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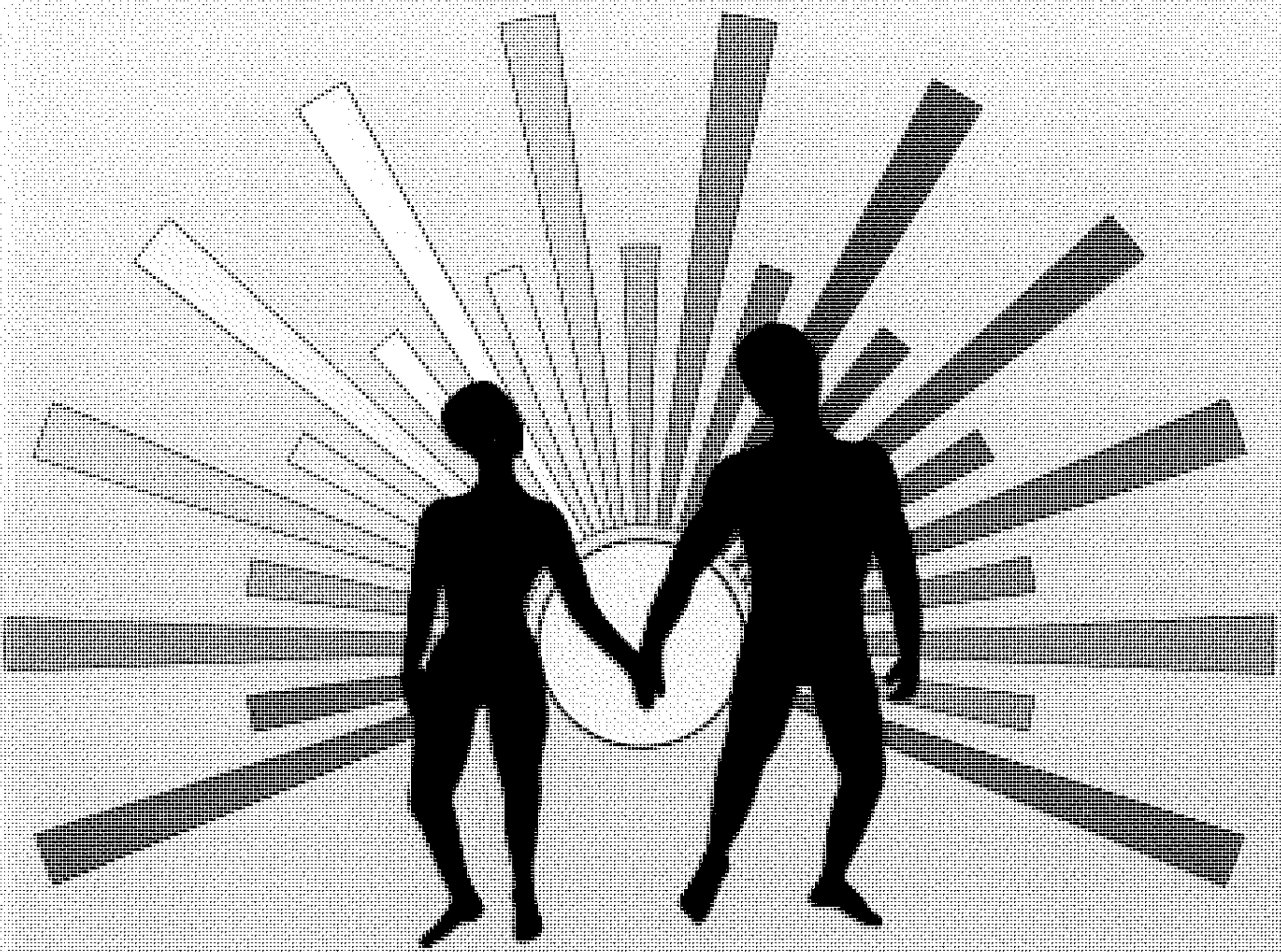
the Science of the Total Environment

An International Journal for Scientific Research into the Environment and its Relationship with Man



