disposal sites giving minimum pollution dispersion from the point source.

In spite of their different origin, mine tailings and dredged materials present strong similarities in behaviour and environmental impact (8). At the Ok Tedi gold and copper mine in the western province of PNG, discharge of chemically treated tailings is permitted provided an acceptable level of suspended sediment in the Fly River is not exceeded.

At the Bouganville copper mine on Bouganville Island, PNG, 600 million tonnes of tailings overburden and natural catchment erosion have entered the river system since the commencement of mining. The system operates in a high rainfall, high seismicity and mountainous zone and to date 40% of the material disposed into the river system has deposited on land. Treatment of the waste dump leachate system appears to have little effect on copper chemistry if the tailings are not adequately stabilised.

Organic matter, together with iron and manganese oxides, coat the suspended sediment of rivers and change the nature of the sediment (8). The organic coating is chemically bonded to the clay and silt and can sorb organic solutes.

In natural systems the log partition coefficient of organic solutes for soil, and the log aqueous solubility give linear isotherms of neutral organic compounds (eg. chlorined hydrocarbons) over a wide range of concentrations relative to solute solubility (9). Partition coefficients of organic substances on soil vary from 20 to 200,000 with the largest coefficients being for the least soluble compounds, such as PCBs and DDT. A relatively water soluble compound, 1,2-dichloroethane, has a small distribution coefficient of 19 but an insoluble compound such as DDT (solubility 0.004 μm/litre) has a large coefficient of 220,000 (9). The sorption of organic solutes from water is related to the aqueous solubility of the solute with the least soluble organic compounds most highly sorbed onto soil sediment. These factors are the prime controllers of transport of organic substances to be considered.

Air Pollution Modelling

This component considers the application of air pollution modelling as a predictive aid, the availability of practical (usable) models, suitable for local conditions and incorporating radiation and photochemical processes. Urban air pollution is comprised of a highly complex mixture of gaseous and particulate components.

There is a range of urban pollution models currently is use (10). In all instances, the models usually do not accurately predict the time of occurrence and location of the maximum pollution episodes. If the requirements of time and space pairing of predictions and observations is relaxed, then the models usually can predict the worst case pollution levels to within a factor of two, the best that can be expected from any model, given the inherent uncertainty in air pollutions measurements. However, many models require detailed data sets which are not always available and severe local problems such as sea breeze effects and complex terrain complicate model performance and increase these problems.

Environmental Analytical Techniques

This component seeks to evaluate specific analytical methods and sampling techniques in use and to produce a Directory of Methods. It is planned to initiate inter-comparisons of laboratories. Attention will be given to improving specific analytical techniques and identifying methods not involving the use of hazardous chemicals. Field methods, with attention being given to simplicity, will be reviewed. There is scope for interaction with the IUPAC Programme 'Chemistry and the Environment' (11).

A specific example of the improvement and development of an analytical technique for the purpose of application to a regional environmental problem is a procedure to measure faecal sterols such as coprostanol (5β(H)-cholestan-3β-ol (12,13). The measurement of this and other sterols may be used to trace the pathway of human sewage in river water, seawater and marine foods. Coprostanol is unaffected by various treatments such as chlorination or aeration of overlaying water or even irradiation and is therefore indicative of the transfer of human sewage throughout most of the food chain.

The Northern Territory - An Example of Control in Development to Preserve Nature

Uranium mining has been undertaken in a national park in the Alligator Rivers Region of the Northern Territory of Australia. The origins of a very rigorous regulatory regime in the Alligator Rivers Region began with the Ranger Uranium Environmental Inquiry (Fox, 14). The Northern Territory is partly located in the tropics and can be considered as a model of a small tropical country with a stable political regime.

Controlled development based on regular review is seen to provide an efficient means of safeguarding the environment from developments such as mining. After ten years operation the environmental impact has been minimal.

Comparison with Global Problems

A comparison can be made between the project components selected above and the general recommendations for the UN Conference on Environment and Development (UNCED) to be held in Brazil in June 1992. The general recommendations of UNCED are as follows:

> Protection of the atmosphere (including global climate changes), ozone layer depletion, atmospheric transboundary transfer of pollutants;
>
> Protection of terrestrial and oceanic resources;
>
> Protection of biological diversity;
>
> Conservation of drinking water resources;
>
> Environmental safety of biotechnological production and applications;
>
> Ecotoxicologically acceptable re-use of waste;
>
> Safe treatment and discharge of toxic chemicals; and
>
> Assessment of health risk of environmental pollution and changes for human health.

It is seen that these recommendations are more general than those on the regional scale considered in this paper.

Conclusions

A means of setting priorities for environmental chemistry has been developed and described. Through Project CREN, the application of environmental chemistry is seen to provide a means of dealing with specific pollution problems facing the Asia-Pacific region. With the limited resources and facilities available, the role of co-ordination is seen to be of prime importance to make effective use of the limited resources, provide training to give skills to control pollution adequately and provide a forum for the development of inter-country co-operation within the region. Controlled development through use of adequate authorizations is seen to provide an efficient means of ensuring that no detriment to the environment occurs from development such as mining.

The Northern Territory provides the example as a model of a small country in the tropics for such environmental controls. The model of Project CREN presented should be applicable to other regions such as in Africa and the Caribbean/South America.

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The Author

1971 BSc University of New South Wales, Australia, 1973 MChem University of New South Wales, Australia, 1978 PhD University of Tasmania. Brief period at the Research School of Chemistry, Australian National University, Canberra, Research Scientist for Analytical Chemistry and Environmental Chemistry at the Alligator Rivers Region Research Institute, Jabiru, Northern Territory, Australia. Currently Senior Research Scientist and has undertaken research on the impact of uranium mining on the tropical ecosystem. Secretary-General of the Federation of Asian Chemical Societies.

Chapter 2 Organising Chemistry to Benefit the Third World

2.1 Aims and Organisation of the Conference

John M Pratt
University of Surrey, Guildford, UK

The longer-term aim of the whole conference on "Chemistry and Developing Countries" was stated to be "to enhance the ability of scientists to contribute to the well-being of their peoples by helping (through new ideas, contacts, information and expertise) to increase their interest and ability to play a more pro-active role in the wider applications of their professional knowledge, eg. in wealth generation and job creation, in institution building and the formulation of relevant national policies, as well as in teaching and research".

The conference focused on the two themes of (1) 'Chemistry for the Environment' and (2) 'Organising Science to Benefit the Third World', with particular emphasis on chemistry - balancing the generation of wealth (via chemical research and chemical engineering) with protection of the environment (via analytical chemistry). Emphasis was placed on the more applied aspects of organising chemistry because of the desperate need of most developing countries to generate wealth in order to fund further development and economic growth and to reduce poverty. It also complements the more academic and physics-related activities of the Third World Academy of Sciences in Trieste, whose President (Professor Abdus Salam) was invited as a speaker, but was eventually unable to come; his greetings were read out at the opening session. In this overview of theme 2 we use the more accurate and less presumptuous title of 'Organising **Chemistry'.**

Theme 2 included talks, 'tabled' papers which were handed to participants on arrival, and posters. Speakers included representatives, past and present, of major agencies (UNIDO, UNESCO, World Bank) and commercial firms (British Technology Group, Unilever, Taiwan's Grand Pacific Petrochemical Corporation) as well as academia. The published papers based on the talks, 'tabled' papers and one poster are listed in the contents; authors were encouraged to include relevant information and ideas arising out of subsequent discussion or reflection, while observing a limit of 1500 words of text (waived in the case of 2.17, which deserved to be published in full as a 'management tool' for possible future action). The wealth of first-hand experience in Third World countries represented by the contributors and the geographical diversity of their origins are emphasised by the curriculum vitae at the end of the papers as well as by the contents of the papers.

In addition, six chemists were invited to London (but one was unable to come at the last moment) to represent various regions of the world (Latin America, Caribbean, West Africa, East Africa, Middle East, Asia) to discuss their problems at a workshop and to make recommendations; their names are included together with the recommendations on pages 5-7.

This was, by all accounts, a pioneering theme for a conference. Two points should be stressed:

1. The enthusiasm and support of the speakers, regional representatives and other participants, which indicates that the conference met a strongly felt need. The resolutions and recommendations (see pages 5-6) strongly urge The Royal Society of Chemistry to "take a more direct interest in the problems of the developing world ... and interact more strongly with UN and other donor agencies ....".

2. The apparent and very recent changes in attitude and likely shift in emphasis on the part of the major donors towards 'institution-building' and strengthening S and T (science and technology) in developing countries (see below). This suggests that the conference has, by a lucky chance, taken place at the right point in time.

The papers and recommendations, together with the ensuing discussions, have provided a dovetailing collection of reports, surveys, analyses and proposals which highlight problems and dangers, identify key factors, and offer models and suggestions for action within the selected area relating to chemistry in the developing world. They identify the willingness to licence in the best available imported technology, coupled with the ability to 'de-bug' and improve such technology, as key factors in enabling countries like Japan and Taiwan to achieve their industrial 'take-off' (2.3, 2.5, 2.10); they also point to areas such as technology transfer and intellectual property rights, where further information (perhaps even a further meeting or background research) is desirable. They indicate a remarkable degree of consensus about the way forward, in particular the need (to select just a few of the many points): to link basic chemistry more closely with wealth-generation, in particular to build up chemical and process engineering; to develop regional collaboration and regional centres of excellence, otherwise funds and expertise will be spread too thinly, as well as more extensive international collaboration; to strengthen support services in both the technical (equipment, workshops, technician training) and information fields (from publishing to data-bases); also the importance of a supportive government and appropriate economic policies and the need for chemists to play a more active role vis-à-vis the media and government bodies. They probably form a unique compilation of information and ideas concerning 'institution-building' in any area.

We restrict comments here to (1) some of the lessons learnt (including points arising from unpublished further discussions) about the potential role of chemistry in wealth-generation in developing countries and the mechanisms required to achieve this, and (2) a summary of the evidence (some of it not available before the conference) for the shift in emphasis on the part of the donor agencies.

Lessons from the Conference; Chemistry and Wealth-Generation

One can now identify several broad areas in which chemistry could make a major contribution. Tcheknavorian and Oxley from UNIDO (2.4) emphasise the need for a local or regional chemical industry to supply the basic chemicals (acids, alkalis, chlorine, solvents, fertilisers, oils, insulating materials, etc.) which are essential to virtually all other industries as well as to agricultural efficiency; the cost of transporting such relatively cheap but bulky chemicals from distant sources would place an insurmountable hurdle in the way of development of quite simple industries and would cause an unbearable drain on foreign exchange. At the other end of the spectrum, Wu (2.10) points out that 'the economic miracle of Taiwan would have been impossible without the establishment of a world-class chemical industry over the last 25 years'. Since, however, Taiwan has a high population density but little in the way of natural resources, and has based its industrial development on the labour-intensive garment and shoe industries before integrating backward into chemicals, it may not provide an appropriate model for most countries in Africa and Latin America which have relatively low population densities but relatively abundant natural resources (whether animal, vegetable or mineral). In these countries it is the more intermediate level of chemical and process engineering, backed by chemical research, which is required for upgrading raw materials (foodstuffs, timber/pulp, plant-derived products, biomass and other agricultural by-products, as well as the better known minerals and oil) to higher value-added products and which could contribute substantially to industrial development and to foreign exchange earnings; but this potential has hardly yet been exploited. There is perhaps some justification in focussing on chemistry and the associated chemical and process engineering when trying to organise science to benefit the Third World!

It has also become clear that there are significant differences in the mechanisms required to link chemistry with wealth-generation in the First and Third Worlds. As a broad generalisation one could say that personnel in pure chemistry (as represented in, say, a university chemistry department) should be linked to personnel in (a) chemical and process engineering, (b) patenting and, to a lesser extent, technology transfer and licensing, and (c) the world of entrepreneurs and venture capital. In the First World one can, to varying degrees, assume the existence of experts in these other fields and of organisations and networks to bring the different parties together (see, for example, Kathoke (2.5)); the system works, even though First World governments may feel their university scientists are not sufficiently interested in possible applications of their work! The assumption cannot be made in the Third World, as shown dramatically by the state of development of chemical engineering. Wu (2.10) points out that the remarkable development of Taiwan's world-class chemical industry depended on "the existence of skilled Taiwanese engineers and technicians able to de-bug and even improve the technology, all of which was originally imported ...". Taiwan now has 36 Departments of Chemical Engineering, which produce about a thousand graduates each year; the first graduated in 1945, ie. long before the dramatic "take-off" of the Taiwanese chemical industry. By contrast, the whole of black Africa still has only two Departments of Chemical Engineering (2.19). There can hardly be a more telling indicator of the failure or inability to mobilise S and T for Africa's benefit and, conversely, of the urgent need to start the 'institution-building' needed to underpin the effective application of S and T.

Entrepreneurs of the required type simply do not exist in some developing countries; the aim must be to encourage the scientists themselves, by providing appropriate training, to develop and commercialise their findings. People with any knowledge of patents may also be absent; it is probably easier for the country to start building up interest and expertise in patents amongst its scientists than amongst its non-technical lawyers. The need for such links between chemists and other groups is obviously far greater in the Third than in the First World, while their existence is far less common. In many cases chemistry (and probably the other basic sciences) could provide the spring-board for developments in chemical engineering (cf. Førland and Førland (2.19), in patents and in entrepreneurial activities.

Even the technologies required may differ in the First and Third Worlds. Chemical firms in the First World and many in the Third World may want the latest, high-tech, continuous process on the market, and networks exist to help them locate such technologies. Other operators in the Third World may actually prefer a batch process because of the serious consequences of interruptions to the process caused by irregular supplies of power and spare parts; the solution he seeks may already be available in some other part of the Third World or in some obsolescent technology in the First World; or a process with accompanying hardware which has been abandoned by a First World firm at the pilot-plant stage could be exactly what is required for a full-scale plant in a Third World country. There appear to be no suitable networks to help the Third World operator locate such technologies.

The links between pure research (in all fields) and wealth-generation in the UK and the effects of the government's R and D policy have been well analysed in an article by Maddock in 1975 (1), which still provides instructive reading. There is a need for a similar thorough analysis for one or more developing countries; some of the conference papers obviously make a very useful contribution to this field.

Changing Attitudes and Emphasis within the Donor Agencies

Evidence of several distinct and very relevant changes in attitude and shifts in emphasis have emerged within the last year and a half from documents and publications of different organisations such as: the World Bank's report on 'Sub-Saharan Africa; From Crisis to Sustainable Growth' (2), published in November 1989 (just after the conference themes had been decided); the UNDP's 'Human Development Report 1991' (3), published in June 1991 (ie. after the conference, but while drafting this summary); and an internal document of the OECD's Development Assistance Committee called 'The Role of Science and Technology in Development Cooperation with the Less Advanced Developing Countries in the 1990s', a shortened version of which is included in 2.2. The three most important and relevant changes would appear to be:

1. An increasing willingness to be frank, to call a spade a spade, and to identify the real problems and issues involving both donors and recipients. The World Bank, for example, slates "weak public sector management" and "the deteriorating quality of government" (p.3) but adds that "Responsibility for Africa's economic crisis is shared. Donor agencies and foreign advisers have been heavily involved in past developments along with African governments themselves. Governments and donors alike must be prepared to change their thinking fundamentally to revive Africa's fortunes" (p.2).

The UNDP's report points out that "If resources are poorly distributed, the cause generally is political. Protected interests and power structures - military establishments, urban and rural elites, corrupt bureaucracies - all can cause maldistribution" (p.9) and that donors sometimes prefer "to forge an alliance with the government rather than with the people" (p.9); it concludes that "it is too often a lack of political commitment, not of resources, that is the ultimate cause of human neglect" (p.11) and suggests that "Requests for aid should include plans to cut back military budgets and to increase the human expenditure ratio" (p.10). As a reviewer noted (4), "A few years ago, the slightest hint of such political conditionality would have produced a reflex accusation of racism and neo-imperialism ... But since the end of the cold war, all this has changed. The UNDP can now argue in public that political priorities in many developing countries are determined not by patriotism but by the greed and vanity of ruling elites".

2. An increasing shift (more correctly, an increasing call for a shift, since it has apparently not yet materialised) from "mega-projects" to "institution-building" and "social expenditure", ie. from short-term to longer-term support, which is echoed in all three documents. The DAC (see 2.2) says "There is a strong tendency in the whole aid system to supply a wide range of capital equipment on a highly subsidised basis while at the same time failing to ensure that the recurrent expenditure on human resource capacities needed to sustain the effective use of this capital is available ... Aid agencies should increasingly shift from a project-by-project approach to a more strategic, capacity building thrust with longer-term commitments ..." while the UNDP Report says (p.8) that donors "prefer to give money for capital-intensive schemes that just happen to require machinery and technical assistance from the same donor countries" and that "too much is often being spent on foreign expertise and too little on building up local institutions and mobilising national expertise". At least one cause of this shift in emphasis is probably disillusionment with previous policies; the World Bank report quoted (p.27) a 1987 evaluation which showed that half the completed rural development projects which it had financed in Africa had failed.

3. An increasing realisation of the contribution which science and technology could and should make to development and hence of the need to strengthen science and technology in developing countries, ie. to shift from an almost accidental inclusion of "science and technology within a policy" to a more positive "policy for science and technology", to use Professor Oldham's phrase (2.3). This is the main thrust of the document prepared by the OECD's DAC (see 2.2), which argues that to achieve the main aim of strengthening the capacity to manage technological change requires, inter alia, building up "a strong national science and technology community" and "a much enhanced partnership between the economic and social policy-makers and science and technology professionals"; it urges "aid agencies (to) seek ways to enhance dialogue with the wider science and technology community in their countries, including NGOs and the private sector". The World Bank also stresses (p.4) that "If Africa is not to be further marginalised ... two initiatives are crucial. Africa must (1) improve its science and technology training and aim at the highest standards for at least a minimum core of specialists and (2) forge new partnerships with qualified firms and research institutes in the developed countries". This change in emphasis has probably been prompted by the success of countries such as South Korea and Taiwan, which obviously owes so much to the effective exploitation of science and technology.

A contributing factor may have been the thought that some of the emerging technologies such as biotechnology, advanced materials and information technology are less capital- and energy-intensive, and therefore more appropriate for developing countries, than the older "smokestack" and "metal-bashing" industries usually associated with development. Scientists must be excused their wry pleasure that the importance of science and technology has at long last been realised!

Summary

The Conference has produced a valuable compendium of information and ideas directly relevant to the problem of strengthening and utilising science (with particular reference to chemistry) in the developing world at the same time as the donor agencies are showing increased interest in institution-building in general and in strengthening science and technology in particular. The next steps involve further discussions between The Royal Society of Chemistry on the one hand and both the Commonwealth Science Council and the OECD donor agencies on the other. It is hoped that this Conference will also encourage other countries to contribute to the on-going process of expanding knowledge and expertise in this field through organising meetings on related topics.

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The Author

The author is a graduate and former member of staff (Fellow of Exeter College) of Oxford University; four years with ICI 1969-73; Professor of Inorganic Chemistry in Johannesburg 1974-85, gaining first-hand experience of much of East and Southern Africa; Head of Department of Chemistry, University of Surrey 1985-91.

Department of Chemistry
University of Surrey
Guildford
Surrey

Tel: +(44) 483-509164
Fax: +(44) 483-300803

2.2 The Role of Science and Technology in Development Cooperation with the Less-Advanced Developing Countries in the 1990s.

John M Pratt
University of Surrey, Guildford, UK

The OECD's Development Assistance Committee organised a meeting in 1990 of experts concerned with aid to the less-advanced developing countries. Discussions at this meeting led to a number of suggested policy 'orientations', which were incorporated into a document with the above title which provided clear pointers to needed shifts in emphasis in aid policy, in particular to an increased emphasis on building up science and technology in those countries. It is, therefore, of great potential interest to the scientific community and very relevant to the subject matter of the conference. With the agreement of the OECD's Development Corporation Directorate, the document has been abstracted with minimum editing and rearrangement to provide the following shortened version, where the numbers in parentheses refer to the original sections.

The orientations set out below are echoed in broad terms in statements and publications emerging from a number of other fora. Some major departures from existing habits are being called for; this is not 'business as usual' either for developing countries or their development partners. The full integration of science and technology into the development process through the building of national capacities and coordinating domestic and international efforts round a set of key technology development missions is a major, exciting task for the 1990s [50].

With the technological choices in front of developing countries rapidly multiplying, the opportunities for applying science and technology to transform the life prospects of masses of poor people have never been so great [6]. However, this requires a capacity [8] to:

(a) identify needs and opportunities;

(b) select technologies that are suited to a country's individual situation;

(c) adapt or develop these technologies in each particular national context;

(d) implement them on a broad scale.

It is not building up science and technology per se that is the core issue, but strengthening the capacity to manage technological change [9]. This involves [10]:

(a) Linking together a series of measures and approaches in the fields of policy-making, central and local administration, education and investment decision-taking in a way that brings about a better exploitation of both existing and new technological options;

(b) A political and intellectual climate which allows and encourages free and open debate about key social and economic problems, the use of the country's resources, and the merits of alternative theories and practices;

(c) Fostering the emergence of a national science and technology community which is able to help identify and respond to national challenges and opportunities and to interface with international and regional science and technology.

The capacities of developing countries to manage technological change are now highly differentiated, both between and within countries. What increasingly defines the less-advanced developing countries is the weakness or even complete absence of a capacity to manage technological change [11]. Among the poorer developing countries only a few, notably India and China, have any significant capacity in this sense. Almost all the others are in a desperate situation [12]:

(a) The personnel, policies, institutions and culture through which technologies can be created or transferred and disseminated are largely missing;

(b) They depend on others to identify their technological needs and they lack the ability to assess the range of technological options available and make appropriate choices;

(c) They lack the economic power to harness the world's scientific and technological endeavours to address their particular needs, while the absence of a flourishing private sector and of significant inflows of foreign direct investment severely restrict their acquisition and application of relevant foreign technologies.

Strengthening the national capacity of less-advanced developing countries to manage technological change should be regarded as a central and urgent development issue for the 1990s [13], but practice in both developing countries and in aid agencies is seriously lagging behind the conceptual progress on how to incorporate science and technology into the development process [19]. Reorientation and effort would be required as follows [20]:

(a) Science and technology programmes and priorities must be derived from a national dialogue among the stakeholders on needs and opportunities, rather than be driven by the 'suppliers' of science and technology, whether domestic or external. There must be a much enhanced partnership between economic and social policy-makers and science and technology professionals, but the defining and coordinating role should be assigned to the former, not to the latter.

(b) A strong national science and technology community must be fostered both through national efforts and the intermediation of regional and international efforts, oriented to serving the basic development needs of their communities.

It must provide capacities in the fields of pure science, applied science and effective technological applications appropriate to local conditions.

(c) At the international level, ways must be found to orient more of the world's science and technology effort to the development problems of less advanced countries. At present there is a major problem of 'market failure', because the low income levels of less advanced countries mean they cannot translate their needs into effective demand through market mechanisms. Science and technology is largely driven by the demand patterns of the developed countries' private and public (including military) sectors. In a world development perspective, this represents a fundamental distortion in the allocation of science and technology resources and should be seen as a central issue for international consideration and action in the 1990s.

A crucial requirement is the establishment of a sound economic policy environment [30]. Proper technological choices are only possible when markets can operate freely and effectively with rational pricing of resources (labour and capital in particular) and outputs to guide decision-makers, including environmental costs whenever possible [31]. Strong market-based incentives for adopting technological improvements are essential, as are the economic and legal conditions for stimulating the creation and flow of affordable proprietary technologies [32].

Donor agencies should make it their primary objective in the less advanced countries to assist them to create a national capacity to manage technological change [33]. There is a strong tendency in the whole aid system to supply a wide range of capital equipment on a highly-subsidised basis, while at the same time failing to ensure that the recurrent expenditure on human resource capacities needed to sustain the effective use of this capital is available. Particularly in less advanced countries this propensity has a major negative impact on the national capacity to manage technological change [34]. Aid agencies should increasingly shift from a project-by-project approach to a more strategic, capacity building thrust with longer-term commitments to help accomplish well-defined technology development missions [37].

A key requirement will be to create a synergy within aid agencies between economic analysts, programme planners, and science and technology specialists so that the building of national capacity to manage technological change becomes a central, early issue in programme design. A high degree of integration of science and technology into all aspects of an aid agency's operations is essential [39]. Aid agencies should seeks ways to enhance dialogue with the wider science and technology community in their countries, including non-governmental organisations and the private sector in this endeavour [40], and should consider long-term 'linkage grants', joining together NGOs, universities, and the private sector in their countries with counterparts in developing countries [41].