SUPPLEMENT
CHEMICAL HAZARDS IN DEVELOPING COUNTRIES

Elsevier

the Science of the Total Environment

An International Journal for Scientific Research into the Environment and its Relationship with Man

Scope

The journal is primarily an international medium for the publication of research into those changes in the environment caused my man's activities. Specifically, it is concerned with the changes in the natural level and distribution of chemical elements and compounds which may affect the well-being of the living world, and ultimately harm man himself. Emphasis is given to applied environmental chemistry. The subjects covered include: (a) application of techniques and methods of chemistry and biochemistry to environmental problems, (b) pollution of the air, water, soil and various aspects of human nutrition, (c) environmental medicine, when the effect of abnormalities in the level and distribution of chemical elements and compounds are given prominence; (d) the use of interdisciplinary methods in studies of the environment; (e) environmental planning and policy.

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Working Group on:

Chemical Hazards in Developing Countries

21–23 October 1993

Organized in collaboration with
THE ROYAL SWEDISH ACADEMY OF SCIENCES

Edited by

Renato Dardozzi
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PONTIFICIA ACADEMIA SCIENTIARVM

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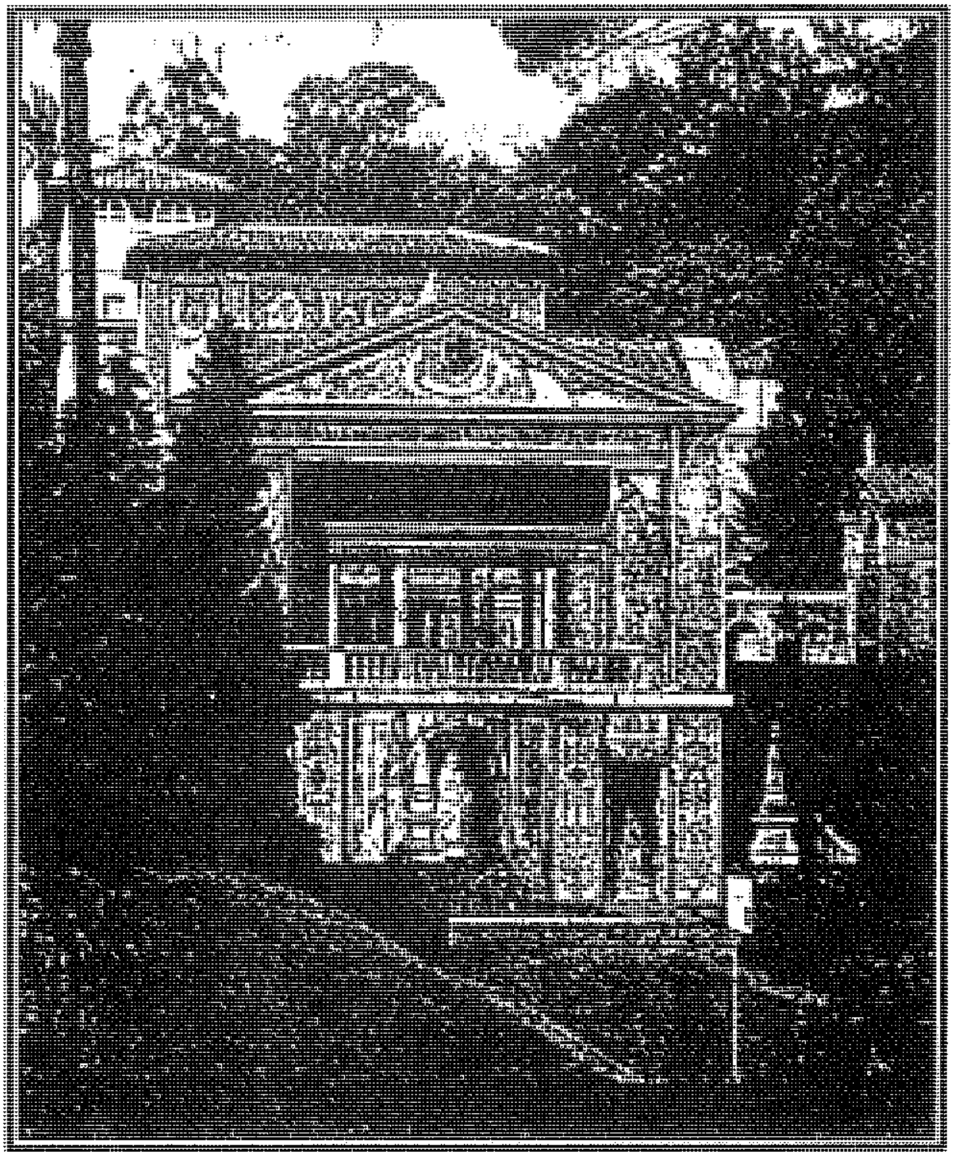