The capacity to manage technological change has to be, by definition, a broadly-based national capacity. At the same time, most of the less-advanced developing countries will not be able, solely on a national basis, to create and sustain flourishing science and technology communities of the size and quality needed to cater for their needs [43]. Particularly in those areas of the developing world where there are many small countries unable to achieve a critical mass of their own expertise, a few regional centres of excellence could provide the most realistic option for developing a vital science and technology community [45]. National capacity building should also be an important objective of international cooperative research schemes, such as mission-oriented 'networks' of scientists and institutions [47].

2.3 Science, Technology and Development: Lessons of the Last 30 Years

Geoffrey Oldham
University of Sussex, Brighton, UK

The new decade is an appropriate time for reflecting on the lessons of the past and fc. looking at possible future trends. There seems to be a new optimism about the potential of science and technology, and of new advances in these fields. This is reflected in the World Bank's report on Africa, and in the House of Lords report on science aid. It is some 30 years since a similar enthusiasm was apparent and it is therefore relevant to consider the lessons which have been learned over this period.

Some Science and Technology Policy Issues with Implications for Development

1. Sources of New Technology and Methods of Acquisition

Should new technology be made or bought (ie. endogenous or imported)? The history of technology acquisition over the past 100 years indicates a heavy emphasis on imported technology.

Decade of the 60s: The 1963 UNCSAT conference typified the attitudes to this issue prevalent during the early 1960s. This was largely a 'supermarket' approach, with the technology of developed countries displayed for purchase by developing countries. Later in the decade it was apparent that there were problems with this approach: the available technology was often not appropriate to the conditions of developing countries, and costs were not affordable; restrictive practices associated with licensing agreements made costs higher than necessary and often prohibited the export of goods manufactured. The developing country policy response to this was, in the main, defensive.

Decade of the 70s: Developing countries experienced static or declining productivity in relation to the same technologies used in the West, for instance in the production of textiles, copper and chemical fertilisers. This implied a need to reimport technology in order to stay competitive. One policy response was for developing countries to develop the skills needed to change and improve technology, in some cases (such as South Korea and Taiwan) very successfully; this could be described as a 'boomerang' effect.

Decade of the 80s: Marked by a decline in the flows of technology from developed to developing countries, owing to debt crises and shortage of foreign exchange, and to an unwillingness to transfer technology to newly industrialised countries.

The experience of the past 30 years has shown that technology transfer is an issue of critical importance and that there is a need for local technical capability to absorb new technology.

2. The Nature of Science and Technology Activities

This has been an area of much confusion. What capabilities are required, and in what order of priority? There is now a reasonably good consensus that the following capabilities are necessary.

(a) Capacity to make decisions, aided by technology assessment capability;

(b) Capacity to use technology and to operate machinery;

(c) Capacity to change technology, to diffuse and utilise it; in other words, the capacity to innovate. This implies research and development, design and creative engineers, and a skilled workforce;

(d) The availability, not just of isolated skills, but of an integrated system;

(e) An environment conducive to innovation. This implies supportive government policies, suitable rewards within enterprises and widespread education in science, including problem-solving techniques.

In the past there has been too much emphasis on research and development. Only 5-10% of qualified scientists and engineers (QSE) are engaged in research and development in the advanced countries (the rest are in teaching, training and production), yet most aid programmes have concentrated on this dimension with the result that in many developing countries, 10-15% of QSE are engaged in R and D.

3. Location of Science and Technology Activities

In the 1950s and 1960s those models of the organisation of science which were transferred to the developing countries were built on what appeared to be essential institutions in communist and capitalist countries. In communist countries, for example China and Cuba, research was based in academies of science, together with a little research in universities. In capitalist countries, activities were based on such institutions as: industrial research organisations, eg. Battelle or CSIRO; universities and agricultural colleges; science and technology information systems; standards organisations; and science councils, etc. However, adherence to this model meant that what was not transferred was that part of the science and technology system which is based within enterprises. This is, in fact, the part of the system which is critical for economic and social development. Most of the activities taking place elsewhere are trappings which support the technical change activities within firms. In the USA and Japan, for instance, most research and development is carried out by firms. Most of the incremental technical change occurs there, as does a vast amount of training.

As we enter the 1990s, it is time to redress the balance within the science and technology system. Government incentives, and more efforts in foreign investment projects, could contribute to this end.

4. **Nature of Technical Change: Radical or Incremental?**

There is a tendency to place too great an emphasis on radical breakthroughs, as opposed to step by step incremental improvements. This is the case not only in traditional industries such as tanning, but appears to be equally important in the oil and aircraft industries. This has human resource implications in relation to the balance between the concentrated efforts needed for a few radical breakthroughs, and the creative engineering skills necessary to introduce incremental changes.

5. **'A Policy for Science and Technology' versus 'Science and Technology Within a Policy'**

One needs to consider both (a) the health of the science and technology system and (b) the utilisation of that system in achieving economic and social goals. There are both supply side policies - the supply and dissemination of knowledge - and demand side policies - the way in which science and technology is blended with other inputs (eg. capital, labour, education) to reach development objectives. Science councils have frequently been charged with both supply and demand and have had little impact other than oversupply. On the other hand, those government departments responsible for sector policies may have little understanding of technology issues, and this equates with an absence of demand. Many governments have been inclined to include science and technology almost as an afterthought to their policies, but there has recently been increasing recognition of the need to develop policies specifically for science and technology.

There are many other issues which need to be addressed, but these five have been selected for two main reasons. Firstly, there are still many misconceptions, and knowledge and understanding on these points is not widely disseminated. Secondly, each of the above points has implications for human resources development.

China Case Study

Some of these points are illustrated by a recently completed joint study undertaken by SPRU and the Chinese National Research Centre for Science and Technology for Development (NRCSTD) (1).

In the early 1980s, China opened its doors to foreign companies for joint venture offshore oil exploration. China wanted rapid development in this area, and the joint venture agreements included a technology transfer clause. After the first two years it appeared that things were not going as well as expected. The SPRU/NRCSTD joint study was therefore welcomed, and extensive interviews were conducted with both Chinese and foreign participants. A number of reasons for the difficulties were discovered.

Secondary reasons included communications (language differences, differing educational backgrounds, disparate management attitudes), views on training (the Chinese participants considered the training offered to be too elementary and were sceptical about on the job training for roles such as drilling supervisor) and the views of the foreign oil companies on lack of Chinese strategy, and lack of Chinese resources to absorb what was on offer. The primary reason, however, was a disparity of view about what was meant by technology transfer. The oil companies considered that this implied teaching the Chinese to do tomorrow what the companies were doing today or, in other words, transferring know-how. The Chinese, however, wanted to master the available technology and gain access to proprietary technology. In other words, they wanted both know-how and know-why to be incorporated in their own body of knowledge. This caused problems because the know-why resided at the oil companies' headquarters with their research and development and special engineering departments. There was also a difference of approach to the question of technology transfer between the staff at headquarters and the operating company staff.

This case study illustrates a number of points: technology transfer is a complex process and requires substantial effort on the part of both supplier and recipient; the importance of incremental technical change; and the need for new approaches to training.

Trends Influencing the Future Ability of Developing Countries to use Science and Technology

Some of these trends are not obviously caused by science and technology, but will influence science and technology policies.

1. Debt

Shortage of foreign exchange limits the ability to import technology. Debt also means there is a lack of resources for research.

2. Global Environmental Issues

Acid rain, CO_2 emissions, possible global warming, and deterioration of the ozone layer are all matters of current public concern. Political pressure for new technologies which can contribute to sustainable development may lead to new funds being made available for development.

3. New Approaches to Knowledge Generation

These include: UN/industry collaboration; international collaboration in precompetitive research, such as the EC Framework programme; inter-firm collaborations and strategic alliances in the areas of research, design, production and marketing; and globalisation of technology. Will the Third World be included or excluded from these developments?

4. Science-based Technologies

Information technology, biotechnology and new materials offer both threats and opportunities for the Third World. They have many characteristics intrinsically of benefit to developing countries, including possibilities for flexible manufacturing, small scale operations and energy efficiency. Information technology may provide substantial opportunities for education, and biotechnology for health, agriculture and mining. Potential threats include: lack of access to technology; in the case of biotechnology, privatised agricultural research, and the possible threat to important export crops, such as vanilla in Madagascar; and, in the case of new materials, threats to commodity exports.

5. Democratisation of Eastern Europe

Will this lead to more resources becoming available for development, or less? The possibility is that foreign investment may be directed more towards Eastern Europe, and there may therefore be less available for developing countries.

Each trend poses threats and new opportunities for those in the Third World who are responsible for using science and technology for development. It will be those countries which can recognise the threats and opportunities and which have a capacity for rapid learning and an ability to embrace innovation which will cope best with the surprises and opportunities of the next decade. This implies a major investment in human resources for building endogenous science and technology capabilities and innovative skills.

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The Author

The author obtained his PhD in geophysics from the University of Toronto, then worked with Chevron Oil Company (California). Formerly Fellow of the Institute of Current World Affairs in New York, then Associate Director of the International Development Research Centre in Ottawa. Currently Professor of Science Policy and Director of the Science Policy Research Unit at the University of Sussex, Chairman of the UN Advisory Committee on Science and Technology, and Senior Adviser to UNIDO on technology policy; has a particular interest in China and South East Asia.

Science Policy Research Unit
University of Sussex
Falmer
Brighton
East Sussex BN1 9RF

Tel: +(44) 273-678174
Fax: +(44) 273-685865

2.4 Impact of the Chemical Industry on the Development of the Third World

A Tcheknavorian-Asenbauer and J H Oxley
UNIDO, Vienna, Austria

There is a mistaken belief that building up a chemical industry is not a priority for developing countries, particularly the smaller and poorer ones, because of its association with capital-intensive petrochemical complexes and the use of potentially dangerous and environmentally hostile processes. Access to chemicals is, however, essential to the operation of virtually all other industries as well as to agricultural efficiency, and more than 30% of UNIDO's technical assistance is directed towards the chemical and related industries.

The industrial revolution, which took place just over 200 years ago in Great Britain, was famous for the extremely rapid development of the textiles, iron and machine building industries; this would have been considerably hampered if the chemical processes for making acids, alkalis and bleaches had not been developed simultaneously. Chemical products such as soaps and disinfectants also played a major part in improving public hygiene and thus increasing life expectancy. Today, industry is even more dependent on chemicals, which are also needed for pharmaceuticals and medicines, housing and shelter, textiles and clothing, food production and food conservation, printing and communications, and for many other basic needs which are just as essential for developing as for industrialised countries.

Not having a chemical industry can severely hinder the economic development of a country. It will have to pay a much higher price for the chemicals it needs than does a rich country with a large efficient chemical industry, and access to the valuable technical assistance generally provided by chemical companies to their customers will be difficult. The cost of transporting basic chemicals such as acids and alkalis, chlorine for water purification, fertilisers, solvents for paint manufacture, formaldehyde for resin manufacture, lubricating oils and insulating materials is often far higher than the cost of making the product in its country of origin and may be twice as high as in industrialised countries. This can put an almost insurmountable hurdle in the way of the development of quite simple industries such as the paints industry or chipboard industry which, with the cheap labour available, could be quite profitable, while the high cost of fertilisers handicaps the development of agriculture and the production of food. The cost of importing and transporting chemicals can represent an unbearable drain on foreign exchange.

For considering the impact of the chemical industry on development, the developing countries can be divided into (a) those large enough and/or rich enough to have a market which would justify the indigenous production of most of the major chemicals required by their industries, agriculture and societies (eg. People's Republic of China, India, Mexico, Argentina, Brazil, Iran, Indonesia) and (b) those too small and/or too poor to have a market which would justify the economic local production of almost any of the chemicals they need (eg. countries with a population of less than ten million, and per capita GNP less than $500 per year). There are also a few lucky ones (eg. those with oil, natural gas or well developed export industries) whose consumption, though small, justifies the establishment of profitable chemical industries making products destined directly or indirectly for export.

Large Developing Countries

For countries large or fortunate enough to be able to have a profitable or potentially profitable chemical industry it is essential to ensure that this industry really does have a positive impact on the country's development. This means:

1. Promoting the growth of agriculture and of those industries which use the products of the chemical industry by encouraging and assisting the appropriate and efficient use of chemicals through, eg. promoting the use of plastics in agriculture, training farmers in the utilisation of appropriate and environmentally safe fertilisers and pesticides, and providing technical assistance and applications and development services to industries using chemical products such as plastics transformation, detergents, textile and paints industries.

2. Ensuring the efficient competitive operation of the chemical industry itself. Major technical improvements continue to be made even in the manufacturing of the so-called mature bulk chemicals such as commodity plastics and fertilisers, while speciality chemicals and special grades of plastics are under continual development in the industrialised world.

   Failure to operate plants efficiently, to increase output by introducing the latest technology, and to develop the use of speciality chemicals could result in stagnation of the industry and the transformation of a profit-making into a loss-making endeavour; this happens all too frequently in developing countries. To avoid this, in addition to needing capital and having the willingness to invest this capital in the modernisation of plant, the owners of chemical plant must ensure the ongoing training of their operators, engineers and managers. Access to information by the establishment of well run libraries with databases is very important. Also, it is essential to have the ability to do enough chemical process engineering design to carry out troubleshooting and at least revamp and modernise simple plants.

3. Ensuring that the chemical industry itself as well as those industries using its products have a positive environmental impact and are operated safely.

Small Developing Countries

The severe negative impact on the development of many small developing countries without an adequate chemical industry can be reduced in many ways. One is to investigate the possibilities of setting up chemical industry operations which are economical even if carried out on a small scale, eg. the formulation and packaging of pharmaceuticals and pesticides, even the production of some of the ingredients. In effect, the manufacture of drugs and medicines is the most important sector of the chemical industry in many countries with a per capita income of less than $1000 per year, contributing on average over 20% of the manufacturing value added by the chemical industry. The next most important chemical related industries are those making soap, cleaning preparations, cosmetics, and the plastics products industry.

An almost positive consequence of the high transport costs for many chemicals which are needed in smaller, developing countries is that it is possible to produce some chemicals locally at a price less than the cost of importing them. The major obstacle in the indigenous production of chemicals is often not the danger that the market might be too small to support a profitable business, but lack of knowledge and experience about the chemical industry.

There are likely to be few experienced chemists or chemical engineers residing in a small, developing country which has no chemical industry. To decide whether to set up a chemical industry or produce just one product, plan for its production, choose and purchase the technology, set up the plant and operate it, requires the assistance of unbiased and highly experienced professionals from the chemical industry. Even if outside experts are available, education and training of local staff, including on-the-job training by the experts, is of paramount importance.

When a type of product, say plastics, is not yet being made in a developing country, it is notoriously difficult to predict what the market will be once it is made there. As there are generally fewer industrial customers for a given product than in an industrialised country, the decision of just one or two entrepreneurs to set up a business which will use the product can mean a quantum jump in demand. The easy availability of a product within the country, without having to obtain import licences and without the delay involved in shipping it in from abroad, is a great spur to demand. The market can also be very positively affected if the producer is able to provide technical and application assistance to the customers. There are many cases in industrialised countries of over-capacity in the chemical industry resulting from too many producers investing in too many plants which are too large. In developing countries, when introducing a product not yet made in that country, there are hardly any examples of a new plant being oversized, provided the price of the product does not increase as a result of a government's desire to protect a fledgling industry.

Another way of helping small countries is to reduce the use of chemicals by improving the efficiency of their utilisation, eg. by encouraging recycling, efficient product design and efficient plant operation in the plastics transformation industry. If it is profitable to use a labour-intensive process for cleaning and recycling plastic waste in an industrialised country, it is far more worthwhile in a developing country; the plastic costs are the same or more, but the labour costs are much less. In many developing countries the potential for saving on the import of plastic resin can be as high as 30%; for a country with a population of 10 million inhabitants and a per capita consumption of plastics of only 1 kilo per annum, this can mean an annual saving in excess of 3 million dollars per year. Another approach is to develop products which do not require chemicals to be expensively transported or to use raw materials which are available locally, eg. using 'water-borne' rather than 'solvent-borne' paints and developing the use of locally available natural products, such as damar resin and rubber seed oil for paint manufacture in South East Asia. This can both reduce a country's dependence on imported chemicals and provide employment and income for those producing these natural products.

P.S. Though our headquarters staff at UNIDO includes a number of highly competent professionals who have both industrial experience and experience with developing countries, the Organisation is highly dependent on its roster of international experts and consultants, many of whom are world famous in their fields. Should anyone wish to help UNIDO to assist developing countries, they are cordially invited to offer their services.

[*Editorial note:* this is an abridged version, prepared by the Editor, of the longer original paper authorised by UNIDO].

The Authors

Mrs Archalus Tcheknavorian-Asenbauer is a chemical engineer (Dipl. Ing. Dr. Techn.) from the Technical University of Vienna. After experience as Associate Professor at the National University of Iran, Consultant in chemical industries to the National Bank of Iran and as a researcher with the Austrian National Oil Company, she joined UNIDO in 1970; she became Chief of its Pharmaceutical Industries Unit in 1978, Head of the Chemical Industries Branch in 1984 and Director of the Industrial Operations Technology Division in 1987, and has been involved in hundreds of projects in the area of the chemical and pharmaceutical industries. Dr John H Oxley is also a chemical engineer (PhD from University College, London) with extensive industrial experience (planning, development, sales, on Boards of Directors of several companies) in France, Germany, India, Iran, Italy, Kuwait, the UK and the USA; Senior Interregional Adviser with UNIDO's Industrial Operations Technology Division for the last five years.

United Nations Industrial Development Organisation
Vienna International Centre
P O Box 300
A. 1400 Vienna
Austria

Tel: + (43) 1-211-313747 (A.T-A)
+ (43) 1-211-315132 (J.H.O)
Fax: + (43) 1-232-156

2.5 Technology Transfer: Ground Rules for Wealth Creation

Rusi Kathoke
British Technology Group, London, UK

Introduction

Technology transfer is a dynamic process that is critical to the creation of a body of knowledge which accelerates the process of technological development, both for developing countries and for industrialised nations.

Of the many specific methods of technology transfer, the one which in the long term is of greatest benefit to the recipient is the transfer of technology by the imparting of knowledge. This process comprises four distinct cycles:

1. The **creation** of an invention or **package** of inventions.

2. The commercial **protection** of the invention created. The process of transferring a technology starts with the communication of proprietary knowledge often called Intellectual Property Rights or 'IPR' for short. IPR is protected by national laws and international conventions through the grant of patents and copyright.

3. The process of extracting optimum value from IPR relating to an invention or body of inventions is the **licensing** of technology.

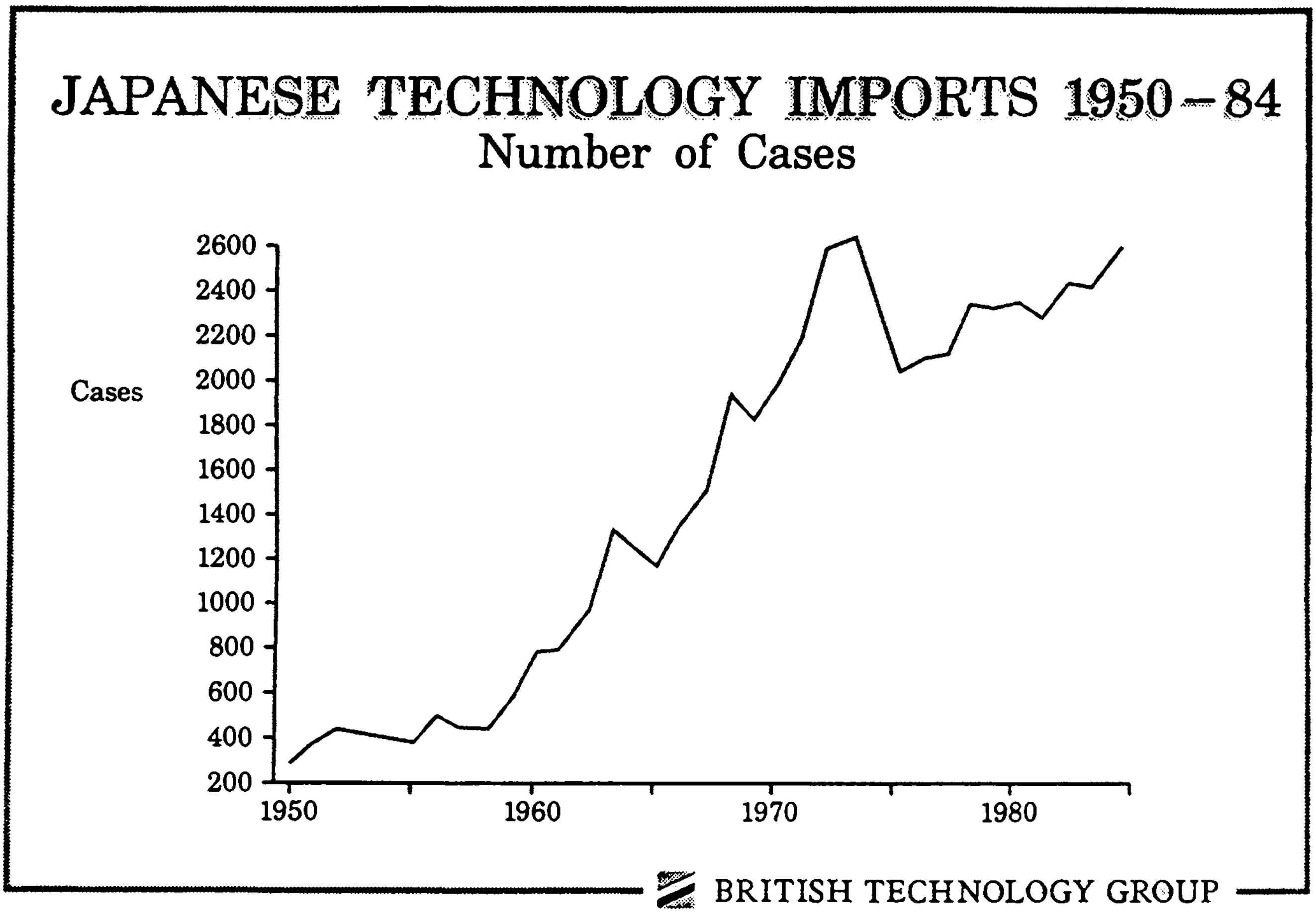
4. Finally, the defense of IPR and the pursuit, through litigation where necessary, of infringers who use IPR without recognising the legitimate commercial and financial interests of the owner. BTG has successfully fought five such cases in the USA in the last five years against infringers ranging from small companies to multinationals to the US Government itself. However, it would be misleading to suggest that the easiest way of creating wealth from technology transfer is through the law courts. On the contrary, it is to be used only as a last resort.

The common thread running throughout the entire process is that it is important to create and commercialise IPR in the technology transfer process.

The Importance of Globally Traded IPR

The flow of scientific information and the trade in IPR stemming from scientific discoveries has historically been international and largely unrestricted. Any successful industrial country today must draw on technology that originated not only from within itself, but also from many other external sources such as companies and universities internationally.

The international market in IPR is large, about $15 billion in 1988 prices, supporting products with an end market value estimated at $300 billion per year. Operating in this market as a buyer clearly provides tremendous opportunities to expand the technological skill base and encourage organically generated industrial growth through technology acquisition. Japan became the industrial giant it is today through a very effective policy of 'licensing-in' foreign technology (see figure below).



The people who benefit from free trade in IPR at the end of the day are the consumers who see competitive, leading-edge products brought to the marketplace in the shortest possible time at the lowest cost justifiable in commercial terms. BTG has become the world's largest and most successful technology transfer company, earning over 70% of its revenues overseas, because we address the global markets to which that technology is relevant. Technological protectionism is exactly the same as trade protectionism - it benefits few and damages most.

The overriding message of all of this is that developing countries will always remain 'developing countries' until they make their indigenous technology internationally competitive. This cannot be achieved unless they are prepared to acquire and absorb the technology they need to compete successfully in the international market place.

The Undervaluation of IPR

Commercially valuable intellectual property, particularly in the form of product and process patents, often arises from research and development programmes (R & D) in industrial concerns. However, in spite of evidence to the contrary, it is surprising how many companies still believe that R & D expenditure will depress stock prices. Companies do not communicate their R & D strategies to their shareholders, or they mistakenly believe that their shareholders will value R & D spend negatively.

A key problem, however, is the internal recognition by corporations and governments of the value of IPR. Although there are notable exceptions, many countries do not understand the full value of the opportunities for licensing-in technology that is relevant to their future development.

Licensing Technology

Because the innovative process cannot be predicted, well-run companies expect not to use 70% of the inventions which are made within their laboratories. However, this IPR almost certainly can be used by other companies with a different product mix, in other markets or geographic areas, or in products unrelated to the core business of the company.

Many developing countries try to 'go it alone'. They take unnecessary risks in technical uncertainty in highly competitive and fast moving technological areas, in costs and in timescales. Some countries believe that the best way of conserving scarce financial resources, particularly foreign exchange, is to develop indigenous technology - all very well if the domestic product is internationally competitive in quality and price. However, this is often a flimsy excuse to protect inefficient domestic producers from legitimate foreign competition.