Casina Pio IV in the Vatican Gardens
Seat of the Pontifical Academy of Sciences

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Foreword

Industrialized countries have undertaken scientific, legal and administrative measures to control pollution and other side effects from the steadily increasing production and use of chemicals.

Comparable controlling measures are widely lacking or not implemented in developing countries, due to a lack of expertise, proper equipment and administrative infrastructure. Chemical hazards are therefore often a more serious problem in developing countries. It appears as a moral duty of industrialized countries, that have provided most of the chemicals and chemical products used in developing countries, to support the efforts of these countries to solve their chemical pollution problems.

Against this background the Pontifical Academy of Sciences in collaboration with the Royal Swedish Academy of Sciences and with support of the Swedish Wenner-Gren Foundation, considered it timely and appropriate to organize a Working Group on "Chemical Hazards in Developing Countries". The meeting was scheduled to take place in the Vatican City (21–23 October 1993).

The aim of the meeting was to obtain an overview of the situation concerning chemical pollution and concomitant health hazards in developing countries in different parts of the world and to discuss possible measures to protect in an adequate way the environment, food chain and human health and welfare. Other important aspects in that context are the transfer of hazardous industrial plants and technologies as well as chemical waste to developing countries. The meeting also aimed at proposing tentative guide-lines and recommendations.