Some governments assume that any technology offered for licence must be second-rate, redundant or otherwise unattractive; this is simply not true, as evidenced by Japan's obviously happy experience with imported technology (see figure on page 108). Developing countries can benefit from licensing-in technology in a number of ways; in particular, it reduces both the development time and the risk. Small companies can acquire fully engineered products. Large companies can license-in either products or discoveries which they can develop into new products. By doing so, they create their own future economic well-being without being in hock to the bogeyman of the Third World, the 'foreign multinational'.

Paying for IPR

Payment for the use of IPR is clearly an issue that has dominated the Uruguay round of GATT. There are two issues that are significant to the framework in which IPR will be traded in future. They relate to the problems of unifying patent systems worldwide. Only by doing this can there be a level playing field when it comes to paying for the acquisition of technology.

1. OECD Countries

It is commonly accepted by economists that a level of monopoly created by patents is acceptable for the increase in innovation and thus wealth that innovation will create. Significant problems, however, are created by the difference in patent standards between countries. The World Intellectual Property Organisation (WIPO) is a forum for one set of discussions aimed at harmonisation and standardisation. The key player in this game, the USA, is also taking independent action through it bilateral agreements with individual countries such as Taiwan and Korea in order to win allies in the current battle over whether priority should be given to the first to invent (the US position) or the first to file (all other industrialised countries).

There is much to be said for uniformity of patent systems. We must ensure, however, that the standards we adopt are the 'best' and not those imposed by the strongest members of the economic order on the weakest. That having been said, the protection afforded to patent holders in the OECD countries, even though it remains variable with mixed success in working towards common standards, is relatively strong and robust. It is a major factor of growth. Which brings us to the second point.

2. Lesser Developed Countries

By comparison, many developing countries provide little or no patent protection or enforce it only weakly. This they do on the grounds that patents are a legal way of the rich exploiting the poor, or that limited national recognition of foreign IPR redresses the economic balance because they get access to technology which they could not otherwise afford. This misguided policy damages developing countries more than the companies whose IPR goes unrecognised, because those developing countries forgo the economic growth they could otherwise generate.

A major mistake in failing to provide enforceable patent systems denies developing countries a flow of growth-creating technology, forcing them into relying on overpriced obsolete technology rather than maximising the returns which could be made from the proper import and use of technology for wealth creation.

Thus, any movement to unify patent systems worldwide would go a long way towards ensuring universal acceptance of the need to reward adequately the use of IPR. The needs and problems of developing countries' ability to pay also deserves sympathetic consideration.

BTG believes that the establishment of a unified and universal system of patent protection should go in hand with the provision of financial assistance to developing countries. This is necessary to ensure that they are encouraged to abide by the rules and to adopt 'best practice' without involuntarily penalising themselves.

Policy Issues for Developing Countries

Attitudes in developing countries vary and the stage of development reached is usually dictated by the receptiveness of countries to foreign technology and foreign investment.

There are countries within the Commonwealth which possess natural advantages like a skilled labour force, an entrepreneurial culture and relatively few 'hang ups' about their colonial past; their governments have a commercial or strategic focus, encourage academic research and emphasise competitive self-reliance, while their industries probably have capabilities in R and D, production, design and engineering. Such countries tend to outperform their counterparts who, although possessing the same skills and potential enterprise, nevertheless still believe in a command economy surrounded by a panoply of controls and a vast and inefficient public sector operating to socio-political objectives whose only aim seems to be the preservation of an entrenched bureaucracy.

The critical role of governments in formulating appropriate policies to encourage the growth in a country's technological capabilities must therefore never be underestimated.

Conclusion

Technology alone will not create growth. However, it is the seed from which genuine growth will emerge. Identifying the seed, placing it in the most fertile ground and then helping it to germinate and bloom is a challenging but highly rewarding task. Patience, dedication and adherence to the principles of technological excellence and commercial realism over a forty year period made British Technology Group the world's most successful technology transfer organisation. If governments adopt those very principles, there is no reason why that success cannot be repeated many fold in different countries.

The Author

Rusi Kathoke was born in India. After obtaining an Honours degree in Economics and History from St Xavier's College, Bombay he qualified as a Chartered Accountant with KPMG Peat Marwick McLintock, London. In 1979 Mr Kathoke joined the National Enterprise Board (NEB) which merged with National Research Development Corporation (NRDC) in 1981 to form the British Technology Group (BTG). He was appointed Assistant Finance Director of BTG in 1982 and Finance Director in 1986. He is a director of BTG's American subsidiary - British Technology Group USA Inc - and is responsible for the development of BTG's business in India in particular and the Third World in general.

British Technology Group is the world's leading technology transfer organisation. The annual sales value of products licensed by BTG amounts to around $3 billion. BTG's licensing strategy is international, with more than 75% of its total revenues arising from overseas. It has recently established its first joint venture in technology transfer by setting up a company in India, British Technology Group India Private Ltd, in collaboration with Creditcapital Finance Corporation Ltd, an Indian Merchant Bank.

British Technology Group
101, Newington Causeway
London
SE1 6BU

Tel: + (44) 71-403 6666
Fax: + (44) 71-528 8690

2.6 University-associated Contract Research Organisations: The Role of SINTEF in Norway and in theThird World

Eiliv Sødahl
SINTEF, Trondheim, Norway

SINTEF (The Foundation for Scientific and Industrial Research) is legally an independent foundation attached to the Norwegian Institute of Technology (NTH), which is the only fully-fledged technological University in Norway. SINTEF was founded in 1950, inspired by the apparent success of many of the numerous contract research organisations (CRO) operating from the campuses of technical universities in the USA. Today it employs nearly 1,900 full-time staff; of these about 1,100 are university graduates, primarily engineers. The annual income was over NKr 1.1 billion in the 1990 (close to £100 million). This ranks SINTEF fourth amongst European CROs (after the Frauenhofer Gesellschaft in Germany, TNO in Holland and VTT in Finland) but first amongst those founded on a non-government (ie. university) initiative.

Over 70% of the income comes from contract work, of which more than half represents work undertaken for industrial clients. Basic grants from the national authorities comprise about 6% of turnover, the remainder being financial support from national research councils for specific projects within fields of national priority. SINTEF (or rather the SINTEF Group) has today a pronounced multi-disciplinary profile with close to 30 operational units. In the SINTEF system, the professional part of the organisation tends to become a replica of the corresponding NTH section, ie. SINTEF is basically organised by disciplines in the same way as NTH.

SINTEF was established primarily to stimulate Norwegian activities. However, SINTEF has also over the years engaged itself directly in a number of Third World projects which have not been an integral part of the SINTEF-NTH co-operation. SINTEF was one of the founding members of the World Association of Industrial and Technological Research Organisations (WAITRO), which was created in 1970 under the auspices of the United Nations Industrial Development Organisation (UNIDO). Although not explicitly expressed in the statutes, WAITRO's activities are primarily geared to the needs of the Third World. SINTEF has actively contributed to the development of this organisation as a vehicle to strengthen North-South co-operation between contract research organisations. I had the honour to serve as the President of the Association for the period 1979-82.

At SINTEF we have found that lack of training at the managerial level is more often the cause of problems in an industrial and technological organisation than lack of scientific skill. It is therefore characteristic of our direct assistance to the Third World that the form of support to research institutions normally takes place on a broader scale than the purely scientific.

Typical projects of this nature have involved assistance to:

- Industrial Tribology Machine Dynamics and Maintenance Engineering Centre (ITMMEC), New Delhi;
- National Institute of Oceanography, Goa;
- Beijing Institute of Software Research and Training, Beijing;
- Bangladesh Petroleum Institute, Dhaka;
- Petroleum Research Institute, Kuala Lumpur.

I also had the interesting and rewarding experience to assist personally in the establishment of The Caribbean Industrial Research Institute at the campus of The University of the West Indies in Trinidad.

Each project has its specific characteristics and challenges. In the case of ITMMEC, for instance, we experienced a lot of problems during the first years, many of which resulted from the inherent conflict between the academic ambitions of the staff at ITMMEC and their new role as servants to industry. However, the last 3 years of the project came off very well, first of all thanks to a strong, industry-oriented and internationally recognised leader of the centre. He left after the NORAD (Norwegian Agency for International Development) support terminated, and priority was apparently put again on academic activities such as university teaching and international publications.

The best example of institutional co-operation is, however, the long lasting co-operation with, and support to, the Departments of Chemistry and of Chemical and Process Engineering of the University of Dar es Salaam (UDSM) in Tanzania. The Norwegian part of this project involves close co-operation between NTH and SINTEF, both parties contributing with qualified staff for teaching and participation in research projects - both in Norway and on secondment to the UDSM. This project started back in 1973, financed by NORAD, on the initiative of Professors Katrine Seip Førland and Tormod Førland (see 2.19).

NTH and NORAD have cooperated in offering training opportunities for engineers and science graduates from developing countries for more than 20 years. During this period more than 1,000 graduates from about 60 countries have studied at NTH under the programme. A NORAD-NTH Coordination Committee was established very early, with overall responsibility for the NORAD sponsored programmes. The Committee reports both to the governing board of NTH and to NORAD. NORAD finances a small administrative office on the NTH campus and provides the funding for the training courses. NTH is also responsible for the academic aspects. Although SINTEF is not formally 'visible' in this picture, SINTEF staff are in effect running two of the five courses mentioned below and are heavily involved in running two of the remaining three.

Under this NORAD programme, NTH is now offering five one-year international diploma courses at postgraduate level. The combined annual intake is about 70-75 students, the majority holding a NORAD fellowship.

The five courses are:

- Pulp and Paper Technology;
- Port and Coastal Engineering;
- Hydropower Development;
- Electric Power Distribution Systems;
- Petroleum Exploration and Reservoir Evaluation.

SINTEF's Third World related activities follow two main avenues: support to the international diploma courses formally organised by the NTH and direct assistance to the establishment and development of R&D institutions. In addition, SINTEF takes a positive attitude towards employees seeking leave to join technological projects in the Third World. Such projects may be run by national or international aid organisations, and a fair number of our professionals have been on such missions. SINTEF also renders services to Norwegian consultancy and engineering firms operating in the developing world, but such contracts are to be considered as part of our normal business.

The main driving force for both SINTEF and NTH to devote resources to the benefit of the Third World is a felt obligation to contribute to the reduction of the development gap between the 'haves' and the 'have nots'. As institutions of importance in Norwegian society, both SINTEF and NTH naturally have an obligation to make such contributions to the official Norwegian foreign aid policy. Presently about 350 or close to 5% of the students at NTH come from the Third World. The fact that NTH does not receive any special economic compensation for 80% of these students probably makes this quite a respectable figure compared with other European universities.

SINTEF's activities oriented towards the developing part of the world are quite modest compared to our total business volume. The employees of SINTEF are in general quite positive towards the prospect of getting involved in Third World projects. However, as an independent CRO we have to earn our living by selling our services at realistic costs. It is therefore a true dilemma that the fees paid by international as well as national foreign aid agencies, although normally considered quite adequate for individual consultants, do not in any way cover the project's proper share of the operational costs of an organisation such as SINTEF. An institution-building project in a developing country requires the engagement of the very best and most experienced people; such people are also in great demand at home. Taking these facts into account, I do not expect SINTEF's Third World related activities to expand in the years to come. Hopefully, they will be maintained at their present level.

The SINTEF experience has served to emphasise two points, both very relevant to the work of aid agencies. Firstly, that cooperation aimed at human resource development and institutional building should be long-term, to allow for the development of mutual relations and confidence. Secondly, that the combination of teaching, training and applied research, including joint research projects, is a very fruitful and effective way of developing relevant competence and expertise in academic and R&D institutions in the Third World.

The Author

Eiliv Sødahl graduated in mechanical engineering from the Norwegian Institute of Technology (NTH) in Trondheim and after industrial experience returned to Trondheim as Senior Vice-President of the Foundation for Scientific and Industrial Research (SINTEF) at NTH, since 1990 as Director attached to the Office of the President of SINTEF. President of the World Association of Industrial and Technological Research Organisations (WAITRO) for 1979-82 and Consultant with UNIDO as a Project Manager for the Caribbean Industrial Research Institute in Trinidad and Tobago 1971-73.

SINTEF
NTH
N-7034 Trondheim
Norway

Tel: + (47) 7-593070
Fax: + (47) 7-592480

2.7 Transnational Business and Technological Adjustment: An Indian Case Study

Ashok S Ganguly
Unilever PLC, London, UK

The pace of technology change is rapidly increasing in the developed economies, bringing with it particular pressure on business to innovate and successfully manage shortening life-spans of products and processes. Information about technology change is, furthermore, rapidly communicated world-wide. This puts into stark relief the relative achievements and failures of different communities and political philosophies, and highlights the dichotomy between the progress of the developed and un(der)developed nations.

The flow of technology and evolution of transnational businesses in developed countries and newly industrialised countries such as South Korea, Mexico and Brazil is well documented. Developments in India and China, where a high degree of self-reliance, slow growth and modest international trade has avoided hyper-inflation and hyper-indebtedness but rendered their economic infrastructures relatively obsolete and fragile, have remained something of an enigma. This paper records the experience of one transnational corporation in India, with particular reference to a classic example of technological adjustment requiring the establishment of a local R&D centre.

The Indian Scene

Industrial development in India since 1947 is marked by distinct and well-defined phases. Up to around 1960, India concentrated on building an industrial infrastructure virtually from scratch. Since the private sector was insignificant at that time, much of this development was undertaken in the public sector. While such a strategy allowed this basic infrastructure to be developed with the limited resources available, persisting with it has turned out to be self-defeating and has led to widespread obsolescence and inefficiency. The Indian private sector has subsequently grown moderately well, mainly in an environment of shortages and absence of competition. The flow of advanced technology and foreign investment has been exceedingly modest, although this had started to change very slowly in the 1980s, particularly in the electronics industries.

During the 1960s, India's major achievement was an impressive increase in agricultural output and productivity. The use of new crop varieties and new transplanting techniques by a tradition-bound farming community are examples of significant technology adjustment. Economic growth has picked up significantly in the 1980s, despite these structural obstacles. India's high propensity rapidly and successfully to absorb transnational technology has been demonstrated in a fairly wide range of enterprises, such as long-range weather forecasting and rural telecommunications.

The success of technology adjustment and adaptation in India is critically influenced by the priorities , abilities and outlook of the local population. Fortunately, the basic education system in India has remained strong and continued to meet the rising demand for engineers and scientists. The use of English has also given ready access to the West. The one area of unmitigated failure has been India's inability to slow down significantly the population growth rate, which now threatens the achievements of the past forty years.

Although many foreign companies which were in India before 1947 have continued to grow and generally prosper, investment by new transnational corporations has been negligible. With the possible exception of the Bhopal disaster, India's competence in managing highly complex and advanced technologies is high. Complex technologies have also been brought to India and made more efficient and environment-friendly by Indian technologists. In contrast, poor management in large public sector units has led to obsolescence in heavy industries and the infrastructure.

It is therefore a great pity that India, despite many advantages, is being gradually left behind as significantly more resources and technologies flow into nearby countries such as Thailand, Indonesia and Malaysia. India's growth has been hampered more by her failure to recognise and take advantage of geo-economic realities and her own inherent strength, than by technology adjustment failure. Nevertheless, realities of economics and market forces are likely to force pragmatic changes even in India, sooner rather than later.

The Unilever Experience

The Unilever subsidiary Hindustan Lever (HL) is acknowledged as one of the oldest, largest and most successful transnational corporations in India. Unilever's pioneering of successful industrial R&D in India has been crucial to this success. Since the establishment of Unilever's R&D centre in India in 1958 was not part of a global strategy per se, it is worth recalling the circumstances which led to its establishment.

In the early 1950s, the consumer goods business of HL was flourishing. It manufactured and distributed well-known household products in both rural and urban markets. However, some of the key raw materials such as palm oil, tallow and certain speciality chemicals and perfumes had to be imported, as were indeed many requirements of different Indian industries during that period. Principally due to a significant fall in India's international trade, the country faced a serious shortage of foreign exchange in the 1950s. Consequently, imports were either drastically reduced or stopped altogether, threatening the future of HL and other import-dependent industries.

HL's strategic analysis of how to deal with this situation led, firstly, to the introduction of petrochemical-based detergents, which had started growing rapidly in the West after World War II, to the Indian market in the late 1950s. In retrospect this may appear obvious. However, the raw materials, chemistry and technology for manufacturing detergents are entirely different from traditional soap-making. Furthermore, the Indian housewife had, through generations, become used to washing clothes with tablets of soap under running water or in village streams. Washing with the new detergent powder needed changes to this traditional daily habit. The success of detergents around the world is, of course, now a matter of history but its origins in a new market such as India provide a fascinating illustration of adjustments of both technologies and products.

HL also decided, secondly, to explore the use of indigenous raw materials as import substitutes to avoid losing its large and pre-eminent natural soap business altogether. Indigenous edible oils were not available for soap-making because India had swung in a few years from being a net exporter of edible oil to being a net importer. Although Unilever had a number of R&D establishments in Europe, they were not equipped to explore raw materials indigenous to India and of urgent need to the Indian business. However, a high-quality research infrastructure and skills were available locally. Consequently, in 1958 Unilever established the HL R&D Centre, its first outside Europe, with an immediate brief to develop technologies to solve its import restriction crisis. This initiative turned out to be one of the most successful import substitution efforts of its time and permanently changed the technology culture and the climate of innovation and self-reliance in HL. It provides a classic example of development by a transnational corporation of a local strategy involving technological adjustment and an instructive contrast to the more direct technology transfer in the detergents case.

Technologies were developed for upgrading a wide range of non-conventional, inedible vegetable oils such as rice bran, linseed, castor, sal, karanja and kusum for use in the manufacture of toilet soap. By thus completely substituting the traditional oils (tallow and palm oil) which are imported, the country stands to save large sums of foreign exchange. In 1989 alone Hindustan Lever used 110,000 tonnes of unconventional oils in soap making, valued at over £15 million in foreign exchange.

Furthermore these developments have resulted in the generation of a large amount of indirect employment. It is estimated that, at current levels of usage of these oils, more than 150,000 additional jobs have been created in the collection of the seeds and the subsequent oil extraction. Just as importantly, these jobs have been created in the least developed parts of the country. A further technological adjustment, also dependent on import substitution, has made possible the production of structured soaps with a performance equivalent to conventional soaps at significantly lower levels of total fatty matter. It is estimated that about 350,000 tonnes of oils will be saved during the next five years, bringing a foreign exchange saving of over £60 million.

The cultural and technological issues involved were quite complex. Innovations involving basic science and technology were, at that time, primarily in the domain of Government and academic laboratories, and commercial exploitation of indigenous technology was virtually non-existent in Indian industry. Setting up an industrial R&D establishment, forging relationships with peer groups and networking with Government and academic laboratories in India and with Unilever laboratories in Europe was time-consuming and laborious. The process of innovation transfer from laboratory to pilot plant turned out to be a fairly complex process. Associated capital expenditure decisions were, by their very nature, high-risk propositions. Invariably the time estimated between discovery and exploitation was overshot. However, the eventual commercial rewards exceeded even the most optimistic forecasts.

Many of the innovations from HL's R&D Centre have subsequently found application in other Unilever companies and the laboratory itself has branched out into various other disciplines. Today, patents, publications and awards bear testimony both to the success of its scientists and to the powerful advantages of being part of Unilever's global R&D network. The research centre continues to attract some of the brightest Indian post-doctoral scientists from around the world. Many of the scientists, after a successful stint in the laboratory, have moved to other parts of the HL business in senior management positions and there is a continuous enriching exchange of scientists with other Unilever laboratories.

Concluding Remarks

The history of HL in India is but one example of the rewards that can flow from appropriate technology transfer or technology adjustment, even in an environment that is only moderately enabling. Given India's regulatory and structural obstacles, few investors other than transnational companies such as Unilever, with an existing large stake in India, had both the incentive and ability to profit from investment in the country after 1947. In contrast, developing nations such as Thailand, Malaysia and Indonesia have attracted large-scale foreign investment and the effects of the resultant technology transfer on their economies are obvious. The combination of free market forces and advanced communication technology will, in time, force the pace of political and economic change in India, China and elsewhere. In India's case the educational, R&D and language infrastructures are already in place to capitalise on the investment that would flow from a more favourable government approach to open-market practices.

The Author

Dr Ashok S Ganguly graduated as a chemist from Bombay University in India, followed by post-graduate studies at the University of Illinois in the USA. He joined Hindustan Lever (subsidiary of Unilever) in 1962, working as a research scientist before transferring to production management in 1971 and becoming Chairman in 1980. Since May 1990 he has been Director (Research and Engineering) on the Board of Unilever PLC in London. He has been involved in many professional and national organisations in India (including member of the Science Advisory Council to the Prime Minister and of the Governing Council of the Council of Scientific and Industrial Research, and President of the Bombay Chamber of Commerce and Industry 1984-5) and in 1987 received the Padma Bhushan (one of India's highest honours) for his contribution to public service.

Unilever PLC
Unilever House
Blackfriars
London
EC4P 4BQ

Tel: + (44) 71-822-6264
Fax: + (44) 71-822-5881

2.8 The International Flow of Scientific Manpower

Alan G Smithers* and John M Pratt†
University of Manchester, Manchester, UK*
University of Surrey, Guildford, UK†

The problem of the 'brain drain' and its effect on economic development in the Third World are well known; planners can plan but they cannot implement without adequate skilled manpower. The aim of this paper is to point out that a potentially massive shortfall of scientists, technicians and engineers in the USA, caused in part by the 'swing from science', could greatly increase both the magnitude of the 'brain drain' from the Third World and the pressures on their governments to find appropriate solutions.

The 'Brain Drain' and the Shortage of Skills in the Third World

In the 1960s two events served to heighten interest in the 'brain drain'. First, the coining of the phrase 'brain drain', originally used in a 1962 Royal Society report to describe the migration of British scientists and engineers to the USA, helped to focus attention to the problem; it was later applied to the migration of skilled manpower in general and from developing countries in particular. Secondly, significant changes occurred in the immigration policies of the major receiving countries (USA, Canada, Australia), eliminating ethnic discrimination and giving priority to highly skilled workers; this triggered a serious loss of skilled scientists, engineers and medics from most Third World countries, which has continued ever since.

The phrase 'brain overflow' was subsequently introduced to emphasise that at least part of the problem was due to a surplus of trained manpower over available jobs in the giving country and the phrase 'reverse technology transfer' to emphasise the serious economic consequences due to loss, both of the resources invested in education and training, and of the potential contribution of trained manpower to the national economy. UNCTAD has found (1) that some developing countries were losing 20-70% of their annual output of doctors and has calculated (2) that in 1970 the value of the incoming scientists, engineers and doctors to the USA was equal to $3.7 billion compared to outgoing development assistance of $3.1 billion, while India's Centre for Research, Planning and Action calculated (3) that the capital value of the transfer of highly qualified people from India during the period 1970-85 was ca $51 billion to the USA, $13 billion to Canada and $2.8 billion to the UK. On the other hand, remittances can be substantial (equal to 15% of India's total exports in 1977 (4)) and expatriates can provide the manpower with the further experience needed (as in Taiwan) when economic development reaches a certain stage. The brain drain can be used to reproach either the developed countries for taking away with one hand what they give with the other or the developing countries for paying insufficient attention to the problems of population growth, job creation and human rights.

Much was written and debated about the brain drain in the 1960s and early 1970s, but relatively little in the 1980s. The recently published conference proceedings entitled 'The Impact of International Migration on Developing Countries' (5) includes several good surveys of the brain drain. Its causes ('push' from developing and 'pull' from developed countries, moderated by passport requirements and immigration laws respectively) and different aspects (economic, ideological, human rights) have been analysed and solutions proposed; the issues are complex. A Sri Lankan cabinet committee investigating the causes of its country's brain drain has listed the main **push** factors as high rate of unemployment, lack of opportunity, low salary, lack of recognition, lack of technical support and equipment, low status and limited participation in decision-making and the main **pull** factors as opportunities for intellectual contact, shortages of manpower and higher standards of living (6). Solutions could include both reform of the education system (to provide skills more relevant to the needs of the country, perhaps also less marketable in developed countries) and better working conditions (salaries, incentives, promotion; facilities, equipment, contact with colleagues; closer involvement in national decision-making) (4,7), but little effective action appears to have been taken. Suggestions for some form of financial compensation of giving countries by receiving countries have frequently been discussed, but never agreed (8). 'The great challenge is to find appropriate solutions for mitigating the negative effects of the brain drain for developing countries, which takes into account the interests of all parties as well as the basic right of human beings to move freely' [8].

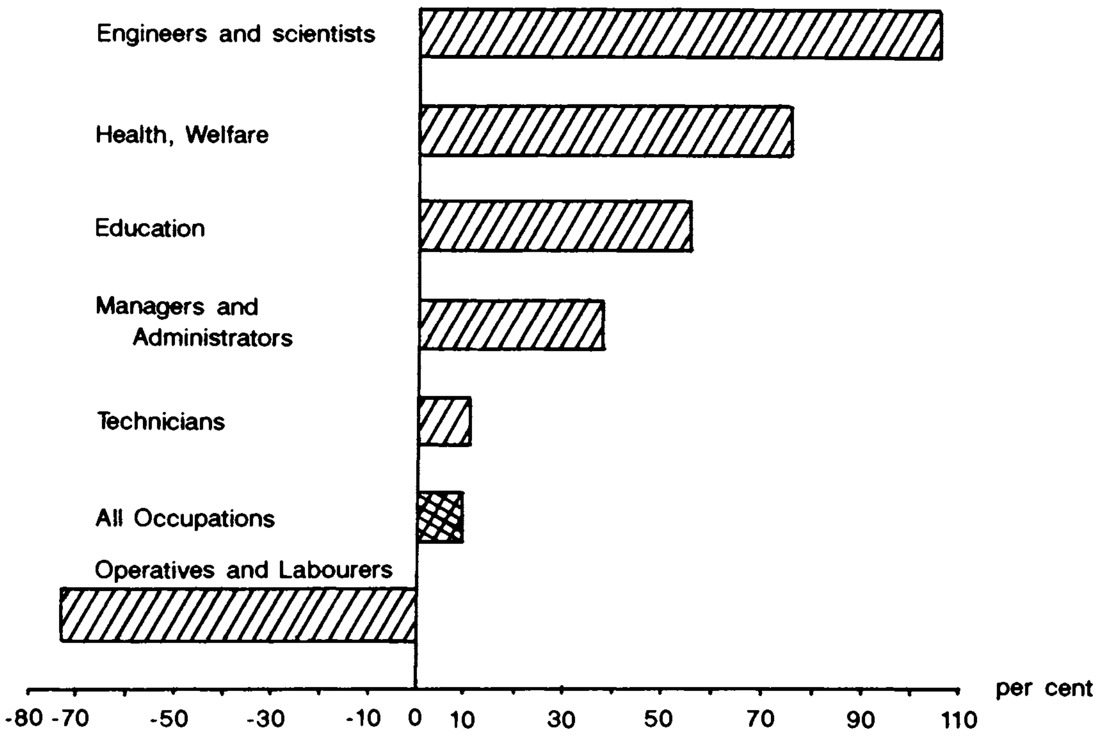
The 'Swing from Science' and the Shortage of Skills in the USA

Both the USA and the UK will see an increasing gap between the demand for, and home production of, STEM (science, technology, engineering, medicine) manpower, all of which depend on school science and mathematics, for three reasons:

1. The **changing skill requirements** of an increasingly affluent and ageing society (see figures 1and 2). Projecting future requirements is fraught with difficulty and the results must be treated with caution. For both countries, however,similar marked increases are predicted for STEM manpower with the interesting difference of an apparently much lower demand for technicians in the UK; this reflects the current under-supply of technicians, acknowledged to be a weakness in the UK economy.

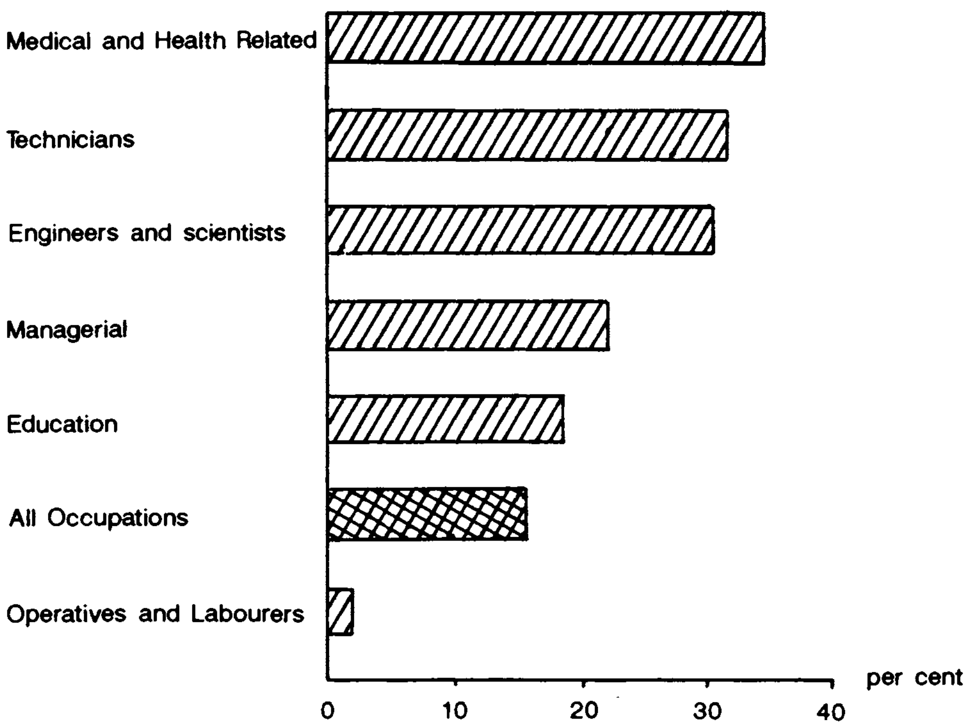
2. **Demographic Trends.** The physical sciences are intrinsically difficult subjects taken by students of high academic ability, as shown by their IQ scores and relative examination performance (9); it is likely that only a small proportion of any population will be able and willing to pursue them to a high level. This means that the supply of physical scientists and, by extension, of engineers is likely to be more closely related to demographic trends than graduates in other fields. Figure 3 shows how changes in the number of schoolchildren taking A-level exams in physics shadows changes in the total population of 18-year olds in the UK; the relatively faster fall in the number of A-level physics entries since 1982 can be ascribed to the swing from science at the school level. Since developed countries tend to have lower birth rates (see Table 1), demographic trends alone will tend to produce relative shortages of STEM manpower in the developed countries and surpluses in the developing countries.

Figure 1. UK Projected Occupational Change 1971-95



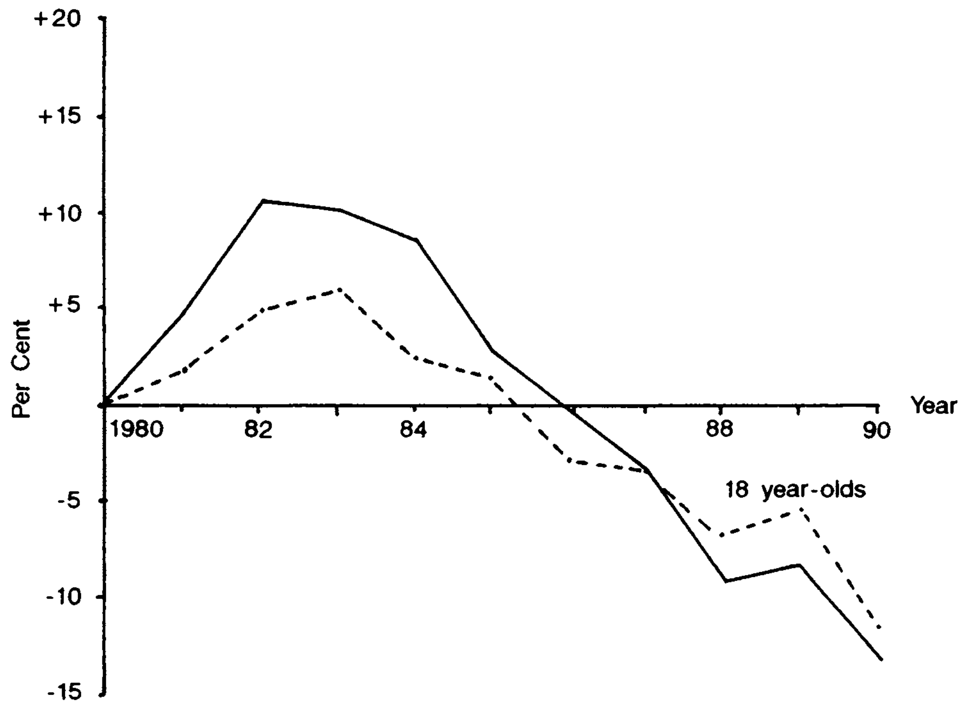
Source: Institute of Employment Research, University of Warwick (1989)

Figure 2. US Projected Occupational Change 1988-2000



Source: US Bureau of Labor (1989)

Figure 3. A-Level Physics Entries in England and Wales in Relation to the 18 Year-Old Population



Source: Smithers (1991) Physics World, 4, *4, 26-31*

Table 1. Population Trends, 1987

Country	Population (millions)	Annual Growth Rate (%)	Median Age in 2000
Nigeria	101.8	3.4	15.5
Malaysia	13.2	2.7	
Bangladesh	103.0	2.4	
India	788.0	2.2	25.4
Australia	16.2	1.3	
Canada	25.9	1.2	
USA	244.1	1.0	30.0
UK	56.7	0.1	34.6

Source: OECD Demographic Yearbook (1989) and Hobbs in 'Exploring the Future: Trends and Discontinuities', Royal Institute of International Affairs, London (1989).

3. The **'Swing from Science'.** Table 2 shows the changes in the preferred university subjects among school-leavers in the UK; many of those who would previously have studied science or engineering now go into business administration or accountancy. Figure 4 shows similar trends for the USA. A recent study at one USA University (Purdue) showed a further serious swing away from science even after enrolment with only 15 of the 97 chemistry freshmen still on the course after 2 years; the major new preference was management sciences but, because those programmes were already full, most enrolled for liberal arts, biology and health sciences (10). It is often assumed that the 'swing from science' is due to association of eg. chemistry with pollution and physics with atomic bombs in the public mind but at least one study (11) has shown that, for the brighter science educated school leavers who might have become science PhDs, factors such as career prospects and the image of the profession are far more important.

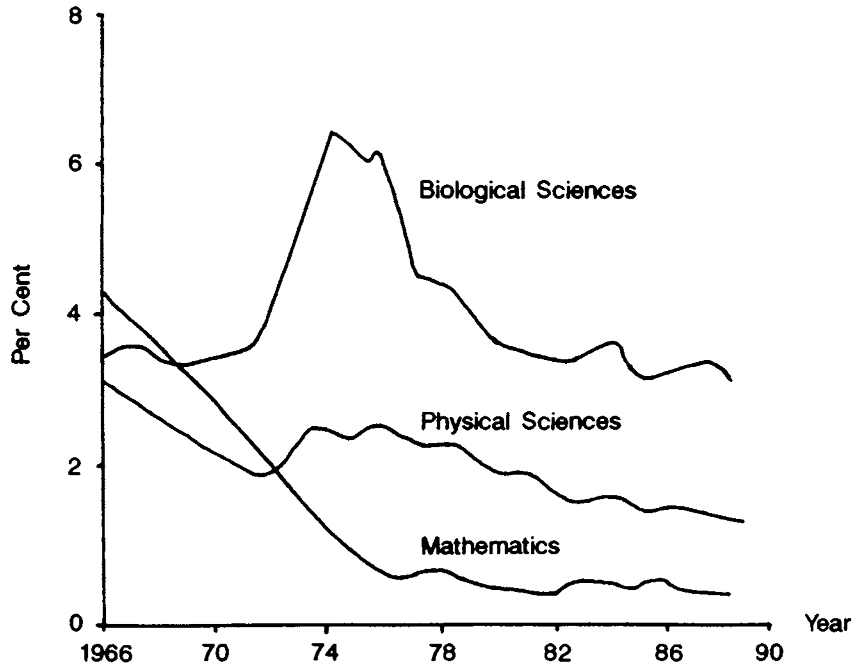
Table 2. University Admissions in UK, 1988

Subject	Applications	Acceptances	Ratio of applications to acceptances	Change in applications 1985-88 (Per Cent)
Biological Sciences	9727	5877	1.7	0.3
Physical Sciences	9118	7153	1.3	- 7.8
Mathematical Sciences	8218	5694	1.4	- 2.6
Engineering and Technology	14274	9466	1.5	- 18.5
Business and Administration	13741	3922	3.5	18.1
Social Sciences	27952	11705	2.4	11.9
All subjects	156981	80496	2.0	- 0.1

N.B. Home students only

Source: Universities Central Council on Admissions

Figure 4. First Year Higher Education Students in the US



Source: Wingspread, 10, *4*, *1*

The production of PhDs in natural sciences and engineering (NSE) has long lead-times and shows a pronounced funnelling effect; see the USA data in Table 3. This is only part of the story because foreign students form an increasingly large proportion of the total PhDs awarded in the USA, accounting for ca 25% of the combined NSE output. In his Presidential Address to the American Association for the Advancement of Science in 1990, Atkinson compared the likely supply and demand for NSE PhDs in the US in the year 2010 (12). He assumed an ouput of 11,250 PhDs (which included 50% of the foreign-born PhDs) available for the home market and compared this with four increasing estimates of demand, starting with the 1988 level of demand (leading to a shortfall of 960), then successively adding in the effects of earlier retirements, expansion in higher education (hence increased demand for staff with PhDs) and increased levels of R and D activity (shortfall of 9600) ie. the shortfall in NSE PhDs in the USA could be anything between 1000 and 10,000 per year.

Table 3. US National Sciences and Engineering Pipeline

Year	Stage	Number	%
1977	High School Sophomores	4,000,000	100.0
1977	High School Sophomores Interested in NSE	730,000	18.3
1979	High School Seniors Interested in NSE	590,000	14.8
1980	College Freshman Planning NSE Degrees	340,000	8.5
1984	BS Degrees	206,000	5.2
1984	Graduate Students, NSE	61,000	1.5
1984	MS Degrees	46,000	1.2
1992	PhDs, NSE	9,700	0.2

Source: National Science Foundation

In considering how this gap might be bridged, the USA has looked towards those groups currently under-represented among PhD recipients (women, blacks, hispanics) but is increasingly coming to view the foreign entrant as the only realistic solution. The extent of immigration into any country is controlled by its immigration laws and these tend to be adjusted in relation to policy and economic need. The idea of a 'green card (ie. permit for permanent residence) on graduation' has been put forward in the USA and similar suggestions made in Canada. Third World countries (and others!) should keep an eye open for changes in the USA immigration laws.

Summary

Developing countries and donor agencies cannot expect a proper return from investments in science and technology, or even from aid in general, until the problem of the brain drain is reduced. The impending shortfall in STEM manpower in North America will (unless filled from, say, Eastern Europe) greatly increase the problem and the need to find solutions. In most countries there is probably scope for re-examining both the production (ie. the education system) and the use (ie. working conditions) of this skilled manpower. The recent changes in attitude of the donor agencies, giving priority to science and technology and placing more emphasis on institution-building, could help to bring scientists and others more into the decision-making process, thereby gaining both their advice and their commitment; the absence of such mechanisms appears to be a common weakness of the present situation.

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The Authors

Alan Smithers has been Professor of Education at the University of Manchester since 1976, where he directs the Education and Employment Research Programme. His team was commissioned to prepare a report on 'the brain drain' for a meeting of Commonwealth Science Ministers in November 1990. John Pratt has been Professor of Chemistry and Head of Department (1985-1991) at the University of Surrey after periods at the University of Oxford, with ICI and as Professor of Inorganic Chemistry at the University in Johannesburg, South Africa; he has an interest in national and international factors currently affecting chemistry, including the 'swing from science'. The authors would welcome comments and reactions to the article.

Professor A G Smithers
School of Education
University of Manchester
Oxford Road
Manchester
M13 9PL

Tel: + (44) 61-275-3446
Fax: + (44) 61-275-3519

Professor J M Pratt
Department of Chemistry
University of Surrey
Guildford
Surrey
GU2 5XH

Tel: + (44) 483-509164
Fax: + (44) 483-300803

2.9 The Problems of Giving and Receiving Development Aid: Where Does Science Fit In?

Ingemar Wadsö* and John M Pratt†
University of Lund, Sweden*
University of Surrey, Guildford, UK†

Every country's development depends ultimately on the availability of skilled manpower in fields such as engineering, technology and medicine; the production and 'development' of such skilled manpower depends, in turn, on the existence of a healthy infra-structure of the pure sciences. In all developed countries it is taken for granted that science teaching and scientific research are essential factors for progress; the same should apply to developing countries.

It is clearly desirable for a developing country to be able to call on its own skilled nationals (whether trained at home or abroad) rather than rely on foreigners on short-term contacts and at a slightly later stage, perhaps in association with other countries of the region, to build up training facilities coupled with a healthy high-calibre science base. Their presence could help to reduce the problem of the brain drain; their absence could weaken the country's future chances of self-sustaining development.

There is, however, reason to fear that many developing countries, especially in Africa, may be denied the chance of building up an adequate science base either because of a belief that world-class science is simply too expensive a luxury for many parts of the developing world or because the claims of science do not have sufficient political appeal in competition with other claims on limited funds.

The aim of this paper is to consider some of the needs and problems of science in the Third World in the light of current patterns of international aid. One of the basic problems is that, while science requires long-term support for 'institution-building', politics and finance both dislike long-term commitment of funds.

The Science Base

High-calibre scientists can be trained and employed and high-class research carried on either in institutes of higher education (as is most common in Western countries) or in separate research institutes (as in most Eastern European countries); we here assume the former. High-class universities could provide a science-based service with the capacity to:

1. Contribute to identifying needs and opportunities and to selecting, modifying and developing relevant technologies.

2. Provide a fast and effective channel of information and communication with the international community of scientists for keeping their country abreast of the latest trends and developments.

3. Conduct teaching at a high level and carry out research of a quality which would make the researchers acceptable as peers by the international science leaders. Clearly the first of these depends on the second, and the second on the third.

The basic sciences differ in their methodology, needs and costs and in their relevance to national activities; such differences would have to be reflected in any national science policy. As a very sweeping generalisation, one could say that: physics is relatively more closely associated with the military as well as with certain sectors of industry; chemistry with industry (in particular the upgrading of raw materials which must form the basis of wealth-generation in many developing countries) and, via analytical chemistry, with environmental matters; and biology with agriculture, forestry and fisheries. In addition to the more direct and obvious funds for research and training, all three sciences will share common needs such as:

1. Supporting technical services (instruments, workshops) and information services (libraries, journals, data-bases).

2. Appropriate and effective lateral links with other national bodies more directly concerned with the setting of national objectives, the translation of R into D, technology transfer, etc: this requirement is even more important in developing, than in developed, countries.

3. Funds to facilitate contact (via conferences, visits) with colleagues on the international scene.

Donors and Recipients of Aid

Statistics concerning the major donors and recipients of official development assistance (ODA) in 1987/88 are given in Tables 1-4 (data taken from refs. 1 and 2. Most such aid (85% in 1988) is provided by the OECD (Organisation for Economic Cooperation and Development) countries (3). As expected (see Table 1), the largest industrial countries operate most of the largest ODA programmes; Japan overtook the USA as the largest single contributor in 1989. Their contributions, when judged as a percentage of GNP (see Table 2), are not as impressive as those of smaller countries such as The Netherlands and the Scandinavian countries.

Saudi Arabia is in a class by itself; its aid programme, directed mainly towards other Arab countries, has probably changed considerably since the Gulf War. Aid from the industrialised socialist countries of Eastern Europe (mainly the USSR) has decreased drastically as a result of their recent political and economic changes, and some are now considered developing countries. Aid from the USSR has been directed mainly to other socialist countries, particularly Cuba.

Table 1. The Largest Donors of ODA* in 1987/1988

Country	Amount (10^9 US$)	% of Total Aid
1. USA	9.4	18.3
2. Japan	7.7	15.0
3. France	4.5	8.9
4. FRG	4.5	8.7
5. USSR	4.2	8.2
6. Italy	2.8	5.5
7. Saudi Arabia	2.4	4.7
8. The Netherlands	2.1	4.1
9. Great Britain	2.1	4.0
10. Canada	2.0	3.9

* Official Development Assistance. Data from ref. 1.

Table 2. Countries Ranked According to ODA as Percentage of GNP in 1987/88

Country	% of GNP	Amount (10^9 US$)
1. Saudi Arabia	3.27	2.4
2. Norway	1.10	0.9
3. The Netherlands	0.98	2.1
4. Denmark	0.88	0.8
5. Sweden	0.88	1.4
6. Kuwait	0.83	0.2
7. Finland	0.55	0.5
8. France	0.51	4.5
9. Canada	0.48	0.2
10. Belgium	0.44	0.6

Data from ref. 1.

Table 3. The Largest Recipients of ODA in 1987

Country	Inhabitants (millions)	Total Amount (10^9 US$)	Amount Per Person (US$)
1. India	810	1.9	2
2. Egypt	50	1.8	35
3. Bangladesh	110	1.6	15
4. China	1070	1.4	1
5. Israel	4	1.3	286
6. Indonesia	170	1.2	7
7. Sudan	23	0.9	39
8. Tanzania	24	0.9	37
9. Pakistan	102	0.9	8
10. Syria	11	0.7	62

Data from ref. 2.

Table 4. Recipients Ranked According to ODA Per Person in 1987

Country	Inhabitants (millions)	Amount Per Person (US$)
1. Israel	4	286
2. Jordan	4	157
3. Bostwana	1	136
4. Somalia	6	102
5. Mauritania	2	96
6. Senegal	7	92
7. Costa Rica	3	87
8. Papua New Guinea	4	87
9. El Salvador	5	86
10. Gabon	1	77

Data from ref. 2.

The major recipients according to both total sum involved and the sum per inhabitant are listed in Tables 3 and 4. Although both India and China receive large amounts of aid, the sums are equivalent to only $1-2 per person per annum. The small country of Israel, on the other hand, has the highest amount of aid per person; it can hardly be considered a developing country and owes it position in the league table to its special relationship with the USA.

The developing countries form a very heterogeneous group and their needs (eg. in the scientific field) can be very different. China and India, whose populations represent nearly half the developing world, are poor countries but have very important natural resources in the form of large numbers of highly educated people, not least in science and technology. From this point of view it is even questionable whether India should be considered a developing country. The same applies to some countries in Eastern Europe and others such as Argentina where political mismanagement has allowed the economy to deteriorate. These countries need help and cooperation to preserve their relatively high scientific and technological level. Their problems are entirely different from those of most developing countries in , eg. Africa, which have never achieved such a standard and where several of the few aspiring universities such as Makerere in Uganda and Legon in Ghana have been virtually brought to their knees by the political and economic state of those countries.

The Problems of Science

It is obvious (and perfectly understandable) that ODA is given by donors and passed on by the recipient governments for a mixture of political, military and commercial, as well as humanitarian, reasons. Political and military considerations naturally tend to be most noticeable in the case of donors who claim to have global responsibilities (or ambitions), while the recipient governments must give some consideration to the political pros and cons of favouring supporters, buying off pressure groups, etc. Commercial considerations underlie the frequent earmarking of aid for capital-intensive schemes which require the provision of equipment and/or expertise from the donor country or for schemes which may serve to open up future export markets.

In addition, politicians in both developed and developing countries prefer to put their money into programmes which produce political dividends, quantifiable financial returns or highly visible prestige constructions in a relatively short space of time; they dislike programmes which require commitments to recurrent expenditure over lengthy periods before results can be expected.

Building up a healthy science base not only requires a long-term commitment of expenditure but, in addition, its eventual dividend is not easily quantifiable; furthermore, scientists are all too frequently associated with those centres of anti-government dissent called universities.

Although there appears to be increasing pressure to devote more aid to longer-term 'institution-building' and 'social expenditure', it will be politically far easier to support institution-building in the applied than in the pure sciences and to support social expenditure on primary education than on university science departments. Anyone who wishes to press the case for supporting the basic sciences must expect an uphill struggle against practicalities, prejudices and perceptions, but forewarned is forearmed.

Doing Science - and doing it properly - will certainly be expensive, but several comments should be made, eg.

1. Not doing science may be even more expensive, in terms of the lower capacity to manage technological change and the likely higher level of the brain drain.

2. There is no need for every (eg. African) country to 'go it alone'; there is, in fact, every reason to build up regional 'centres of excellence' to share the costs - every reason except the difficulty of getting agreement between national governments.

(As loyal chemists we should perhaps also add in parentheses (3). Research in physics can be very expensive, due to the demands of Big Science (eg. particle physics, astronomy); by contrast, research in chemistry is relatively cheap).