Renato Dardozzi Claes Ramel

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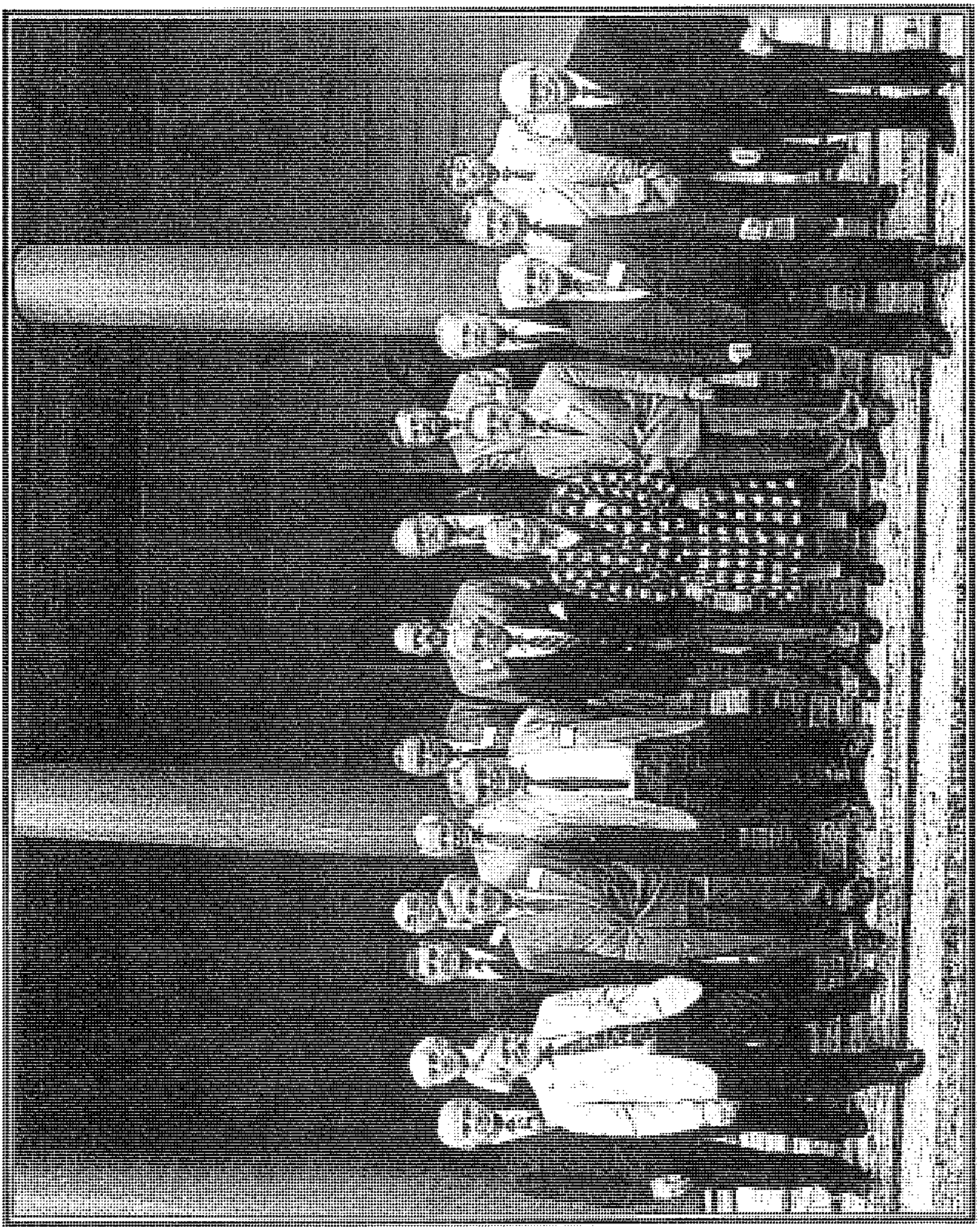

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Solemn Papal Audience

On the morning of 22 October 1993, His Holiness John Paul II granted a Solemn Audience in the Apostolic Palace of the Vatican to the participants in the Working Group 'Chemical Hazards in Developing Countries'.

The group, introduced by the President of the Pontifical Academy of Sciences, His Excellency Professor Nicola Cabibbo, was paternally received by the Holy Father, who at the end of the Audience wished to greet personally all the participants.

The Holy Father pronounced the following discourse:

Distinguished men and women of Science,
Ladies and Gentlemen,

1. It gives me great pleasure to meet you, participants in the Workshop on "Chemical Hazards in Developing Countries" organized by the Pontifical Academy of Sciences in conjunction with The Royal Swedish Academy of Sciences, and with the support of the Swedish Wenner-Gren Foundation. The very enunciation of the theme of your meeting highlights the importance and timeliness of your reflections. Who cannot but be deeply concerned by the prospect of the already existing and ever expanding danger from pollution and other side effects of the production and use of Chemicals? Indeed, your discussions, reflecting the highest levels of scientific competence, will be of great relevance to the growing public concern about the environment. I am confident that the publication of your studies and proposals will be of interest to the appropriate agencies and to governments, both in industrialized and in developing countries.

2. In most industrialized countries, attention is paid to the risks to human beings and to the environment from man-made chemicals. In some countries regulations are in place. But in developing countries, where most chemical hazards have their origin in the import of chemical substances and technologies, a lack of expertise and of necessary infrastructures often renders efficient control difficult or impossible. Very few countries in fact have a specific legislation regulating the handling and use of toxic chemicals. Other problems in developing countries concern the introduction of highly polluting industries, not subject to the more rigorous control that is applied in developed countries. It is a serious abuse and an offense against human solidarity when industrial enterprises in the richer countries profit from the economic and legislative weakness of poorer countries to locate production plants or accumulate waste which will have a degrading effect on the environment and on people's health.