Conclusions

There, are however, some encouraging signs. In its report on 'Sub-Saharan Africa; from Crisis to Sustainable Growth' (4), the World bank says that "If Africa is not to be further marginalised, (it) must improve its science and technology training and aim at the highest standards for at least a minimum core of specialists (which implies long-term commitments), and forge new partnerships with qualified firms and research institutes in the developed countries". We would suggest there is an equally strong case for forging much stronger links than at present with universities in the developed world, encouraging them to become directly involved in both teaching and research. They have the expertise and many of their staff probably feel some moral obligation to help the developing countries. Programmes could be arranged where developing and developed universities are connected in pairs (or even in larger associations), initially in a mother-daughter but later in a sister-sister relationship, over a lengthy period (say 15-20 years).

We would strongly urge the donor agencies to earmark some aid for a deliberate longer-term 'science injection policy' aimed at: building up the basic sciences (physics, chemistry, biology, together with mathematics); developing regional centres of excellence; ensuring strong lateral links to other bodies involved with national policies and with development, production and wealth-generation in general; and involving universities (as well as firms and research institutes) in the developed world more closely than at present. We would also urge scientists to consider whether and how shorter-term support could best be used to promote the overall longer-term aim of institution-building for the basic sciences.

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The Authors

Ingemar Wadsö is Professor in Thermodynamics at the University of Lund, has been closely associated with IUPAC since 1967 and a member of the IUPAC Bureau since 1985, has taught and examined at the University of San Agustin, Arequipa, Peru and given a lecture course at the Panjab University, Chandigarh, India. John Pratt has been Professor of Chemistry and the Head of the Department at the University of Surrey since 1985 after periods at the University of Oxford, with ICI and as Professor of Inorganic Chemistry in Johannesburg, gaining first-hand experience of much of East and Southern Africa; has an interest in national and international factors currently affecting chemistry.

Professor I Wadsö
Chemical Centre
University of Lund
P O Box 124
S-221 00 Lund
Sweden

Tel: + (46) 46-108175
Fax: + (46) 46-104533

Professor J M Pratt
Department of Chemistry
University of Surrey
Guildford
Surrey
GU2 5XH

Tel: + (44) 483-509164 (direct)
Fax: + (44) 483-300803 (University)

2.10 Planning a Chemical Industry - Taiwan, ROC: A Case Study

Ting Kai Wu
Grand Pacific Petrochemical Corporation, Taiwan, Republic of China

The 'Economic Miracle' of Taiwan, based on her successful transformation from an agrarian to an industrial economy, would not have been possible without the establishment of a world-class chemical industry over the past 25 years. This paper attempts to analyse how such a development has been accomplished in a land with a population of 20 million but practically no natural resources and to note the problems caused by this rapid and successful transformation, which resulted in a slow-down in the 1980s, and the strategies for future growth and development (N.B. values are given in US $).

What the Statistics Show

Taiwan's per capita GNP has risen steadily from $919 in the 1950s, through $1671 in the 60s, $3626 in the 70s and $6501 in the 80s to $7358 in 1990, achieving a growth rate of 10% pa in the 70s, as its agrarian economy was transformed into an export-oriented industrial economy:

	1952	1990
Total value of export sales	$0.12 bn	$67.2 bn
% as agricultural, including processed, products	91.9	4.4
% as industrial products	8.1	95.6

In 1990 the total value of industrial production was $165.3 billion and of export sales $67.2 billion (13th in the world), giving her foreign reserves of ca $80 billion (1st or 2nd in the world). The chemical industry is the largest industrial sector, contributing one quarter (24.2%) of the total production value of $165.3 billion but only 8.5% directly to the export sales of $95.6 billion. This demonstrates its strategic importance as a supplier of materials and other chemicals in underpinning the export industry; cf. the electrical/electronic and textile sectors with 16.8% and 11.6% of total industrial production but contributing 23.6% and 15.3% to export sales.

Development of the Chemical Industry

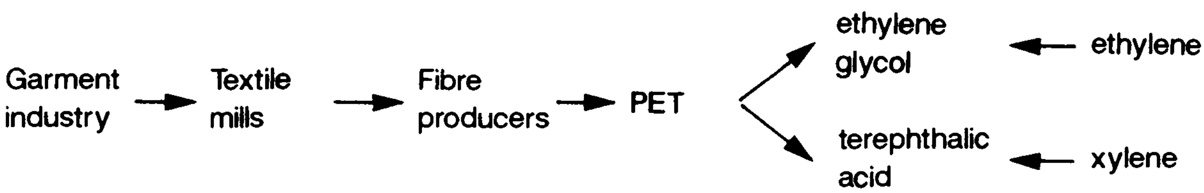
The development of Taiwan's chemical industry can, for convenience, be divided into the following phases:

1913 - 1943 (Japanese colony)	Manufacturing of basic chemicals (eg. fertiliser, chloralkali)
1944 - 1953	Production of substitutes for imported consumer goods (eg. consumer commodities, agricultural products)
1954 - 1967	Development of light industries (emphasising paper/food/textile products etc.)
1968 - 1975	Beginning of backward integration of petrochemical industry (boosting the export of textile products)
1976 - 1988	No. 3 and No. 4 naptha crackers started with the fastest growth of petrochemical industry
1989	Restructured strategy to shift away from commodities to higher valued chemical products and advanced materials

As a result of this growth Taiwan now ranks 1st in the league of world producers for PVC (with a capability of 1.1 million metric tonnes pa) and acrylonitrile-butadiene-styrene polymer (0.63), 2nd for polyester fibre (1.3) and pure terephthalic acid (1.0), but still only 16th for ethylene (0.91)!

Main Factors Contributing to this Success

1. Establishing an integrated chemical industry, eg. integrating backwards from a garment industry depending on cheap labour and imported materials by successively developing the following capabilities (where PET is polyethylene-terephthalate or terylene):



Similarly the shoe industry was strengthened by development of the plastics industry.

2. **Development of a 'Debottle-Necking' Capacity**

The necessary chemical plant could not have been operated successfully without the existence of skilled Taiwanese engineers and technicians able to de-bug and even improve the technology, all of which was originally imported from the US, Japan or Europe. The Taiwan VCM Corporation, for example, started production of VCM (Vinyl chloride monomer) based on the UCC process (ethylene + Cl_2 $\rightarrow$ ethylenedichloride; cracking $\rightarrow$ vinyl chloride + HCl) in 1973. The plant failed in 1975 but was reorganised and production increased from the original 120 tonnes/day to 150 tonnes/day in 1976 and eventually to 180 tonnes/day in 1979 with an energy saving of 30% and productivity of 2.07 (exceeding the world standard of 2.05) tonnes VCM per tonne of ethylene.

3. Cooperation between up/mid/down-stream operators which, for example, enabled the effects of the 33% appreciation of the Taiwanese against the US dollar over the four years 1987-90 to be absorbed by the mid-stream operators without adversely affecting export sales. This was accomplished by a joint agreement to price the chemical raw materials, intermediates and products in US currencies with reference to their US Gulf coast contract prices.

4. **Strong Support by the government**

- Tax incentives (4 or 5-year tax holiday).
- Investment incentives (duty-free import of machinery and equipment).
- Well-planned industrial zones.
- Government-owned low-profit raw material and intermediate manufacturers CPC (Chinese Petroleum Corporation) and CPDC (China Petrochemical Development Corporation).
- Production/procurement agreement between CPC and petrochemical suppliers (January 1983 -December 1986).
- Custom/tariff protection.
- Export incentives.

5. An abundant supply of well-educated human resources. Most relevant for building up the chemical industry has been the supply of graduates in chemical engineering, which has increased as shown below:

	BSc	MSc	PhD
1985	954	112	4
1986	932	177	9
1987	950	193	14
1988	956	207	10
1989	942	184	17
1990	948	288	24

The first chemical engineers in Taiwan graduated in 1945 and there are now 36 Chemical Engineering Departments in the country. Many of these graduates emigrate to the USA and Japan but an increasing number return home as the job opportunities increase, bringing with them extremely valuable training and experience. They proved to be invaluable to the current and future development of ROC's chemical industry by their direct participation in the management of the existing institutions and their entrepreneurial efforts in creating new businesses.

Recent Weaknesses and Problems:

- Environmental opposition from local communitities.
- High labour costs due to severe labour shortage.
- High cost of industrial land (300 times higher than in US).
- Shortage of own R and D capability.
- Government policies of liberalisation and internationalisation.
- Offshore diffusion of downstream fabrication factories (eg. shoes, textiles).

This has resulted in the expansion of Taiwanese industry overseas; the chemical industry has invested in the USA (including a $1.7 billion petrochemical complex by the Formosa Plastics Group), Thailand, Malaysia, Philippines, South Africa and Europe. Many foreign chemical firms have also set up plant in Taiwan in the plastics and polymers field, eg. Dow, Dupont, Himont, Hoechst (all completed in 1990), EMS-Chemie, ICI and Rhône-Poulenc (due for completion 1991).

Goals for Future Development

1. Strengthen raw materials supply eg. by boosting ethylene production from 0.7 (in 1980) to 1.5 (in 1995) million metric tonnes pa by the commissioning of two naptha crackers.

2. Develop engineering plastics, advanced materials and other high-valued chemical products, aiming by 2000 to achieve 12% of the world market for engineering thermoplastics (worldwide market of $12.5 billion forecast), 12.5% of high performance fibres ($2.4 billion), ca 15% of advanced organic matrix composites ($10-12 billion) and 12% of high value-added plastic parts ($24 billion).

3. Increase effort in pollution abatement; direct investments in pollution abatement already include $1.8 billion for CPC's no. 5 cracker and $0.83 billion for FPC's no. 6 cracker.

4. Promote R and D activities by accelerating the trend as shown by the following actual and targeted figures.

	1985	1986	1990	2000
% of chemical industry sales reinvested in R and D	0.22	0.34	1	3
No. of employees engaged in R and D per 1000 chemical industry employees	1.95	2.25	3	6

Possible Lessons for Other Developing Countries

- Provide strong governmental support.
- Establish an integrated chemical industry.
- Obtain (ie. import) the best available production technology but,
- Develop own 'debottle-necking' capability and technology, then own R and D capability.

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The Author

Dr T K (Peter) Wu was born in China, received his university training as a chemist in the USA and worked with du Pont from 1966 until returning to Taiwan in 1985; currently President of Grand Pacific Petrochemical Corporation (producer of styrene monomer and ABS plastics).

Grand Pacific Petrochemical Corporation
9th Floor
42-1, Hsu Chang Street
Taipei
Taiwan 100015
Republic of China

Tel: + (886) 2-311-4731
Fax: + (886) 2-361-4240

2.11 The Importance of Professional Organisations and Professional Qualifications

M Mohinder Singh
Ministry of Science, Technology and Environment, Kuala Lumpur, Malaysia

This paper briefly examines the development, organisation and role of the national scientific professional societies in Malaysia, with particular reference to chemistry. Malaysia is a country with a rapidly developing chemical industry, whose government has recognised the important contribution which professional societies can make in the country's drive to develop industrial technology and has recently taken active steps to enhance their role.

Prior to independence (1957) there were only a few professional societies, mostly local branches of those established in the UK such as the Malaysian Section of the Royal Institute of Chemistry (now The Royal Society of Chemistry) which still has a membership of over 120.

Since independence, there has been a steady growth of national-based discipline-oriented professional societies, especially since the 1970s. There are now some 40 active science-based national professional societies in the country, including the Malaysian Institute of Chemistry with a current membership approaching 1400.

The Malaysian Institute of Chemistry (MIC)

The Institut Kimia Malaysia (The Malaysian Institute of Chemistry) was established on 8 April 1967 as a professional society for chemists and registered under the Malaysian Societies Act 1966 on 13 October 1967. In 1975, with the enactment of The Chemists Act by the Government of Malaysia, the Institute became a statutory corporation with the power to regulate the practice and promote the interests of the profession of chemistry in Malaysia. Chemistry has therefore joined the other professions regulated by enactments (accountants, pharmacists, advocates and solicitors, veterinary surgeons, dental surgeons, engineers, medical practitioners, surveyors and architects) which all interact directly with the public and hence need to be regulated to ensure that the public interest is safeguarded and there is no malpractice. The Institute is run by a Council of 14 members, all of whom are elected except the Director-General of Chemistry, who automatically becomes the Registrar of the Institute.

The most important legal aspects of the Act are that it empowers the MIC 'to regulate the practice and promote the interests of the profession of chemistry in Malaysia'. The act requires that all chemists, who give or provide any chemical analysis in a determinative capacity and who certify or declare in writing the result of any chemical analysis for the public, should be members of the Malaysian Institute of Chemistry, and the Institute is empowered:

(a) to determine the qualification of persons for admission as members;

(b) to provide for the training, education and examination by the Institute, or any other body, of persons intending to be members and of members practising or intending to practise the profession of chemistry in Malaysia;

(c) to regulate the practice, by members, of the profession of chemistry in Malaysia;

(d) to promote the interests of the profession of chemistry in Malaysia; and

(e) to render such pecuniary or other assistance to members or their dependants as it thinks fit with a view to protecting or promoting the welfare of members.

Besides the registration and examination activities under the Act, the Institute carries out a whole range of professional and social activities to promote chemistry at various levels, including chemistry awards at school, university and professional levels, promotion of laboratory safety and the holding of symposia and conferences.

The most important section for the protection of the public is section 23 which is reproduced here:

"1. No person who is not registered under this Act shall (a) practise or hold himself out as a registered chemist or as a person of any other like description, (b) advertise by any means or in any manner as being engaged in practice as a registered chemist, or (c) adopt, use or exhibit the term 'registered chemist' or its equivalent in any other language or any other term of like description in such circumstances as to indicate or be likely to lead persons to infer that he is a registered chemist.

2. No person shall give or provide in a determinative capacity, or certify or declare in writing the result of, any chemical analysis for the purpose of determining the composition or specifications of any substance or product consumed or used by, or intended for the consumption or use of, the public or any section thereof, unless (a) he is a registered chemist, or (b) he is a registered pharmacist .... (for specified purposes), or (c) he is an employee working under the supervision of a registered chemist or registered pharmacist...

3. Any person who contravenes any of the provisions of subsections 1 and 2 is guilty of an offence and is liable, for the first offence, to a fine of one thousand dollars or to imprisonment for one year and, for a subsequent offence, to a fine of two thousand dollars or to imprisonment for 2 years".

In order to carry out these functions, the Institute has established regulations for the practice of the professions and for the training, education and examination of persons desirous of practising the profession of chemistry in Malaysia.

There are three grades of membership of MIC, which in order of increasing seniority are the Licentiateship (LMIC), the Associateship (AMIC) and the Fellowship (FMIC). All members of the Institute are designated as registered chemists. The membership of the Institute is close to 1400. In order to enable chemists with degrees from unrecognised universities to be recognised, the Institute has since 1978 conducted qualifying examinations annually.

As a part of the regulating exercise, the Institute maintains a register of chemical laboratories. All registered chemists are required, under the code of ethics, to inform the Institute of the names and location of laboratories under their charge. In order to promote a high standard of chemical analysis, the Institute launched a scheme of laboratory accreditation in 1986. 46 laboratories are now accredited in the areas of ores, metals, edible oils, essential oils, latex, SMR rubber, effluent, soil and plant, fertiliser, pesticide (paraquat and warfarin), feed meal, petroleum (oil and gas), cement and coal, and water. One of the essential requirements of the scheme is that laboratories must implement recognised monitoring procedures or participate in cross-check exercises. Cross-check exercises are available in several areas, namely latex, SMR rubber, effluent, palm oil, soil, plant, fertiliser, ores and pesticides. The accreditation scheme has certainly contributed to better quality control in the laboratories.

Under Section 27, the Minister of Science, Technology and Environment has appointed senior chemists in the public service as Inspectors for the purpose of the Act. They have over the years carried out routine visits to laboratories to check on the presence of registered chemists, safety features and existence of quality control practices, but it has not been necessary so far to bring any laboratory to court for offences under the Act. The visits have resulted in ensuring that chemical laboratories employ registered chemists (those who did not previously comply have subsequently rectified the situation or employed consultants) and that adequate safety features are present, thereby contributing to a safer laboratory environment.

Regional and Inter-professional Cooperation

There are now several regional federations of professional societies in Asia, including the Federation of Asian Chemical Societies (FACS) established in 1979. Its membership now comprises the 22 national chemical societies in Australia, Bangladesh, Brunei, China, Hong Kong, India, Indonesia, Iraq, Japan, Jordan, Korea, Kuwait, Malaysia, Nepal, New Zealand, Papua New Guinea, Philippines, Singapore, Taiwan, South Pacific, Sri Lanka and Thailand. Its major activities include: holding the Asian Chemical Congress every two years; publication of the FACS Newsletter; the FACS Foundation Lectureship, the Young Chemists Award and other Awards for contributions to chemistry; organisation of regional workshops and symposia in collaboration with international organisations (such as UNESCO); and establishing Working Groups on subjects of special interest to the region, such as environment, instrumentation, chemical education and chemistry-industry interaction.

The MIC is also a member of two Malaysian umbrella organisations for professional societies:

1. Malaysian Professional Centre (MPC) established in 1973 as a result of the initiative taken by the Commonwealth Foundation to strengthen professional societies in several countries (including Malaysia) by establishing Professional Centres.

2. Confederation of Scientific and Technological Associations in Malaysia (COSTAM) established in 1980.

There is some overlap in membership (MPC's 17 and COSTAM's 19 member societies both include the Medical Association and Institution of Engineers as well as MIC) and in aims (which include promoting cooperation between societies, publishing a periodical, formulating and expressing opinions), but the MPC tends to attract the larger societies and those not concerned with science and technology (dentists, vets, pharmacists, architects, planners, social workers). Many of the activities of professional societies will receive a boost from recent government action.

National Plan for Industrial Technology Development

In May 1990 the Government of Malaysia, recognising the low level of technological capability in the country, adopted a comprehensive 'National Plan of Action for Industrial Technology Development' with a view to accelerating its efforts towards industrialisation. One of its recommendations is to 'encourage and increase the role of professional and science-oriented societies through incentive and support measures'.

In keeping with the recommendation, the Ministry of Science, Technology and Environment provides financial assistance to professional societies for organising activities which increase public understanding and appreciation of science and technology, as well as activities that enhance science and technology capabilities of the country. In 1991, the Ministry set aside a record budget of $1 million ringgit for the National Science and Technology Week held from 8-14 August.

The Ministry of Science, Technology and Environment of Malaysia has recognised that the major weakness which restricts S and T-based professional societies from playing a more significant and meaningful role is the lack of funds and of secretarial and supporting facilities. It is therefore considering establishing a National Resource Centre for science and technology-based non-Governmental Organisations (NGOs) which would, for example: encourage cooperation between NGOs and the Ministry, harness their resources towards national projects and obtain their comments and advice; help to promote science (eg. school science clubs, public awareness campaigns); provide at a nominal charge common secretarial facilities such as permanent address, fax, photocopy, printing, equipment, PC, addressograph, etc. which can be used by NGOs (currently only a small handful of the larger NGOs have easy access to these facilities); build up a documentation centre on the NGOs; and publish regularly, jointly with NGOs, a popular Science and Technology Bulletin/Journal and other publications.

Conclusion

Malaysia has recognised the important role that professional societies can play in the socio-economic development of the country and has taken strong positive steps to harness this valuable resource. The change in the role of the MIC from professional society to statutory corporation, associated with enactment in 1975 of the Chemists Act, opened up a new and exciting chapter for the profession of chemistry in Malaysia. It provides the necessary safeguards to ensure that chemistry is used for the best interests of the nation and the public and at the same time provides the impetus for the development of the profession. As in the case of other similar Acts which regulate the practice of the different professions, the Chemists Act has confirmed the importance of professional qualifications. Among the main advantages are proper regulation of the profession, orderly growth, greater professionalism, avenues for professional advancement, regular updating of scientific knowledge through training courses, workshops and symposia, and contribution to the scientific and technological manpower of the country.

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The Author

Dr M Mohinder Singh has been Director of Science and Technology with the Ministry of Science, Technology and Environment in Malaysia since 1989; formerly Head of the Analytical Chemistry Division of the Rubber Research Institute of Malaysia. Has been actively involved with many professional associations and is currently President of the Malaysian Institute of Chemistry, Deputy President of COSTAM, member of the Board of Trustees of the International Foundation for Science and Editor of UNESCO's Asian Coordinating Group in Chemistry.

Ministry of Science, Technology and Environment
14th Floor
Wisma Sime Darby
Jalan Raja Laut
50662 Kuala Lumpur
Malaysia

Tel: + (60) 3-2938915
Fax: + (60) 3-2936006

2.12 Contributions to the Development of Chemistry in South America: The Link between the Universities of Surrey, UK and San Agustin, Peru

Angela F Danil de Namor
University of Surrey, Guildford, UK

Based on experience gained in the 1961-70 period as an undergraduate student and later as a member of the teaching staff at the National University of the South, Bahia Blanca, Argentina, we have been developing long term projects in chemistry with well established objectives taking into account that applied science requires basic science and if genuine help is to be given to developing countries this help should be geared to provide the basis so these countries are able to develop their own technology. I discuss here:

1. The development of an MSc programme in chemistry at the National University of San Agustin, Arequipa, Peru.

2. Research developments in areas relevant to the needs of Peru.

3. The creation of the European Latin American Research Group on 'Macrocyclic Ligands for the Design of New Materials'.

1. Establishment of the MSc Programme in Chemistry in Peru

The MSc programme in chemistry at the National University of San Agustin, Arequipa, Peru was established in 1984 as the result of an agreement of collaboration in the field of chemistry signed by this University and the University of Surrey, UK. This programme was financially supported by the Overseas Development Administration (ODA), the British Council, the Peruvian National Research Council (CONCYTEC) and the University of San Agustin. The University of Surrey agreed to provide the academic staff to run most of the postgraduate courses in Peru with myself as Academic Director of the MSc programme.

This programme is currently offered to members of the academic staff of eight Universities in the southern region of Peru as well as graduates in chemistry and related areas working in industrial institutions in Peru. Its aims are:

(a) to provide up to date knowledge in the three main branches of chemistry (organic, inorganic and physical chemistry).

(b) to emphasise the role of industry in the national economy of the country by the introduction of two postgraduate courses in industrial chemistry.

(c) to provide the basis for future research developments by encouraging students to make critical assessments of scientific papers related to the lecture course.

The course is run as a 3-year 'batch' process with intakes in 1984, 1987, and 1991. The award of the MSc degree of the University of San Agustin is given after the successful completion of twelve postgraduate courses in chemistry and a final research project, lasting two and a half years on a part-time basis.

The postgraduate courses (two years) are Inorganic Chemistry I and II, Organic Chemistry I, II and III, Physical Chemistry I, II and III, Quantum Mechanics, Mathematics and Industrial Chemistry I and II. Most of the courses were taught in English with simultaneous translation into Spanish during the first year. In the second year, students became familiarised with the language and translation was not always required. A period of six months was allocated for the research projects, most of which were funded by CONCYTEC. The areas covered ranged from aspects directly related to local industry (copper extraction, food science, natural products, water pollution) to pure academic research (different aspects of solution chemistry, metal extraction, thermochemistry). These projects were designed taking into account the available resources in terms of laboratory facilities in San Agustin which are very limited. Some of the projects were carried out in industry or with facilities provided by other universities in Peru. All research projects were externally assessed by Professor Wadsö, University of Lund, Sweden. A number of presentations to national conferences have emerged from these projects. A few projects have contributed to papers published in international journals. In the Peruvian context, this is undoubtedly a remarkable achievement. 8-9 separate staff (mainly chemists, also two chemical engineers and one biochemist and not all from Surrey) were involved in the MSc programme; 3 members of the San Agustin staff who graduated with MSc degrees in 1987 were given the responsibility of lecturing on some of the postgraduate courses. In order to assess their contribution to these courses, exams were set and assessed by the University of Surrey. This was a useful experience given that the University of San Agustin should be prepared to take over the running of the whole MSc programme in a few years, without any external help. The local staff was also in charge of running the practicals associated with the lecture courses, with guidelines provided by the University of Surrey.

Results. The total number of MSc graduates in the 1984-90 period is forty-one (twelve in 1987 and twenty-nine in 1990) at a total cost which would have covered only the training of four Peruvian postgraduate students in the UK at MSc level. The situation as far as employment is concerned is most encouraging since 68% are at present in academic posts in various Peruvian universities, 20% are in industry, 7% in technical jobs and 5% in business.

Future plans. The third intake of MSc students will take place in August 1991. Most of the courses will be taught by MSc graduates with guidelines provided by the University of Surrey. The supervision of research projects will continue to be the responsibility of the University of Surrey. The training of MSc graduates at PhD level in overseas Universities is now underway.