The answer, certainly, is not to deny developing countries the imports and technologies they need, especially when these have to do with food production and the setting up of basic industries: "Peoples or nations too have a right to their full development" (Sollecitudo rei socialis, n. 32). In fact, developmeut, which ensures the conditions required for the exercise of fundamental rights, belongs to the domain of universal human rights. It is a direct consequence of the universal destination of the goods of creation.

3. Although primarily scientific and technical, your Workshop is not without great interest also for the Church: not in the sense that the Church has any particular scientific competence in the field, but in the sense that what is in question cannot be divorced from the ethical and moral character of the development which has given rise to this problem.

A fundamental principle of the Church's approach to development is expressed succinctly in words of my predecessor Pope Paul VI: "Development cannot be limited to mere economic growth. In order to be authentic, it must be complete: integral, that is, it has to promote the good of every person and of the whole person" (Populorum progression, n. 14). This does not mean that the Christian holds a negative view of the greater availability of material goods and the spreading of those industries which produce them. It means — as I have written elsewhere — that "development cannot consist only in the use, dominion over and indiscriminate possession of created things and the products of human industry, but rather in subordinating the possession, dominion and the use to man's divine likeness and to his vocation to immortality" (Sollecitudo rei socialis, n. 29).

Man's spiritual nature and his transcendent vocation imply a fundamental solidarity between people, whereby we are all responsible for each other. Respect for the natural environment and the correct and moderated use of the resources of creation are a part of each individual's moral obligations towards others. This truth applies also to relations between peoples and nations. In this context the technical dimension of the theme of your discussions is inseparable from its moral aspects. It would be difficult to overstate the weight of the moral duty incumbent on developing countries to assist the developing countries in their efforts to solve their chemical pollution and health hazard problems.

4. The international community, for its part, should continue to promote global agreements regarding the production, trade and handling of hazardous substances. In the 1990 World Day of Peace Message I wrote that, "the concepts of an ordered universe and a common heritage both point to the necessity of a more internationally coordinated approach to the management of the earth's goods" (n. 9). Specifically in relation to the environment, I noted that "the right to a safe environment is ever more insistently presented today as a right that must be included in an updated Charter of Human Rights" (1990 World Day of Peace Message, n. 9). The 1992 United Nations Environmental Conference in Rio de Janeiro took steps in this regard, and in Chapter 19 of Agenda 21 several actions, which are especially relevant to developing regions, are recommended. The Holy See gladly agrees with the proposal in Agenda 21 that recommends the setting up of an International Forum on Chemical Safety, with the purpose of giving developing countries assistance to increase their competence and capacity in this field.

5. The human family is at a cross-roads in its relationship to the natural environment. Not only is it necessary to increase efforts to educate in a keen awareness of solidarity and interdependence among the world's peoples. It is also necessary to insist on the interdependence of the various ecosystems and on the importance of the balance of these systems for human survival and well-being. Mere utilitarian considerations or an aesthetical approach to nature cannot be a sufficient basis for a genuine education in ecology. We must all learn to approach the environmental question with solid ethical convictions involving responsibility, selfcontrol, justice and fraternal love.

For believers, this outlook springs directly from their relationship to God the Creator of all that exists. For Christians, respect for God's handiwork is reinforced by their certain hope of the restoration of all things in Jesus Christ, in whom "all the fullness of God was pleased to dwell, and through him to reconcile to himself all things, whether on earth or in heaven, making peace by the blood of his cross" (Col 1.19–20).

6. Ladies and Gentlemen, I wish to encourage you in your commitment. I pray that your Workshop will be successful in suggesting guidelines for controlling the problem of chemical pollution and consequent health hazards in developing countries, and that it will offer valid recommendations for the protection of the environment, food chain and human health in different parts of the world.

Upon all of you I invoke abundant divine blessings.

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President's Address to the Holy Father

At the Solemn Audience granted to the Working Group participants on 22 October 1994, the President of the Academy, Prof. Nicola Cabibbo, delivered the following address:

Holy Father,

The honour You confer to our Academy of Sciences by following our work and addressing us words of encouragement fills us all, Academicians and Participants of our Working Group on chemical hazards in the 3rd world, with profound gratitude and deep encouragement which strengthen our dedication for our work.