2. Research Developments in Peru

There is no doubt that international organisations have made significant contributions to the training of Latin American graduates at PhD level. However, it is often found that this training has not always been geared to the best benefit of the individuals or the countries involved, either because the research undertaken was not relevant to the needs of the country, or the Latin American institution does not have the funds required to acquire the research facilities needed by the returners to develop the research in which training was given. This has often resulted in brain drainage frustration. The steps taken by the Commission of the European Communities to overcome these problems are most encouraging. Although the main aim of the Community is to support high calibre research proposals (as assessed by the peer review system which operates at present), the implications of these research proposals to the scientific and economic development of a particular country are seriously considered.

As far as Peru is concerned, the Community is currently supporting a research project on "The Extraction of Copper by New Complexing Agents", involving the Universities of Surrey (UK), Catholic 'Santa Maria' (Peru), the Royal College of Surgeons (Ireland), ICI (UK) and the copper mining industry 'Cerro Verde' (Peru). As a result, two MSc graduates from San Agustin who are currently members of the Catholic University of Santa Maria are working on this project. They are expected to complete their PhD theses in March 1993.

3. The European-Latin American Research Group on 'Macrocyclic Ligands for the Design of New Materials for Environmental, Extraction and Recognition Purposes'

As a result of the successful development of the MSc programme at San Agustin and a network of contacts established with a large number of academic and industrial institutions in Latin America, a group of European scientists from 6 different countries currently collaborating in research activities have agreed to amalgamate their complementary skills to develop long-term research programmes in chemistry in collaboration with academic and industrial institutions in Latin America (Argentina, Brazil, Chile, Costa Rica, Peru and Uruguay).

After discussion with government officials, national and international organisations in various Latin American countries, it was decided to launch a research group on 'Macrocyclic Ligands for the Design of New Materials for Environmental, Recognition and Extraction Purposes', involving the production of macrocyclic ligands targeted for particular process applications, followed by the incorporation of these ligands into polymeric frameworks or natural materials (silica, alumina, cellulose, etc.) as well as the study of their properties. Applications would include the extraction of metals, the removal of pollutant agents, the resolution of racemic mixtures, etc. These processes are particularly relevant to Latin America where most countries possess an enormous amount of mineral resources, some of them not yet exploited, and where the environmental problems caused by methods currently used for metal extraction or resulting from the establishment of petrochemical industries are becoming a serious concern. The development of separation techniques based on new materials targeted to isolate biologically active compounds in natural products is another aspect that the group is planning to tackle.

The main objectives of the group to promote research in Latin America are:

1. To develop joint research projects in the specified research area.

2. To organise international meetings and workshops aiming to attract participation of young Latin American scientists including an international conference on 'Macrocyclic Ligands for the Design of New Materials' organised by the European-Latin American Research Group with the sponsorship of the International Union of Pure and Applied Chemistry (IUPAC) which will take place at the University of Surrey from 14-16 September 1992.

Conclusions

The quality of graduates produced by academic institutions is a key factor for industrial development in Latin America or elsewhere. The best way to achieve high quality graduates is by opening up opportunities to the teaching staff in Latin American universities. The MSc programme has offered this opportunity and these graduates have made excellent use of it. Their dedication, their efforts and their creativity to produce high quality work with limited resources should encourage highly industrialised countries to invest further in the developing world.

The MSc programme in Peru has in effect:

(a) Built up local capability and encouraged the initiation of MSc courses in other areas at San Agustin (Physics and Mathematics);

(b) Produced graduates with an excellent background to pursue PhD studies elsewhere;

(c) Increased links among British, European and Latin American institutions. The creation of the European-Latin American Research Group with the participation of industrial and academic institutions from Europe and Latin America is bound to strengthen these links even further and to contribute significantly to the mutual benefit of the institutions involved.

The Author

Dr Danil de Namor graduated with a BSc in Biochemistry from the National University of the South, Argentina in 1967. She was a member of the teaching staff at the University until 1970 when she came to Britain. In 1973 she gained a PhD in chemistry from the University of Surrey, where she is now a Lecturer in the Department of Chemistry and Assistant Dean for Academic Links with Latin American Universities, also an elected Associate Member of the Solubility Commission of IUPAC.

Department of Chemistry
University of Surrey
Guildford
Surrey
GU2 5XH

Tel: + (44) 483-300800 ext 2588
Fax: + (44) 483-300803

2.13 Technician Training and Instrument Production in India: The Experience of CSIO

S R Gowariker
Thapar Corporate R & D Centre, Patiala, India

Realising the importance of instrumentation as a national activity, the Council of Scientific and Industrial Research established the Central Scientific Instrument Organisation (CSIO) in 1959 at India's newly planned city of Chandigarh. The aims and objectives of the CSIO were to train instrument engineers, to undertake the repair and maintenance of all scientific/ medical instruments available at the educational institutions and hospitals in India and to develop the design and production of education/scientific/medical instruments.

The first activity to start at Chandigarh was the establishment of the 'Indo-Swiss Training Centre' (ISTC) in technical collaboration with the Government of Switzerland (Swiss Foundation). At ISTC a three-year diploma course for boys is conducted. During the training period students are trained extensively in theory and practicals covering all aspects of instrumentation (optical, electrical, electronic, geoscientific, medical, etc) technology, including workshop and foundry practice. This course is based on the Swiss pattern of training technicians. The minimum qualification for undertaking the course is passing the school final examination. The ISTC diploma is highly regarded, both in Government establishments and in industry. About 70 students are admitted after strict aptitude and general knowledge tests in technical and science subjects, followed by an interview. Nearly 5000 students apply for the course every year. In addition, ISTC conducts one-year post-diploma courses in industrial electronics and in die and mould. The annual intake for the post-diploma courses is around 30 students. Over the past nearly three decades ISTC has trained more than 1300 instrument engineers who are contributing substantially to the instruments industry in India.

In view of the large size of the country and the distribution of educational institutions, hospitals and industries, CSIO had set up nine well equipped Service and Maintenance Centres (S & M Centres) all over India. With trained manpower available at these centres, CSIO has achieved great success. The repair work done at the S & M Centres is at a subsidised cost, recovering practically only the cost of components plus small handling charges. At some places the centres take total responsibility for the maintenance of equipment on an annual contract basis. In most developing countries, large numbers of imported instruments are not in working condition owing to the non-availability of spare parts and after-sales service. In addition, the world instrument industry is undergoing a major technological change with the advent of micro-processor based instruments, resulting in a rapid rate of obsolescence; as a result, leading world instrument manufacturers are unable to supply spare parts after a few years of manufacture. Developing countries also often lack funds for spare parts and maintenance. CSIO, therefore, encourages its S & M Centres to undertake modifications/adaptions of customers' equipment, using local expertise to keep down-time at a low level. Using the CSIO model, practically all universities in India have started a University Service and maintenance Instruments Centre (USIC).

In addition, the Government of India has set up more than nine Regional Sophisticated Instruments Centres (RSIC) all over the country, where costly analytical instruments are available for use by the staff of universities and industries. These RSICs conduct seminars, workshops and training programmes for the users. CSIO staff play an advisory role in various activities of the USIC and RSIC.

Right from the beginning, optics (and optics related work) has been a major thrust area at CSIO. Today, it is India's leading centre for doing work in optics of international standard. In geometrical optics it has generated substantial capability in lens design and manufacture and, based on the knowledge generated at CSIO, a major optical industry has been set up in the Ambala-Roorkee area of India. Through these industries the country's requirements for surveying instruments, for education and engineering and for microscopes and microscopic optics for hospitals and research are fully met by indigenous production. Some of these industries have also fulfilled export orders. CSIO has a modern optics shop with facilities for curve generation, optical grinding, polishing, lapping, coating (single and multiple layers), etc. For the past ten years, scientists at CSIO have been engaged in diffraction - limited optics, including space optics. CSIO has set up modern facilities for holography. Large size high-efficiency holograms (white light, rainbow, etc.) are produced in the laboratory. Some original work done at the holography laboratory has been published in international journals. CSIO has a major programme on short-haul applications of fibre optics. Under this programme, CSIO has successfully designed and built a ten-line telephone system for a colliery in Bihar. This is the first telephone system ever to be installed in a coal mine in India. The optical fibre for this was drawn at the Central Glass Ceramic Research Institute, Calcutta and the work was coordinated by the Central Mine Research Station, Dhanbad. CSIO has also produced and supplied optical-fibre educational Kits-MODEMS. On the medical side, efforts have been successfully made to produce LYPROSCOPE for the family planning programme. CSIO has established a full characterisation facility for assessing the quality of an optical fibre; under this programme the refractive index profile, attenuation and spectral characterisation of any optical fibre can be measured at an Echelon III level.

Under the auspices of the Department of Science and Technology, and in collaboration with the Indian instrument industries, CSIO undertook a three-year intensive programme of development of several analytical, geoscientific and agri-electronics instruments. Three major analytical instruments were developed: a low-cost short-column scanning electron microscope (SEM) with 75 Å resolution and 80,000 magnification was developed with clean vacuum suitable for biomedical and material science applications: secondly, a micro-processor based Atomic Absorption Spectrophotometer (AAS) with dual lamps was developed: thirdly, a micro-processor based, dual beam UV-Visible Spectrophotometer was completed. All three instruments are now in commercial production in India. In the geoscientific area, batch production of analog seismographs with drum and chart was developed. Batch production of digital cassette seismographs using C-MOS technology along with cassette readers was also developed. Both these instruments are of stand-alone type and are used in remote terrain for the measurement of micro-tremors and earthquakes. Since India is a largely agricultural country, many field-usable agri-electronics instruments will be required, mainly to measure the quality and constituents of soil, if scientific methods are to be employed to obtain greater yields of grain per hectare from the land.

CSIO developed and manufactured field-usable instant pH-meters, soil, salinity testers and soil analysers. These and other agri-instruments, such as grain moisture measuring instruments, are manufactured by Indian industries.

In collaboration with the Society for Applied Microwave Electronic Engineering Research (SAMEER) and the post-graduate Institute of Medical Research and Education in Chandigarh (PGI), CSIO developed a modern 4 million volt Linear Accelerator (LINAC) for the treatment of cancer patients. This project was supported by the Department of Electronics of the Government of India. The LINAC is now operational at PGI hospital, treating about 40 patients every day for the past year or so. A consortium of Indian industries will manufacture 4 MV LINACs to provide facilities to treat cancer patients, whose number has increased considerably in the past few years.

Another important project undertaken at CSIO is the development (and limited production) of a Scanning Tunnelling Microscope (SEM) with atomic resolution as a joint project with the Naval Research Laboratory of USA under the INDO-US programme. A SEM capable of operating in air is already undergoing final trials; in the second phase, an SEM capable of operating under ultra-high vacuum conditions will be developed. CSIO has a major programme of development of sensors for robotic operation, supported by the Department of Electronics; tactile and vision sensors are in an advanced stage of development. CSIO is presently executing an UNDP project on the development of a set of micro-electronics instruments required for producing very large scale integrated circuits (VLSI) in the 1-2 micron range, viz. optical stepper for optical lithography (I line), high current ion-inplanter, molecular beam epitaxy system (MBE), reactive ion beam etching systems, radio frequency/DC sputtering unit, electron beam evaporator and VLSI tester. CSIO has also developed a set of physics-based equipment for pollution monitoring, including automobile exhausts, and undertakes to manufacture special equipment for the Indian Navy and Air Force.

From the above, it is quite evident that CSIO has fully met its objectives. CSIO also provides a resource centre for Indian industries and other establishments. It publishes a 'Directory of Scientific Instruments and Components' as well as a house journal ('CSIO Communications') and has a fairly large library, computer centre, well equipped machine shop, foundry and metallurgical laboratory, documentation services and hostels for ISTC students, all housed on spacious land with thousands of trees. CSIO accepts engineering students from various universities for summer/practical training; many students are offered a stipend by the CSIO. National seminars/symposia/workshops are regularly held by the CSIO.

CSIO's experience could be utilised in other developing countries. Through international bodies like UNDP, UNIDO, WHO, etc., CSIO undertakes training programmes for members of other developing countries. The lack of skilled manpower and inadequate industrial infrastructure are some of the major constraints in undertaking high quality research work in the developing world. Developed nations can guide and provide training programmes, which could be conducted in the developing countries at considerably reduced costs; India could be considered as a suitable venue.

The Author

Dr S R Gowariker began his scientific career at the Bhabha Atomic Research Centre and was Director of the Central Scientific Instruments Organisation at Chandigarh from 1983 to early 1991. He is now the first Thapar Fellow at the Thapar Corporate R & D Centre and an Emeritus Professor of the Council of Scientific and Industrial Research as well as Chairman of the Board of Governors of the Technical Teachers' Training Institute in Chandigarh.

Thapar Corporate R & D Centre
P O Box No 68
Patiala 147001
India

Telex: 394-207 TRDC IN

2.14 Science and Technology in Latin America and the Caribbean: Strategies for Tackling Present and Future Challenges with Limited Resources

Gustavo Malek
UNESCO, Uruguay

Introduction

Latin America is facing a very difficult situation with problems increasing in the economic and social fields, in education and in S and T (science and technology), particularly since the start of the 1980s:

- the region is severely affected by external debt and the energy crisis;
- the percentage of the population living in critical poverty is increasing;
- there is great concern about the need to preserve natural resources and to manage the environment intelligently;
- indicators of S and T activity, such as patents and scientific publications and available human and financial resources, provide no grounds for optimism;
- there is an increasingly serious inability of the education system to cope with the accumulation of knowledge and wisdom and to 'teach to think' and a growing divergence between education and S and T;
- the 'brain drain' out of the region may be joined by an increasingly severe 'internal brain drain' into unrelated professions.

There have, however, been some encouraging signs which must be built on, in particular a distinct improvement in the political situation and in regional collaboration, together with an increasing awareness of the importance of S and T and of education, even though this has not yet been reflected in the formulation of relevant policies, in the allocation of resources or in the overall planning processes. The financial restrictions continue to have very negative effects on education and on S and T in general.

The economic crisis will last for some time and requires that we (governments, private and public institutions) search for new and imaginative strategies, both national and regional and compatible with limited resources, which can serve to raise the standard of living without undue sacrifice of natural resources or destruction of the environment. To achieve this there needs to be a constant, on-going analysis and evaluation of the whole process with a critical analysis of priorities and - even more difficult - of postponements. Above all, states should endeavour, even at extreme sacrifice, to allocate the greatest amount of resources possible to education and to S and T.

Actions and Strategies to be Carried out on a National Basis

1. It is essential to establish well-defined and realistic S and T policies aimed at increasing the number, type and quality of human resources engaged in S and T with the maximum financial support possible in the present crisis situation, together with the priorities and mechanisms required to implement them. These S and T policies should be closely related to policies in other sectors, particularly education, and a close relationship established with productive sectors.

2. Scientific communities and related bodies need to be effectively trained in planning and cooperation in the making of political, economic and social policies that affect related areas; the role of universities and professional bodies is very important here.

3. Basic science should be given the importance it deserves.

4. A more rational and intelligent use of knowledge and information generated at the world level needs to be achieved; S and T information services should be strengthened (or established) in the countries.

5. The public, both at the level of political decision-making and among the general public, should be made aware of the importance of S and T development in improving both the economic sector and the quality of life.

6. Scientific planning and management, both in the universities and other institutions, should be improved.

7. Priority should be given to selected areas, themes and lines of S and T research, and areas of concentration and excellence chosen in order to avoid dissipation of energy and expertise.

8. Greater participation by the private sector in S and T research should be sought.

9. The right mechanisms must be established for transferring the results of S and T research to the productive sector.

10. Based on personal experience, I would recommend that the planning, coordination and promotion of S and T activities should be located outside the sphere of influence of education ministries and have direct links with the Prime Minister and the finance and planning ministries.

11. Adequate S and T personnel must be trained at the graduate and post-graduate levels.

12. Technological research should walk on two legs, viz. (a) appraisal and improvement of endogenous technologies, and (b) adaptation and assimilation of imported state-of-the-art technologies.

13. The measurement of S and T activities and the preparation of detailed and relevant analyses for decision-making need to be improved.

14. National consultancy and technical assistance services should be strengthened.

15. Training of specialised human resources capable of formulating and implementing integrated S and T projects is required.

Actions and Strategies to be Carried out on a Regional Basis

These are even more important than the national actions because, in the prevailing economic climate, most of the complicated problems can only be solved by working together. Regional and sub-regional integration, which is presently advancing with firm steps, provides the conceptual framework within which S and T development should also take place; conversely, many of the problems presented here are factors which will lead to accelerated integration. As examples:

1. Significant progress has been made in biotechnology on the basis of agreements between Argentina and Brazil, to which Uruguay has adhered and other countries will shortly be associated; the same applies to the field of informatics.

2. Most of the high-level meetings that have taken place recently (eg. those of the 'Group of Eight', now widened and called the 'Group of Rio') give particular emphasis to S and T developments in their working schemes and include educational and cultural aspects; these are concrete and pragmatic actions in the process of implementation.

3. Another important area that warrants special attention is preservation of the environment and its natural resources; the Treaty signed between the eight Amazon countries is an excellent example.

4. Regional integration is also greatly assisted by the action of international and regional organisations, eg. the major regional programmes organised through UNDP and its specialised regional programmes in the field of biotechnology. A similar regional programme in the field of chemistry is being set up.

The university system participates in the process in two ways: by training people who are capable of understanding and carrying out integration, and by formulating projects and concrete scientific, technological, educational and cultural actions in the countries at sub-regional level and even to perceiving regional actions. The strategy must be to develop a capacity for S and T within the countries on a regional level by creating critical masses of researchers in intelligently selected areas and to request international (bilateral and multilateral) support; efforts such as those being made by the University of Surrey with the British Council in post-graduate training in chemistry (with spectacular results in Peru), provide very valuable examples (see 2.12). We need the help of all, not as a gift but as working partners, to achieve the new model of 'integrated development' based on the application of knowledge, information, S and T and the improvement of our education systems.

Postscript

Finally, referring to this conference which forms part of the 150th Anniversary celebrations of The Royal Society of Chemistry, I feel to a certain extent that I am bringing to the Society the best wishes of the scientific community, particularly the chemists, of Latin America and the Caribbean. The meeting has achieved the objective of bringing together men and women from the world over. At a meeting in 1988 on chemistry teaching, organised by the National University of San Luis in Argentina and sponsored by UNESCO and IUPAC, the theme was 'Chemistry as a universal language for the unity of nations'. The truth of this attractive theme has been successfully demonstrated here in London at this event.

The Author

Gustavo Malek has been Rector of the Universidad Nacional del Sur, Bahia Blanca, Argentina, and Minister of Culture and Education in the Argentine Republic. From 1973 to 1976 he was International Coordinator of the Columbia/UNESCO/UNDP Major Project and from 1976 until October 1990 Director of the UNESCO Regional Office for Science and Technology for Latin America and the Caribbean.

Boston 6232
11500 Montevideo
Uruguay

Tel: + (598) 2-601200
Fax: + (598) 2-414317 (UNESCO)

2.15 The Changing Political and Economic Climate: The Need for New Initiatives

Erik Arrhenius
Institute for Natural Resource Management, Stockholm, Sweden

The present rapid changes in the economic and political climate, the emergence of environmental considerations and the search for more efficient natural resource management are prompting changes in development activities, as evidenced by the Brundtland report 'Our Common Future', the establishment of an environment department in the World Bank, and the discussions within OECD's Development Assistance Committee on 'The Role of Science and Technology in Development Cooperation with the Less-Advanced Developing Countries in the 1990s' (see section 2.2). There are, however, severe constraints on incorporating scientific knowledge into appropriate development policies and operations. This adds to the economic problems of development and reduces our ability to tackle the poverty and debt crisis afflicting large groups around the world.

These constraints are well illustrated in present global environmental issues such as: the transboundary transport of chemical wastes generated by chemical industries; the emission of 'green-house gases' from energy production, as well as industrial and agricultural activities, threatening to disrupt the infrastructure of human societies by possible rapid climate change; the threat to the protective ozone shield imposed by the stratospheric breakdown of long-lived chloroflurocarbons; the loss of organic material from agricultural soils leading to decreased soil fertility, and at the same time emission of greenhouse gases; the wasteful destruction of tropical forests which are a source of biodiversity and could be used as a source of material for industrial manufacture of valuable chemical products. A closer look at some of the issues surrounding the 'greenhouse' effect is illustrative.

The major part of the radiation absorption increase is caused by carbon dioxide emissions from the combustion of fossil fuels in transport and other energy production. There is abundant knowledge on increased efficiency in the production, transfer and end-use of fossil fuel generated energy as well as their substitution by other fuels such as biofuels or hydrogen, with no net CO_2 production. Also non-fuel techniques have risen to high technical sophistication and high efficiency. The policy support for these solutions and the inclusion of known 'greenhouse-low' technology in development operation has, however, been extremely weak and development activities have been dominated by conventional fossil fuel technology in plants with lower efficiency than in most industrialised countries. It has been calculated that in order to supply the energy needed to support the expected development activities for the next decade, an investment of 100 billion dollars per year in energy production is needed, compared with the World Bank's present yearly lending for energy investment of less than 5 billion dollars. The additional emission of carbon dioxide, if this programme could be financed, is 80%. This highlights the urgent need to overcome the constraints on Science and Technology utilisation for economic reasons as well as for achieving sustainable development.

The increase of carbon dioxide in the atmosphere is the result of a shift in balance between emission and elimination, but attention has largely been focused on emission (fossil fuel for combustion and destruction of tropical forests) and the processes of elimination (as carbonaceous matter in soils, marine organisms, etc.) has been largely ignored. Important factors here are the biochemical processes in agricultural soils. Present agricultural practices have led to a decrease of carbonaceous material in soil and to a serious loss of agricultural fertility in large areas of the world, notably in Africa. A doubling of the present average carbon content of such agricultural soils to reach the average grassland level would counterbalance 50-100 years oversupply to the atmosphere at the present rate. Since counteracting this critical loss of agricultural fertility now under way in several tropical countries would also counteract unwanted increases in the atmospheric content of greenhouse gases, such action should be stimulated. Much of the scientific and technological knowledge needed to implement these changes in agricultural practice is available but has not been incorporated into development policies and operational activities.

Chloroflurocarbons have been considered as a threat to the stratospheric ozone layer which protects the earth against deleterious shortwave UV irradiation. This effect is due to the stability of these molecules, which allows them to reach the stratosphere where they give rise to active chlorine species which catalyse the breakdown of ozone. This has led to political decisions in the so-called Montreal process favouring less stable chlorofluorocarbon species which will not reach the stratosphere. CFCs are also extremely powerful greenhouse gases, at present responsible for 25% of the marginal increase in the total greenhouse effect, but the new less stable CFCs are almost as powerful greenhouse gases as the old ones. Thus, by neglecting this scientific information in a political decision, we are throwing away an excellent opportunity for further action against the 'greenhouse' effect.

These are some examples of constraints in receiving and utilising scientific and technical information for efficient development and welfare. Some of these constraints reside in the conventional economic evaluation systems, which exclude technical developments that do not appear as directly economically feasible and which do not properly consider so-called 'externalities' such as threats to the sustainability of ecosystems or to human health, welfare and survival. Bilateral and multilateral development organisations consider the commercial availability of techniques as a prerequisite in economic development work and do not have functional mechanisms for bringing new more natural resource efficient techniques to commercial availability. The present rapid changes in goals and intentions imply that present commercially available technology does not meet our requirements. Mechanisms for removing constraints in the process leading from basic knowledge of needs to commercial availability of natural resource efficient technology are thus urgently needed. The main constraint on achieving efficient and environmentally sound technology in development work is neither the lack of scientific understanding of biogeochemical systems and processes, nor the absence of appropriate technical solutions, but poor utilisation of existing scientific and technical knowledge.

What is then needed in order to stimulate this implementation process? I should like to stress the need for some clearing house for structuring scientific and technical information into forms in which it could be more efficiently utilised in the development process. This process should comprise mechanisms for bringing scientists, technologists, entrepreneurs and venture capital holders into closer contact and could counteract the present imbalance between economic and scientific-technical capacity which is now manifesting itself within the multilateral development system. New conditionalities need to be designed for evaluation systems based on efficiency criteria in energy systems, as well as in agriculture, forestry, construction etc. The competence of the emitters (scientists and technologists) and the receptors (politicians, administrators and decision makers including the general public) to manage an efficient transfer of scientific and technological information is of crucial importance. Above all, scientists need to learn the language of economics and politics, to understand the aims and pressures of economists and politicians, and to gain credibility by working and writing at the interface between science and policy.

The Author

Professor Erik Arrhenius is a biochemist-biologist, Professor of Environmental Toxicology at Stockholm University 1971-1985, Professor of Natural Resources Management and Director of the Institute of Natural Resources Management at Stockholm University since 1985, spending 1988-1991 on leave as Principal Science and Technology Advisor at the World Bank.