We come once more to report to You the results of our scientific reflections and to hear Your words of great wisdom and admirable depth. We know Your profound interest in the improvement of the existential quality of man's condition.

The Pontifical Academy of Sciences, in collaboration with the Royal Swedish Academy of Sciences, has considered the exigence to organize a Workshop on "Chemical Hazards in Developing Countries". The meeting aims at an overview of the situation concerning chemical Pollution and concomitant health Hazards in developing countries in different parts of the World, and to discuss possible measures to protect in an adequate way the environment, food chain and human health and welfare.

Industrialized countries have undertaken scientific, legal and administrative measures to control pollution and other side effects from the steadily increasing production and use of chemicals.

Comparable measures are lacking or not widely implemented in developing countries, due to a lack of expertise, proper equipment and administrative infrastructure. Chemical hazards are therefore a more serious problem in poor countries. It appears as a moral duty of industrialized countries, that have provided most of the chemical products used in developing countries, to support the efforts of these to solve their chemical pollution problems. Other important aspects in this context are the transfer of hazardous industrial plants and technologies and of chemical waste to developing countries.

The Meeting aims at proposing tentative guide-lines and recommendations for the solution of these grave problems.

We ask Your Holiness to bless the work of the scientists who take part in the Meeting so that, from the study of the difficult situation which emerge from this work, You may draw inspiration for enlighting the behaviour of the developed Countries towards the developing ones. The developing countries must receive an authentic help so that they may reach, not in a long time, a human condition of dignity, for life.

Chemical Hazards In Developing Countries

Claes Ramel: Opening Remarks

The international science community has a responsibility to engage in the many serious environmental problems of the developing countries. This has been the incitment for a collaboration between the Pontifical Academy of Sciences and the Royal Swedish Academy of Sciences, which was initiated in 1990 by a conference on the preservation of tropical forests after a suggestion by the former President of the Pontifical Academy of Sciences, Professor Chargas. In his speech at that conference the Pope stated the responsibility and stewardness of Man not only towards our own species but also towards other living organisms in the world and therefore the destruction of the rich ecosystems of tropical forests must be counteracted. The conference constituted a valuable contribution to the topic of preservation of biological diversity. This field obtained an international recognition through the Biodiversity Convention, which was signed at the UN Environmental conference in Rio.

A continuation of the collaboration between our two Academies of Sciences was encouraged, and together with the President of the Pontifical Academy, Professor Marini Bettolo, we decided to take up another essential and somewhat related problem for discussion at a conference in the Vatican — Chemical Hazards in Developing Countries. We regret that Professor Marini Bettolo cannot be with us today but we are very glad that his intention with such a conference now has become reality and we wish all the participants welcome. From the Swedish side the conference has been possible, thanks to economic support from the Wenner-Gren Foundation.

Since World War II the extensive use of synthetic chemicals has become an inevitable part of modern life in developed countries. We all know, however, that development has had serious consequences on our environment. This was first given a comprehensive consideration by Rachel Carson in her book *Silent Spring*, which became the trigger for an opposition against the unrestricted use of pesticides and other chemicals harmful to the environment. Carson focused her attention on persistent chemicals such as DDT, which had disastrous effects on the wild life, with obvious risks for negative health effects also in human populations.

In Sweden, already in the middle of the 1950s we had in fact an experience from the destructive effects of another persistent pesticide, alkyl mercury, on bird populations. Because of the use of organomercurials as fungicides for seed dressing, some populations of seed eating birds were nearly eradicated. Worse, however, was the observation that some predatory birds were found to suffer from extremely high content of mercury by secondary poisoning through the consumption of seed-eating preys. This pointed to a risk situation also for humans by the consumption of animals, which had been exposed to mercury from treated grains. Later a more serious concern was attached to fishes contaminated by industrial release of mercury. This concern was amply verified by the intoxication catastrophes in Japan and Iraq.