Institute for Natural Resource Management
Stockholm University
10691 Stockholm
Sweden

Tel: + (46) 8-164214
Fax: + (46) 8-159522

2.16 Technology From the People: Managing Appropriate Technology Innovation in a Changing World

Matthew Gamser, Frank Almond and Ray Holland
ITDG, Rugby, UK

Why does so much R&D aimed at producing technology to help the poor in developing countries end in failure? Formal R&D often fails to deliver the goods because it is out of touch with the needs and aspirations of the poor, and because it is not making use of one of the greatest innovation resources - the knowledge and experience of poor producers, who need to be viewed as its clients or customers. Many of the R&D success stories of Western industry (the Boeing 747, Scotch tape, and one third of all IBM software, to name a few) owe much to customer ideas and to managers getting clients involved in the technology development process. Poor people are neither ignorant, backward, nor helpless regarding technology and the process of technological change. They are no more mystified by machines and products from industrialised countries than are many people from those countries themselves. Artisans' knowledge of how available raw materials can be most effectively used often is superior to engineers'.

People's Technology

Technological development in most countries is dominated by imports of products and machinery from outside and often hinders people's innovation. It puts formally trained scientists and engineers in front, and artisans and other 'informal' innovators at the back. Such policies lead to poor people losing control over their local resources and over the decision making that affects their future. Paradoxically, this situation can stimulate the development of people's technology. Even if government actions stifle local innovators, the worsening plight of the marginalised groups provides a greater motivation to innovate. Unlike research scientists, who innovate to satisfy their professional aspirations, people's technology innovators do so to survive. Increased poverty can encourage the growth of people's technologies.

Imported technologies are often 'parachuted' into a country in a fixed package; their hardware and skills needs are set before their arrival and may bear little relation to local skills and experiences. People's technologies, on the other hand, develop and diffuse slowly and steadily through a trial-and-error process. They rely on close communication between users and producers to identify the changes required to improve them. They develop in a way that retains and builds upon local skills, and closely reflect the priorities of local people. They spread, however, only with great difficulty. Local innovation is not recognised by the formal scientific and industrial community and growth occurs in a 'horizontal' pattern across groups of poor people, but prevailing social, political and institutional structures place barriers against this sort of interaction. The full potential of these technologies is, therefore, seldom realised.

Local Innovators and the Ignored Technological Revolution

From the perspective of large and extensive 'technology transfer' projects, the history of technology in developing countries is a tale full of problems and short on progress. However, from the perspective of poor people and the technologies they employ in daily life, recent history shows many dramatic innovations. Africa often is singled out as the region most resistant to technological change, but it is in Africa that some of the most rapid and remarkable changes have occurred at the grassroots level.

* Tanzanians were forbidden to grow coffee until the 1930s. Today, local smallholders account for both the majority of coffee production and the majority of coffee processing of both arabica and robusta beans. The small-scale processing equipment is virtually all locally made. Far from being intimidated by foreign crops and technology, Tanzanian farmers absorbed it at an impressive speed. By comparison, the Scandinavian nations took far longer to adopt the machinery and processes of the English industrial revolution!

* The 1980s brought a crisis to Sierra Leone's salt supplies, made up largely of rocksalt imports from Senegal. When foreign exchange grew scarce, imports dropped. A development agency tried and failed to introduce solar salt manufacturing (through open pan evaporation). Local salt producers, extracting salt from filtering brine-rich salts, saved the day. They improved their techniques and expanded their output; today they provide 40% of national supplies - and their production and market share continue to grow.

Asia is seen as less of a technological 'problem child', but some of its poorest countries and regions often are derided in much the same manner as Africa. Yet the cases from the poorest parts of Asia demonstrate innovations that rival those from now richer areas, in terms of their transformation of life at grassroots level.

* Nepal is one of the world's poorest and most technologically 'backward' countries. In the 1950s it had virtually no local engineering capacity. Today it has at least 12 private companies designing and installing hundreds of micro-hydro schemes, which provide mechanical and electrical power for crop processing and other rural needs. These small firms are literally lighting up the countryside and transforming rural women's lives by reducing the time and drudgery of crop processing tasks. The firms are nurturing local engineering knowledge and skills that support other initiatives, such as large-scale electrification projects and the growth of new manufacturing industries. Nepali companies now export turbines and other micro-hydro system components to other Asian countries and to Europe.

* Blacksmiths in Bangladesh have attracted little public attention, but they account for 5% of the country's gross output, 9% of its value added, and 11% of total manufacturing GDP. The 10,000 blacksmithing enterprises are a major source of off-farm employment in a nation with an estimated 65 million landless poor. Blacksmiths also help in import substitution, producing spare parts for power tillers and tractors that otherwise have to be imported - at twice the cost.

One of the most widely researched and reported areas of energy technology in development is that of stoves for the poor. Scientific institutions and aid agencies have invested much time and effort in this cause, and a certain degree of success has been achieved in urban areas. However, few improved stoves reach rural households, where cooking fuel and kitchen environment problems hit hardest.

* In Zimbabwe a metal grate cooking system, consisting of a metal grate provided by metalworking artisans and a hearth and windscreen constructed by women users in the kitchens, can be found in the vast majority of rural homes. This system has evolved over time as cooking practices, and cooking pots in particular, have changed. It owes virtually nothing to formal research and development, and remains unreported in stoves literature - but it is the innovation upon which most rural Zimbabwean food preparation depends. The grate system provides a versatile and energy-efficient way of using firewood to cook local dishes.

Recognition and Collaboration

Technologies arising from laboratories have a support system to nurture their introduction and development. People's technologies generally have no such help. Poor people are not recognised as sources of new technology, so their initiatives are rarely examined, much less promoted. Yet cases where such recognition has taken place show great potential for collaboration between scientists, policy makers and local innovators.

* The development of the local micro-hydro industry in Nepal accelerated rapidly after the National Electricity Authority repealed a ban on private electricity generation for small mills, and even more rapidly after the government's Agricultural Development Bank offered capital subsidies for mill upgrading. Local fabricators and foreign hydro experts have cooperated in experiments on new component designs and production techniques to reduce costs further, making the benefits of micro-hydro innovations affordable to poorer mill owners and communities.

* In Gujurat, India, staff from a local engineering research institution encouraged local artisans to persevere with attempts to produce multi-purpose, animal-drawn farm implements, and helped to persuade the government to include this type of tool in its farm equipment subsidy scheme. The multi-purpose tool bar has become one of the most popular new implements in the state. It has saved farmers time and has increased yields by enabling greater control over fertiliser application. New manufacturers have set up in rural areas to produce the toolbar. Agricultural labourers, increasingly displaced by tractors and other large-scale machinery, retain their jobs on farms using the tool bar.

Small enterprises, particularly production enterprises, play an important role in developing countries' economies. They provide a large proportion of manufacturing employment and GDP. For women, and landless and other disadvantaged groups, small-scale off-farm production often represents their sole means of generating income. There are many technologies for small-scale production that could help poor producers and a considerable body of knowledge and experience exists - but it will remain a diffuse and largely inaccessible resource for both producers and scientists, as long as communication between these groups remains poor.

The world knows of Leonardo da Vinci, Louis Pasteur and Thomas Edison and the impact they have made on human life. Few have heard of Nigeria's Ologbon Ori (cassava processing equipment) or Nepal's Akkal Man Nakarmi (turbines and other hydro-mill equipment), but they and others like them are playing a similar role for their people. Compiling information on such local innovators helps us to understand their skills, potential and obstacles and to help them to do it better. Recognising the contributions and the potential of people's technology opens the door to cooperation, in which local experience can combine with scientific knowledge to tackle small-scale production problems. In Kerala, the new state 5 Year Plan has allocated resources for artisan fishermen to work with the Central Marine Fisheries Institute in the continued development of the former's artificial reef designs. In Nigeria, some polytechnics are including training sessions with metalworking artisans in their curricula, to provide students with a broader spectrum of ideas and methods in their technological education. Tanzania's TASTA award programme builds bridges between its R&D institutions and small producers. Hopefully, these small steps are a sign of things to come.

Science-led innovation is a relatively new phenomenon in the industrialised countries. In the great upsurge of innovation called the Industrial Revolution, new technologies arose when a number of critical factors came together at one time - needs, markets, new materials, scientific discoveries and the practical experimentation of individuals who were, in the main, not trained scientists (Trevithick, Darby, Boulton, Watt). In developing countries, people's research is driven by that same need to engineer practical solutions that drove the pioneers of the Industrial Revolution.

* In the 1960s and 70s the Appropriate Technology Development Association in Lucknow, India, under the late M K Garg was instrumental in developing practical small-scale industrial technologies for the production of white crystal sugar, Portland cement, whiteware pottery and cotton yarn. Much of the innovation was arrived at by a process Garg called 'action research'; in a situation where scientific skills were scarce, it was cheaper and quicker physically to try out alternative solutions than to develop them on paper. The additional value of learning through doing enriched the skills of that organisation.

Pragmatic action research may sometimes follow blind alleys and miss better solutions that are based upon somewhat different principles. This is where injections of expert assistance may help.

* In the case of ATDA's mini cement plant, early work on the upgrading of the raw material was not yielding results. A brief mineralogical study by the British Geological Survey using an expensive and sophisticated Beta Probe Analyser diagnosed the problem and enabled the work to continue in a more productive direction.

Science-based R&D institutions should study locally-based R&D processes and support them by giving access to their facilities and skills to solve problems identified by local innovators, rather than trying to export ready made solutions over their fences. One of the best examples of this sort of institutional behaviour is the work of the Technology Consultancy Centre in Ghana, where it has assisted this integration by moving away from its university campus base to found R&D support facilities (called Intermediate Technology Transfer Units) in the midst of informal manufacturing areas around the country.

The 'Tinker, Tiller, Technical Change' Project

In 1988 ITDG decided to help in building bridges between R&D institutions and artisan innovators by assembling a group of 17 researchers from 14 countries to examine successful people's technologies in a project named 'Tinker, Tiller, Technical Change'. Their work has not only provided the findings presented in this paper, but has also helped ITDG to re-examine its own role in technology development and dissemination.

The 'Tinker, Tiller' investigators each selected a technology from his/her country and carried out detailed field studies of its evolution, its social and economic importance, and its limitations. At the same time they met with colleagues in their regions to learn how the factors supporting and hindering locally developed stoves compared with those affecting building materials, and those affecting food processing machinery. Having carried out their field work, the 'Tinker, Tiller' group met together to see how people's technology in Asia differed from that in Africa and in Latin America. They shared their work with representatives of donor agencies, non-government agencies and research institutions at a seminar in London in 1989. Books in English and Spanish containing their full studies and regional analyses have been published.

The researchers have not been content to stop at this point. The Latin America group, all of whom come from R&D organisations (all NGOs), are organising personnel exchanges to try out alternative technology development strategies. In Asia a project called 'Do it Herself' is examining the contribution of women to innovation; women are the majority producers in many small enterprise sectors. As Rosabeth Kanter, one of the world's leading thinkers on the management of industry writes, 'the problem before us is not to invent more tools, but to use the ones we have'.

The Authors

Frank R Almond is the Chief Executive of the Intermediate Technology Development Group and a chemical engineer by profession who worked in the steel and power industries before joining ITDG 13 years ago. Ray E Holland is Operations Director and an electrical engineer who worked with renewable systems and technology support to small enterprises before joining ITDG 12 years ago. Matthew S Gamser joined ITDG as a Policy Economist in 1986 after working in a number of countries in Asia, Africa and the Pacific.

ITDG
Myson House
Railway Terrace
Rugby
CV21 3HT

Tel: + (44) 788-560631
Fax: + (44) 788-540270

2.17 Scientific Instruments in Developing Countries: Addressing the Equipment Management Problems

W J Martin
Willana Consultants, Sale, Cheshire, UK

Introduction

Modern technology, in the form of a wide spectrum of advanced instruments and equipment, has been introduced into the countries of the less developed world. A need has thus evolved for the planned procurement, utilisation, maintenance and repair of sophisticated apparatus in industry, the health services, research and educational institutes and the agriculture sector. The situation has created a demand for an informed administration, for maintenance, repair and calibration facilities and for a cadre of technologists trained in instrumentation and employed in an advantageous career structure who are capable of maintaining this equipment.

Because of rapid changes in technology, there is also a requirement for staff re-education and continued up-dating of repair facilities as the equipment and the skills of personnel become out-of-date. The absence of such an infrastructure, at both the administrative and technical level, has placed in jeopardy huge capital investments intended for the betterment of large populations, from both the private sector and aid agencies, in a wide range of expensive equipment in organisations dealing with industry, health, research, education and agriculture. The WHO, for example, estimate that 60-80% of biomedical equipment in developing countries is non-functional (see page 179).

The problem of scientific equipment in developing countries epitomises the problems of trying to bring the benefits of modern technology to the Third World without paying adequate attention to building up local skills and a supporting infrastructure. An appreciation of the complexity of the problem has recently led to coordinated action by member states and aid organisations to address these issues. This article summarises the attempts by a number of organisations over the last three decades to provide for adequate instrument repair and maintenance and is intended as a 'management tool' to facilitate the interchange of experience and coordinated action.

International Agencies

International agency interest in this area began almost 30 years ago with the UN conference 'Application of Science and Technology to Development' held in 1963, which established an expert Advisory Committee. This Committee produced a set of comprehensive recommendations and basic guidelines in 1971 (1). Numerous conferences and seminars involved with the application of science and technology were held worldwide in the 1970s, culminating in the UN Conference on Science and Technology for Development (UNCSTD) convened in Vienna in August 1979.

The International Atomic Energy Agency (IAEA) has reported that, at any given time, between 10-30% all of the instruments it distributed over the last 10 years worldwide for technical assistance and cooperation projects were out of order. This was caused largely by the absence of efficient local maintenance and repair service capabilities (2,3). In response to this problem, which affects an IAEA ca. US$ 23 million annual instrument budget over approximately 1000 projects, the IAEA Seibersdorf Laboratories in Austria began a series of six-month ten-man fellowship programmes in November 1987, to train technicians and engineers from developing countries (4). Participants from several countries in Africa, the Middle East and East Asia have attended these courses and a Nuclear Instrumentation Network (NIN) was set up to promote continued contact between nuclear technologists and to encourage cooperation with other organisations. The NIN in African Countries (NIN/AF) has surveyed national needs and an African Regional Project (RAF/4/004) funds the training of national personnel, supplies spare parts and manuals and carries out urgent repairs (5).

The International Foundation for Science (IFS) supports young non-established scientists from developing countries to do experimental research in developing countries. As more than 70% of the support is directed at equipment and laboratory supplies, the Foundation is interested in the long-term upkeep of the hardware it provides. A 1985 survey of 500 grantees by IFS (6,7) found that between 20 and 50% of laboratory equipment in developing countries was not functional and in some institutions virtually nothing functioned. In response to this situation the Foundation instituted a 3-year pilot aid project on instrument upkeep in nine SADCC countries (8). Workshops on the operation and maintenance of scientific equipment were held in Harare (1988) and Tanzania (1990) (9); a third workshop is scheduled for Malawi in 1991. The International Centre for Analytical Technology (Luton, UK) runs these workshops for IFS with additional support from IDRC (Canada), UNFSTD, the World Bank, DANIDA and the Commonwealth Science Council. A Network of Users of Scientific Equipment in Southern Africa (NUSESA) was set up to share experiences. IFS plans a joint project with the Taiwan National Science Council, Precision Instrument Development Centre (PIDC) in Taipei to provide service and training facilities for laboratories in developing countries. IFS also has an input into the Commonwealth Higher Education Support Scheme (CHESS) which proposes technician training programmes in Southern Africa (8).

UNESCO. In response to the 1976 UNESCO General Conference resolution 2140-42 urging action on the issues and problems of instrument upkeep, a global consultation meeting of specialists was held in Paris in 1978 (10) attended by representatives from Singapore, Ghana, England, Philippines, Indonesia, Argentina and France. There followed a series of regional workshops on training instrument technicians in Indonesia (11), anglophone Africa (12,13) and francophone Africa (14). Details of courses in Kenya for earth science technicians (15) and a proposed course for seismic technicians (16) were provided at UNESCO conferences in East Africa and a survey of instrument maintenance courses operating in African Institutes was carried out for UNESCO (17). The UNESCO-initiated **African Network of Scientific and Technological Institutions (ANSTI)** runs a technician training programme with support from the Deutsche Gesellschaft für Technische Zusammenarbeit GmbH (GTZ) and a project for manufacturing chemistry equipment in developing countries, in conjunction with the **International Union of Pure and Applied Chemistry.**

The World Health Organisation (WHO). Between 60% and 80% of laboratory and diagnostic equipment in developing countries is non-functional (18), leading to the description of some Third World regions as the 'graveyards of biomedical equipment' (19). In response to this situation, WHO held the first interregional meeting on the maintenance and repair of health care equipment in Nicosia in 1986, attended by participants from 25 countries, international organisations , aid agencies and major manufacturers (20). The recommendations from this conference led to a Global Action Plan (21) which emphasised awareness promotion, policy formation and policy initiation, information exchange, improvement of national health care technical services, and manpower training (WHO/EMRO operates a Regional Training Centre for Health Technologists at the Higher Technical Institute in Nicosia, Cyprus). A comprehensive overview of approaches to the health care equipment problem is provided by a Round Table and discussion among national and international experts (22). Surveys of medical equipment policies have been carried out in China (22) and São Paulo, Brazil (30, 31). WHO recently carried out a joint workshop in Nairobi with GTZ on public health maintenance strategies in the developing world (24). An excellent article on the need for appropriate healthcare laboratory technology in developing countries is available (25), as is a comprehensive report on modern hospital technology management (26).

National Agencies

The National Institute of Health (NIH), USA Department of Health and Human Services has a Biomedical Engineering and Instrumentation Branch (BEIB) which participates in equipment repair and maintenance programmes (27). The agency operates with the **US Agency for International Development (USAID**) on programmes in Egypt (28) and with the **Pan American Health Organisation (PAHO)** on programmes in Latin America (29). In São Paulo State, the public health system has 560 hospitals, 2100 health centres and 10 research and manufacturing facilities. The healthcare equipment policy devised and implemented for these facilities has been described (30, 31). Guidelines for designing medical instruments for use in developing areas of the world, based on the author's experiences in Jamaica, China and Egypt, have been provided in another publication (32). NIH also cooperates with USAID (see page 180) on projects to improve the repair of clinical equipment in the Caribbean.

Overseas Development Administration, UK (ODA) and the **British Council** provide assistance to the Nigerian university system under the University Equipment Maintenance Project. This involves four pilot Maintenance Development Centres at universities in Zaria, Ile-Ife, Bauchi and Calabar. (This project overlaps a World Bank activity to fund maintenance programmes in all Nigerian universities). The purpose of the ODA project is to encourage the development of a maintenance rather than a replacement culture in the universities. Four pilot Maintenance Development Centres (MDCs) have been established, maintenance technician training programmes are under way and workshops have been organised on relevant topics. The University of the West of England at Bristol (UWE) (formerly Bristol Polytechnic), which has been running courses in equipment maintenance over the last 15 years, is the consulting institute for this project.

UWE also repair equipment, supply spare parts and develop outreach courses for other universities in Nigeria. Between 1982 and 1989, ODA employed UWE to develop a teaching laboratory and repair workshop for scientific equipment in the University of Alexandria. ODA are cooperating with the Swedish International Development Agency (SIDA) in an extensive programme to upgrade technical colleges in Sri Lanka funded by a US $ 16 million loan from the Asian Development Bank. A loan of US $30 million is proposed for a second phase of this programme. The British Council and ODA are also cooperating with the World Bank in an instrument maintenance facility for Indonesia. The International Centre for Analytical Technology (ICAT) in Luton (UK) is providing a training and consultancy input to this project and Gallenkamp Ltd are supplying equipment (L Orton, private communication). Westminster College in the UK is also involved in a wide range of instrument maintenance training programmes for developing countries.

The Swedish Agency for Research Cooperation with Developing Countries (SAREC) has studied the equipment problem and progressed to holding a workshop on 'Repair, Maintenance and Development of Scientific Instruments' in Madras in 1986 in conjunction with the **Federation of Asian Scientific Academies and Societies (FASAS)**. They intend to hold a similar session in Singapore and to publish two comprehensive documents on the equipment issue and on policy issues. This agency cooperated with the Trieste-based **International Centre for Theoretical Physics (ICTP)** in a meeting in Tanzania on the manufacture of physics equipment. A second agency in Trieste, the **Third World Academy of Sciences,** awards small grants to institutions in developing countries to purchase spare parts.

The US Agency for International Development (USAID) supports projects in Latin America through the NIH as described above. It has supported a facility in Nepal for instrument repair and a Caribbean regional maintenance service. The Agency also funds a programme where hundreds of personnel are brought from abroad to the USA for training.

Scientific and Engineering Societies

American Association for the Advancement of Science (AAAS). The Directorate of International Programmes in this Association carried out a feasibility study of Equipment Repair in Developing Countries during 1988-89 (33) which was funded by the USAID. A worldwide survey of selected government, non-government and scientific institutions was carried out and recommendations based on the survey results presented at a 1989 meeting held at the Instrument Society of America facility in Raleigh. Studies described in the survey included a 25 university review by the **Association of African Universities** and a 1987-88 assessment of problems in Vietnam by the **Hungarian Instruments Measuring and Technique Service (MMSZ).** UNIDO and MMSZ are preparing to establish an instrument centre in Ho Chi Minh City. A German study conducted by ENVIRON concentrated on East Africa. At a subsequent meeting in Cairo in December 1988, a plan of action was evolved for addressing the equipment problem. AAAS activities in this area have currently been temporarily suspended (J H Taylor, AAAS - private communication).

The AAAS **Consortium of Affiliates for International Programs (CAIP)** has 70 scientific and engineering societies as members. Of these, the **American Institute of Biological Sciences (AIBS)** organised seven biomedical engineering programmes in developing countries during the early seventies, with support from the National Science Foundation, starting with one in Dubrovnik (34). The programme continued in Tunis and major facilities for maintenance and training have been established in Cairo, with the assistance of AIBS consultants (33). An account of the activities of other CAIP members will be found in the AAAS survey document (33). A **Continuing Committee on the role of Scientific and Engineering Societies in Development** was set up in 1980 and meets annually. It seeks to facilitate the exchange of information and ideas between scientific and engineering societies and others interested in utilising science and technology for development. It publishes a newsletter 'Scientific and Engineering Societies in Development' obtainable from the AAAS.

The **International Council of Scientific Unions (ICSU)** through its **Committee on the Teaching of Science** has conducted a workshop in Nairobi for repair and maintenance technicians (35) and ICSU's **Committee on Science and Technology for Development (COSTED)** is involved in work in this area (36).

Programmes within Developing Countries

Institutions with instrument maintenance and repair courses for technicians are to be found in six African countries, viz. Ghana, Kenya, Nigeria (five centres), Swaziland, Tanzania, and Zambia (17). Singapore and Indonesia have UNESCO-initiated courses (10).

The **Central Scientific Instrument Organisation (CSIO)** has been established by the **Indian Council of Scientific and Industrial Research (CSIR)** mainly as a training facility (37). Seven **Regional Sophisticated Instrument Centres (RSIC)** have been established by the **Indian Department of Science and Technology** to develop new instruments and provide equipment services (33). (For further details see Section 2.13).

The **International Centre for Insect Physiology and Ecology (ICIPE)** in Kenya maintains and repairs equipment for outside organisations in addition to providing a service for its internal requirements.

The **HEJ Research Institute** of Karachi employs equipment experts at salaries similar to those of researchers. This policy has avoided the low status traditionally accorded to these technicians and increased the productivity of the Institute (33).

Sources of Information

A preliminary investigation of some 10 computer data bases was carried out to locate those containing references to publications on instrument management in developing countries. Appropriate sources were found in NTIS (10), Engineering Information Inc. (15) and INSPEC (22), representing 43 distinct references. IAEA documentation, the 6th, 7th, 8th, 9th and 11th proceedings of the IEEE annual Engineering in Medicine and Biology conferences and the proceedings of the IEEE AFRICON 87 conference are very relevant (38, 39, 40). Fifteen agencies were contacted for details and replies were received from the seven organisations acknowledged below. Much of the detailed information in this area is not available in the public domain. Many accounts of workshops and seminars with particulars of institutions, participants and courses covered are hidden in the files of large agencies. As a consequence, much information of potential use to organisers of assistance programmes is not easily accessible.

Conclusions

The causes of unsatisfactory instrument maintenance in developing countries have been well documented (13, 20, 22, 25 and 41). They involve a complex interplay of circumstances including:

- Poor organisational policies within the donor and recipient governments and aid agencies with little on-the-ground evaluation or provision for on-going maintenance.
- A lack of appropriate information and the means for its dissemination.
- Insufficient and inappropriate manpower development and training.
- A poorly developed and supported technical service.

Ways will have to be found by all the agencies involved to overcome these problems through collaboration, the pooling of experience and resources, standardisation and joint procurement policies, otherwise the developing countries will continue to be denied the benefits which modern technology could provide for their populations.