In several developing countries there is today another hazardous source of mercury contamination through the use of mercury in gold panning, which we will hear more about by Dr. Moreira from Brazil.

In the Western industrialized countries the risks from chemicals in the environment have become an issue of great concern. When considering health hazards to man, long term effects from the exposure to chemicals have been in focus of attention. In particular it was realized that we are exposed to many carcinogenic compounds, which we release in our domestic, occupational and outer environment. This has lead to radical regulation of the manufacturing and use of chemicals and a number of persistent and biologically reactive chemicals are now completely forbidden for use in these countries. The contamination of our food by pesticide residues is usually efficiently controlled in most developed countries. The contribution from an exposure to synthetic chemicals to the cancer panorama in developed countries probably is quite low. Dr. Bruce Ames, who introduced the well known bacterial test for mutagenicity in 1973 and who emphasized the carcinogenic risk from synthetic chemicals in the 1970s has in later years concluded that much of the concern about these chemicals as to their carcinogenicity is less justified today. Ames therefore has advocated a shift in attention to natural carcinogenic compounds, which he believes are responsible for a far higher frequency of cancer than synthetic chemicals.

Ames conclusion in this matter is supported by epidemiological and experimental evidence in developed countries. However, such conclusions derived from developed countries, clearly to not apply to developing countries in general, where the contamination of chemicals often is drastically different as compared to developed industrial countries. It should be pointed out that there is also a dramatic difference between western Europe and the former Soviet Union, where the chemical contamination of the human environment by man made chemicals constitutes a very serious environmental and health problem, also with respect to long term effects such as cancer.

In contrast to the situation in developed countries, pesticides constitute a major environmental problem in developing countries and there are imminent risks for acute and chronic health effects by pesticides — both occupational and general epidemiological. There are many reasons for this difference between developed and developing countries in this respect. The rapidly growing populations in many developing countries has compelled an increase in food production to an extreme, combined with a constant fight against pests, which take a higher toll of the production in tropical regions than elsewhere. On top of that land degradation through deforestation, decertification, soil errosion and lack of secured water supply makes the situation in many developing countries critical. For instance the deficit in Africa of grain is estimated to become 44 million tons by the year 2000.

The use of pesticides in developing countries has resulted in extensive resistance of pests to many pesticides. It has been estimated that over 500 pests have become resistant to ordinary pesticides. This has given rise to a vicious circle with increased use of pesticides. As an example in India the Cotton Ball Worm, Heliothis, has gradually acquired resistance to many pesticides. The farmers use up to 30 insecticide sprays to fight this devastating pest on cotton plants, including chlorinated hydrocarbons, organophosphates, carbamates and pyrethroids.

The extensive and to a great extent uncontrolled use and handling of pesticides in developing countries implies health hazards to people. Millions of people get poisoned each year and it has been estimated that 20000 deaths occur from pesticide exposure — mostly in developing countries.

The unintentional contamination by pesticides of natural populations of animals and plants can cause disturbance of the natural ecological balance, wiping off of predators of various parasites, often resulting in an increase of secondary pests. The biomagnification of persistent pesticides often cause severe effects in higher tropical levels. Other side effects are pollution of ground and surface water.

The pesticide use in developing countries is a necessity for their survival, but there is an obvious need of regulatory actions based on risk benefit evaluations. There are, however, many obstacles for such a development. Thus there is a lack of research facilities for control and monitoring, inadequate legislation and guide lines for registration of pesticides, lack of toxicological data on pesticides primarily used in developing countries etc. The time lapse between the introduction of hazardous pesticides and its banning or restrictive use has in many cases been unreasonably long in developing countries. Examples of this time lapse, according to Dr. Sebae in Egypt, are over 25 years for organochlorines, 35 years for toxaphene, 20 years for chlorimeform, 30 years for ethylene dibromide and and dibromochloropropene, 30 years for tributyl tin, organomercurials, organoarsenicals and bisdithiocarbamates.