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The Author

Dr W J (Liam) Martin directs instrument research programmes to help develop equipment for automating processes in the clinical and life-science laboratory. Between 1958 and 1981 he spent over 20 years in technical education in three African countries. He has been a UNESCO consultant on several instrumentation education projects and a Senior Lecturer in the Kenya Polytechnic. His over 40 publications on laboratory instrumentation include seven directly relevant to equipment technologist training in developing countries.

Willana Consultants
4 Derbyshire Road
Sale
Cheshire
M33 3EA

Tel: + (44) 61-969 1765

2.18 Books in the Third World: The Role of The Ranfurly Library Service

David Membrey
Ranfurly Library, UK

Introduction

"Through lack of funds and chronic foreign exchange constraints, much of Africa is becoming a tragically ***bookless society,*** *and the situation has deteriorated still further since 1983 [date of the previous edition]. Foreign exchange is so scarce that many university and public libraries have been unable to purchase any new books for the past five years at least, much less maintain their current periodicals collections. Most bookshops present a picture of empty shelves; schools are without books; and teachers and scholars are divorced from the material to pursue their studies, to maintain their understanding of developments taking place in their disciplines elsewhere in the world, and to keep their teaching and research up to date ... lasting damage is being inflicted across a whole generation of people going through either primary, secondary or university education in Africa today. A generation of students are now being taught by lecturers who are unable to gain access to current research and scholarship".*

(Hans Zell, The African Book World and Press, 4th ed., 1988, p. vii.)

"Somehow we have to keep trying to get across the message that development is to some extent dependent on access to information, and most information is contained in publications ... It can hardly be argued that any country can develop far without educated people, or that education can be carried on without books ... It is not a question of choosing between information or heath care: to provide food and health care in the longer term requires investment in information".

(Maurice Line, 'Universal Availability of Publications in Less Developed Countries' in Nothing to Read? The Crisis of Document Provision in the Third World, ed. D. Membrey, 1990, pp. 35-44).

"I have now returned to Nigeria and while I await the delivery of the first consignment I wish to indicate that the need for books here is just immense. Frankly there is no library here that has anything like current periodicals. Most libraries I have visited in the North since my return have scarcely added any new stock in the last eight years. I have visited some leading bookshops in Zaria, Ibadan, Owerri and Enugu and I find that the cost of textbooks is so high (compared to the average income) that it is no wonder that most students are unable to buy any at all".

(Letter from Dr D Igbafe, Department of Animal Science, Ahmadu Bello University, Zaria, Nigeria).

The above quotations give an idea of the problem. There is no shortage of people who can tell you at first hand how bad the situation currently is in the universities and tertiary institutions of the developing world, but what can be done in both the short- and the long-term to alleviate the problem?

The long-term solutions lie in two areas: firstly, building up in all countries a healthy publishing industry that can publish the majority of the literary output of the nation; secondly, the availability in all countries of enough hard currency so that books published overseas can be easily imported when necessary. These are situations that we in the West are so used to that it is difficult to imagine life without them. In the UK we publish some 65,000 new titles every year; in many countries of sub-Saharan Africa the annual publishing output is about a thousandth of that! What little is published tends to be predominantly school textbooks (a reasonably safe market) and moral or religious phamplets (such ephemera are cheap to produce and are a sign of the lasting influence of the mission press in Africa). It is a sad fact that in many countries both the strength of the local currency and the viability of local publishers are deteriorating at the moment. So the long-term solutions to the book famine are receding into the distance year by year. Clearly some short-term 'disaster relief' measures are needed to help those whose requirement for books cannot wait.

Publishing in Africa

A complex mesh of problems combines to make the publishing scene in Africa extremely fragile. Most people that have any experience of it agree that it will be many years before the publishers of sub-Saharan Africa are able to satisfy their own markets. The risk is that, in the meantime, the very market upon which such an industry depends will wither and die.

Paper production, printing, authorship, editorial skills, government support, distribution and advertising, all present their own particular problems. Not enough book-quality paper is produced (it is cheaper and safer to produce paper for packaging), wood has not yet been properly developed as a cash crop in Africa and even where papermills have been set up (as in Mafinga, Tanzania) other problems plague the process. The lack of suitable rolling-stock for the railways meant that it was not easy to transport the paper. Lack of foreign exchange meant that the lack of one small spare part could bring a huge machine to a halt for months. This is one unfortunate result of new technology that has hit both paper production and printing; as the machines get more complex, down-time increases. Some of the most reliable printers in rural Africa are the old mission presses that still use old letter-press machines. Ironically, some of the African papermills are forced to sell their paper overseas in order to earn the foreign currency they need to keep their machines going, consequently putting their paper financially out of the reach of the local printers. Paper production - or importation - is often controlled by the government as a covert means of censorship, especially of the popular press.

The printing and publishing market is often dominated by huge parastatal bureaucracies. Not the least of the problems with such organisations is that as soon as someone proves good at their job they are moved on to something else. They also kill competition because the government will make it very hard for small publishers to get into the textbook market (by far the most lucrative market for African publishers).

Many printers have given up on books and now only print labels, bags and wrappers. Like the paper producers they are plagued by a lack of foreign currency with which to buy spare parts, printing plates and chemicals. I have come across many books published in Africa that were in fact printed in the Far East!

The influence of the large publishing houses in Europe and the USA is also far from beneficial. There was a time a few decades ago when Nigeria was the biggest market for UK-published books outside of the UK. There are still many publishers in the West for whom the textbook market in Africa is still very important. Because of economies of scale these publishers can produce competitive textbooks (printed in the Far East) and market them intensively in Africa.

Distribution is probably the weakest link in this chain and is often left out of the equation altogether. As we all know from television documentaries about food aid, it is one thing getting produce to the main port or capital of a country but the logistics of distributing it to the far corners of the country are often literally insurmountable. We are now quite used to hearing of famine relief funds being spent on lorries; a few years ago that would have been considered extraordinary. Books are bulky and they are rarely considered a priority so they often have to wait at the back of the queue.

I have tried to give a general picture of the publishing scene in Africa in this section. I have conflated experience and knowledge gained from various anglophone sub-Saharan countries and, although the picture is better in some than in others, all these problems and many others are endemic throughout the region.

The Book Aid Scene

"In Africa I have seen rooms full of unusable books. Graciously received, and displayed during official visits, they consume needed accommodation and other resources ... Gifts of fewer, selected, especially requested, up-to-date books and journals can be a god-send".

(Professor K Kirkwood, Letter, 18 January 1988, The Times.)

When faced with the true scale of the problem, it is very easy to get carried away and decide that anything would be better than empty shelves. In fact some things are worse than empty shelves. I have seen schools in Zambia where almost the only books were the rows of works of Kim Il Sung donated by the Korean Government: similarly I have seen university libraries that did not know what to do with 500 copies of one title donated by an American publisher when the library could barely justify one copy on its shelves. I cannot emphasise enough the importance of supplying only what is requested. There may be an eight-year run of a journal available in the UK, taking up many meters of shelf space but if (as often happens) overseas libraries only want the last ten years of the journal, then it is better to break up the set than waste time and money on collecting and shipping books that are not wanted.

Similarly with monographs, in a well-stocked UK library, out-of-date books that still have some useful sections can be of use; however, in a poorly equipped library with few academic or library staff to guide readers, it is very important that the few books that are available are 100% useful.

In the UK there are many professional or academic bodies and individuals that send books overseas on an ad hoc basis, usually doing it just once, though sometimes there is an ongoing commitment. Often a retired academic will endeavour to get his library to a university where he has links. Sometimes this is carried out independently, sometimes it is done with the help of an organisation such as the Ranfurly Library Service (RLS).

Large scale book aid in the UK is carried out by two organisations, RLS and the British Council. The British Council administers the ODA-funded Book Presentation Programme. This takes the form of grants given to institutions to spend a certain amount of money on UK published books. A list to the value of the grant is made out by the institution and the British Council orders the books.

The Ranfurly Library Service (RLS)

RLS is Britain's largest book aid charity. It is an independent NGO, which works in partnership with people in over 70 developing countries. It despatches about 700,000 books every year and has been operating for over 35 years. RLS sends about 75% of its output to Africa; the rest goes to the Caribbean, South East Asia, Central America and the Pacific, with a small but growing percentage going to Eastern Europe. Currently about 25% of its output is at tertiary level.

Its aim is to support education and literacy in developing countries by providing relevant books in response to requests from libraries and educational institutions suffering acute book shortages. It achieves this by acquiring surplus books from UK donors (publishers, libraries and individuals), employing librarians with relevant experience to select from the donated stock and, where necessary, raising funds for the purchase of essential books. It is also a long-term aim to promote local publishing and library development.

RLS sends books through either the Donated Book Programme or new book projects. The Donated Book Programme involves the shipping of about 500,000 books a year. These are given to RLS by publishers, institutions and individuals and then matched up to the requests RLS receives from all over the world. Whenever possible we encourage the people requesting books to come and select personally from our warehouse. Over the last few years we have placed increasing emphasis on various new book projects. These involve raising funds specifically for the purchase of books that are often donated. The receiving institution selects the books they want and RLS ships them. We have recently carried out a project in cooperation with the Tropical Health and Education Trust that involved buying sets of essential texts on AIDS and sending them to rural health centres in Malawi and Ethiopia. We also worked with the Institute for African Alternatives (IFAA) to send core collections of books on African studies and development to universities in Tanzania and Nigeria.

RLS also has a commitment to supporting local publishing in the countries that we help. We do this indirectly by ensuring that our book donations are not likely to damage local publishing. An initiative that we have recently started to develop for the support of African publishers is the buying of books published in Africa for re-distribution in Africa. This is possible due to the existence of the African Books Collective (ABC) which is an umbrella organisation run by a group of African publishers to make their books available in Europe and the USA. The list is predominantly university level at present and represents about twenty publishers. By buying large quantities of books from these publishers, RLS is not only providing them with much-needed hard currency but also making their publications available in Africa. Ironically it is much easier to import books from one African country to the UK and then export them to other African countries than it is to transport them directly within Africa - a result of the continued existence of well-worn colonial trade routes.

International Campus Book Link (ICBL). This is a project that it is planned will operate as an element in the tertiary level program at RLS. It was set up with the help of various other organisations to try and make our book aid to universities more targeted. We hope that this project, once operational, will enable us to handle runs of journals much more easily than has so far been the case. A pilot version of ICBL was run in 1989/90 and once fundraising has been successful it is hoped that the full scale project will get under way later in 1991. The main difference between this project and the way RLS handles tertiary material at the moment is that we will have enough staff to be able to send out lists of books so that unwanted material can be vetoed by the receiving institution. ICBL will also set up a database of journal titles and issues that have been offered and requested.

Conclusion

The aid agencies in the North and governments in the South need to attach more importance to publishing as an essential element in long-term development and as a crucial support to cultural independence. The whole question of the choice of language and the importance that has for a country's cultural and economic development cannot be faced until the country has the capacity to publish what it wants in the languages it chooses. The famous Kenyan writer Ngugi wa Thiong'o has only been able to start publishing in his native Gikuyu language now that he is well enough established in the English speaking world that his works are automatically translated; for most other Africans this is not an option.

Cooperative publishing and distribution projects are an answer to some of the problems mentioned above. An international publishing venture such as that proposed for SADCC countries ought to thrive but has no hope unless all the governments involved are firmly committed to it. The African Books Collective is another such venture that has already got off the ground but is still a long way from financial security. Most people in Europe and North America still would not think seriously about buying a book published in Africa, but without the foreign currency that we can provide they will never thrive. Even such an eminently sensible venture as ABC has faced many hurdles, harsh export controls and currency laws being the prevalent ones.

So far as the short-term relief, book aid, is concerned the most important development that is needed is a recognition by people with support to give (that is both books and money) that this form of aid is actually as important as any other. You only have to look at the huge improvements in perinatal mortality when the mothers are literate to see that no development is possible without information.

D J Membrey
Deputy Director
Ranfurly Library Service
39/41 Coldharbour Lane
London
SE5 9NR

Tel: + (44) 71 733 3577
Fax: + (44) 71 978 8006

Some Useful Addresses

The American Association for the Advancement of Science (AAAS)
Sub-Saharan journals distribution program
1333 H Street NW
Washington DC 20005
USA

This initiative began in 1985, now 88 professional societies and organisations provide more than 2,400 subscriptions to some 100 journal titles. These are sent to 150 university and research institutions in 35 countries.

Australian Centre for Publications Acquired for Development (ACPAD)
International Development Program of Australian Universities and Colleges
GPO Box 2006
Canberra 2601
Australia

Started in 1982 to collect academic books and journals for universities in developing countries. The scheme now involves some 50 universities in South East Asia and the Pacific. Publications offered by ACPAD are listed and these lists are circulated to libraries in the program so that they can select their requirements. However, if a large collection of books is offered, it is not cost-effective to list each title so the entire collection is offered on the understanding that unwanted material will be passed on to other libraries.

Netherlands Periodicals Project
NUFFIC
Institute of Social Studies
The Hague
The Netherlands

A small but efficient project that concentrates on the provision of back runs and current subscriptions of journals but which also arranges the shipment of collections of textbooks.

The Canadian Organisation for Development through Education (CODE)
321 Chapel Street
Ottawa
Ontario K1N 7Z2
Canada

The Canadian Organisation for Development through Education (CODE)
321 Chapel Street
Ottawa
Ontario K1N 7Z2
Canada

This is a large educational charity that has programmes dealing with the shipping of donated books as well as providing materials and training for local publishing projects.

The Third World Academy of Sciences (TWAS)
International Centre for Theoretical Physics
P O Box 586
34136 Trieste
Italy

Formally founded in 1985, the aim of TWAS is to unite men and women of science from the Third World with the objective of enhancing the promotion and vitality of basic and applied sciences in the Third World through nurturing excellence and fostering the future generation of promising scientists. There is an extensive programme of research grants and fellowships as well as a scheme to provide spare parts for scientific equipment. TWAS also runs a journals and research textbooks scheme. They ship relevant material, to libraries and institutes in over 50 countries. If anybody has relevant material the cost of packing and transportation is covered by TWAS. TWAS also supports local publishing by buying a number of copies of popular scientific publications produced in the Third World for distribution to local libraries within the region.

African Books Collective Ltd (ABC)
The Jam Factory
27 Park End Street
Oxford
OX1 1HU

Tel: + (44) 865 726686

A major new self-help initiative by a group of about twenty African publishers to promote their books in Europe and North America. Used by RLS as a means of distributing African books within Africa. They include many of the most significant publishing houses in the following countries: Ghana, Kenya, Malawi, Nigeria, Senagel, South Africa (represented by Skotaville Publishers) and Zambia.

Institute for African Alternatives (IFAA)
23 Bevenden Street
London
N1 6BH

Tel: + (44) 71 251 1503

Established in 1986, the purpose of IFAA is to encourage research and discussion on contemporary problems in Africa. They run conferences, seminars and courses and produce a newsletter and occasional publications. They have been very active in publicising the plight of book-starved African universities and in raising funds to help alleviate this problem.

The International Group of the Library Association (IGLA)
25 Bromford Gardens
Westfield Road
Edgbaston
Birmingham
B15 3XD

This body represents those members of the UK library profession who have an active interest in supporting and learning about libraries overseas. It holds seminars and conferences and publishes a quarterly journal, Focus. The most recent set of conference proceedings is of particular relevance to the book famine and is called: Nothing to Read? The Crisis of Document Provision in the Third World. Proceedings of the seventh conference of the International and Comparative Librarianship Group of the Library Association, Westhill College, Birmingham, 31 August - 2 September 1989, ed. D Membrey, 1990. The proceedings represent one of the few recent, in-depth studies of the book famine.

The African Book Publishing Record
Hans M Zell, Editor
Hans Zell Publishers
Butterworths (Services) Ltd
Borough Green
Sevenoaks
Kent
TN15 8PH

This is the only journal covering the publishing scene in Africa in detail. It has, over the years, provided many excellent articles on all aspects of the book scene in the continent. One issue (vol. XVII, no. 1, 1991) has a report entitled 'Crisis in Third World Publishing: Recommendations for Action'. Besides publishing articles and reports, about half the space is taken up with a detailed subject, country and author index to books recently published in Africa.

2.19 Developing a Chemical Engineering Course for Tanzania: Collaboration in Chemistry between the Universities of Dar es Salaam, Tanzania and Trondheim, Norway

T Førland and K S Førland
University of Trondheim, Norway

Cooperation between the University of Dar es Salaam (UDSM) and NTH (the Norwegian Institute of Technology, which forms a faculty of the University of Trondheim) in the field of chemistry began more than 20 years ago. We shall empahsise two issues at the Chemistry Department at UDSM that are common to many developing countries:

1. The need for education in chemical engineering.

2. The lack of textbooks in chemistry.

1. Development of Chemical Engineering at UDSM

There is both a great potential and a great need for creating a chemical industry based on local raw materials in Tanzania. The problem, however, was to find a proper strategy to start a course in chemical engineering. The simplest way was to start the course within the Chemistry Department as a supplement to the course in chemistry. In 1973 the Faculty of Science had been encouraged to start MSc programmes, particularly in applied fields. An MSc programme in chemical engineering fitted well into the university structure. The courses in chemical engineering could be based on a BSc in chemistry, with physics and mathematics. This would give the first graduates in chemical engineering within a few years.

Already at this stage an education program for future local teachers in chemical engineering was started. Well-educated Tanzanians should participate in the institution building as early as possible. They know the social conditions, the cultural traditions and the aspirations of the nation. Furthermore, Tanzanians should be involved in decisions such as how much emphasis there should be on basic knowledge and creativity, and how much on practical training and maintenance in the education. Financial support was provided by NORAD (Norwegian Agency for International Development) and consultancy assistance on the chemical engineering courses was obtained from SINTEF (The Foundation for Scientific and Industrial Research - see 2.6). It was realised from the beginning that in the long run there ought to be a Bachelor's course in chemical engineering to streamline the education for a larger group of students. The start as a MSc course on a smaller scale, however, gave useful experience with the new profession.

The MSc Course in Chemical Engineering

In 1974 two senior teachers from NTH-SINTEF were employed to plan the MSc course in chemical engineering. Planning involved theoretical courses, exercises and practicals. The preparations were carried out in Trondheim over a period of 6 months (half time employment). A laboratory of $30m^2$ (about 300 square feet) was available in the Chemistry Department. Ten experiments were prepared covering different unit operations. The cost of the laboratory equipment was about £10,000 (1974). Local mechanical and electrical assistance was additional.

The capacity of the course was an intake of 8-10 students each year. Three Norwegian teachers were employed. The first intake was in October 1976. During the first months of studies, the students helped making laboratory equipment ready for use. The curriculum for the two year MSc course comprised:

Unit Operations I: Fluid/Particle Mechanics, Heat Transfer

Unit Operations II: Liquid/Gas and Liquid/Solid Mass Transfer.

Industrial Chemistry: Tanzanian Industry. Material and Heat Balances.

Chemical Reaction Engineering.

Process Control: Recording Instruments, Automatic Controllers.

Plant Design and Economics.

Masters Theses: A chemical plant based on Tanzanian raw materials was designed by a team of 2-3 students, examples being:

1. Ammonia from Songo-Songo Natural Gas.
2. Ethanol from Sugar Cane Molasses.
3. Sodium Alginate from Brown Marine Seaweed.
4. Salts from Lake Natron.
5. Yeast from Sugar Cane Molasses.
6. Purified Oil from Mafura Nuts.

Further Development

The Department of Chemical and Process Engineering (CPE) was established in the Faculty of Engineering in 1980. The basis was the chemical engineering course in the Chemistry Department (described above) and the process engineering course in the Department of Mechanical Engineering (started in 1978 with support from the Swiss Development Corporation). The MSc course based on the BSc in the Chemistry Department ended in 1982. By that time, 30 MSc (Chemical Engineering) degrees had been awarded.

The 10th anniversary of CPE was celebrated with an international conference 'Chemical and Process Engineering for Development' in 1990. During the years 1983-1990, 240 candidates graduated with a Bachelor's Degree from CPE. It is now one of the two established departments of chemical engineering in Central, East and Southern Africa (the other one is in Ife, Nigeria), and it may accept students for education in chemical engineering from other countries. Those who are interested in the Tanzanian experience and the present courses given at CPE may address inquiries to:

The Head, Dr (Mrs) M R Halfani
Chemical and Process Engineering Department
University of Dar es Salaam
P O Box 35131
Dar es Salaam
Tanzania

Tel: + (255) 51-48601
Telex: 41561 UNIVIP TZ
Fax: + (255) 51-48274

Closely connected to CPE is the 'Institute of Product Innovation' (IPI), which will strengthen the link between CPE and Tanzanian industry. The new director of IPI is Dr C L C Migiro (previous head of CPE). His address is:

Institute of Product Innovation
University of Dar es Salaam
P O Box 35075
Dar es Salaam
Tanzania

Tel: + (255) 51-49192 ext 2989
Telex and fax: the same as CPE

2. Chemistry Texts for Developing Countries

The shortage of reading material, textbooks, journals, etc. is a problem in many developing countries. The lack of hard foreign currency and the high prices make texts from industrialised countries unaffordable. It will be a great help if quality textbooks could be published locally, minimising the expenditure of hard currency and reducing the price of textbooks. Such textbooks could be written by scientists from industrialised countries in cooperation with local staff, or by senior scientists in the developing countries. Aid organisations can encourage this by giving fellowships to textbook authors and economic support to cover the initial printing expenses.

An example of such activity is a textbook in thermodynamics for students of chemistry and chemical engineering at the University of Dar es Salaam (1). The first draft of the manuscript was written during a stay at UDSM. Local teachers in the field and other resource persons were consulted in the course of writing the draft. In the book, local examples are used in order to make the subject less abstract to the students and to motivate them. The theory in the book is closely connected to experiments in a previous textbook on practicals in physical chemistry (2). This book contains 22 experiments covering thermodynamics, electrochemistry and chemical reaction kinetics. A theoretical background is given for each experiment. A handbook for the staff was worked out to secure continuity in teaching them when staff turnover is rapid. Details about equipment and repair work are given in the handbook. NORAD contributed to the printing costs for the practicals book, so that it could be sold to the students for the cost of reprinting (£1 in 1980).

Since the shortage of reading material is a common problem to many developing countries, the distribution of cheap textbooks across country borders could help solve the problems in several countries. The Southern Africa Development Coordinating Conference (SADCC) has announced plans for establishing a SADCC University Press to publish textbooks for several countries. With economic assistance from industrialised countries, it could start on a small scale making available to several countries texts that have already been printed in one of them. After gathering experience, the activities could gradually be extended.

A well equipped library is invaluable for research. The publishers of periodicals and speciality textbooks could do a great service to the universities in developing countries by sending complimentary copies of their publications to university libraries.

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The Authors

Professors Tormod and Katrine Seip Førland both graduated in chemistry from the University of Trondheim in Norway and, after 5 years in the USA, returned to Trondheim. They were appointed by NORAD (Norwegian Agency for International Development) to a 5-year teaching assignment in East Africa, which also led to the writing of a number of university textbooks for local use, and in 1991 were jointly awarded the Gunnerus medal of the Royal Norwegian Society for Sciences and Letters for their contributions to research and education in Tanzania. TF received a DSc (honoris causa) from the University of Dar es Salaam in 1990.

Department of Chemistry
NTH
University of Trondheim
N-7034 Trondheim
Norway

Tel: + (47) 7-594182 (TF) or 593997 (KSF)
Fax: + (47) 7-591676

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CHEMISTRY AND DEVELOPING COUNTRIES

This volume is the outcome of an international conference on 'Chemistry and Developing Countries' held in London from 6-8 April 1991, organised by The Royal Society of Chemistry (RSC) in association with The British Council and The Commonwealth Science Council.

It addressed issues relating to chemistry for the environment and the organisation of science to benefit the Third World. These are complex matters and were discussed in the light of a rapidly changing economic and political climate, the emergence of global issues with a chemical component (CFCs, AIDS, etc.) and the spreading of a much more frank and realistic attitude in many quarters as evidenced by the 1989 World Bank report on sub-Saharan Africa. The contributions to the conference were adopted as the RSC's input to ICSU's 'ASCEND 21' and subsequently to the UNCED conference held in Rio de Janeiro in June 1992.

The papers in this volume are wide-ranging in their brief and scope, covering many areas of sustainable development, wealth creation and institution building, as well as providing ideas on the effective use of science in safeguarding health and the environment. Several case studies are discussed and a number of important recommendations identified for action that relate to science policy, technology transfer and coordination with aid agencies.

The contributors are not only scientists and technologists, but also industrialists and development experts, many of whom are advisers to Governments and aid agencies. This book should appeal to all those wishing for an honest appraisal of past mistakes and for an enlightened approach towards the scientific and developmental needs of the Third World.

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