Scientific experience from developed countries to improve the situation in developing countries is important, but it must be realized that extrapolation of data from temperate to tropical zones must be done with caution. Degradation and biomagnification of chemicals can be widely different. Much laboratory work has to be done within developing countries themselves.

The developed countries are ultimately responsible for much of the chemical problems in developing countries and it ought to be their responsibility also to assist the developing countries in solving their problems in this respect. In chapter 19 of agenda 21 from the UN conference in Rio 1992, dealing with chemicals, the necessity of assisting developing countries is firmly established and several actions of particular importance to developing countries are recommended. Thus in order to better control the trade with hazardous chemicals it is recommended that all countries by the year 2000 should adopt the concept of 'Prior Informed Consent', PIC, which was introduced in 1989 by UNEP, FAO and ILO. Another important suggestion in agenda 21 concerns the formation of a special UN body 'International Forum on Chemical Safety' in April 1994 the 'International Conference on Chemical Safety' will be held in Stockholm in accordance with recommendation in agenda 21 in order to discuss the implementation of the intentions of agenda 21 on chemical safety. An important task of this conference will be the formation of the 'Forum for Chemical Safety' which will constitute a particularly important aid for developing countries. Director General Kerstin Nibleus, who is our chair person today, is responsible for that meeting in Stockholm and she will give further information on that issue.

The solution of chemical hazard problems in developing countries will require the engagement of the scientific communtiy and it is therefore essential that scientists from developed and developing countries get together and exchange experiences in order to turn the development in the right direction. I am sure we will get much valuable information on many aspects of chemical hazards in developing countries during this conference and hopefully also suggestions of solutions of some of the many problems.

Scientific Papers

Part I

The Present State of Chemical Pollution in Developing Countries

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Chemical safety and health in Latin America: An overview

Dr. Jacobo Finkelman[1]

1. Introduction

In recent years there has been increasing local and international concern over chemicals in the environment and its potential adverse effects on human health. Such concerns have arisen in response to information on the wide spread distribution of chemicals in almost every single ecosystem, in particular those which sustain humans. Some environmental problems, such as contaminated land, have resulted from poorly controlled discharges of wastes of chemicals and the careless use of pesticides, whilst others, such as air pollution, are a direct consequence from uncontrolled emissions from power plants, industry stacks and motor vehicles.

Many environmental and health problems are closely associated with the continuous release over many years of chemicals into the environment with insufficient attention to an analysis of their behavior in soils, water and their impacts on humans and other species. Chlorinated organ-compounds illustrate this problem. For example, PCBs and DDT were developed as relatively stable substances, so it is not surprising today that, as a result of a widespread use and release into the ambient these substances are now universally distributed (UNEP, 1992), and because their potential bioaccumulation they are often detected in human tissues (WHO, 1992a).

As nations develop, industrial activities and the production and use of chemicals rise in parallel to their standard of living. Industrialization is central to economic development and improved prospects for human health and well-being, but industrial activity carries the risk of adverse health effects for the worker and the general population, either directly, through exposure to harmful agents or practices, or indirectly, because of degradation of the environment (WHO 1992b).

Industrialization, it is often said, is the engine of socioeconomic development. Following the Second World War, the countries of Latin America applied this philosophy in an effort to develop and broaden their economies, which up to that time were based essentially on the production and export of primary agricultural products and metallic minerals, and the importation of finished products and consumer goods. The newly emerging independent states of the Caribbean followed suit in the 1960s and 1970s.

Initially, the objective was to produce their own consumer goods, often starting from imported semi-finished or finished components. The so called 'screw driver' or assembly industries. The imported components were eventually to be produced locally thus creating a truly local manufacturing capability. This strategy was reasonably successful to the extent that many Latin American countries now make most of the components of their consumer products. In the smaller coun-

[1]Representative of the Pan American Health Organization/World Health Organization (PAHO/WHO) in Guatemala.

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tries of the Caribbean and Central America, where the lack of sufficiently large internal markets do not allow for a scale economy, this policy has been somewhat less successful.

As countries gathered steam, efforts were made to link industry with the region's own natural resources, and to begin to process their raw materials and to manufacture the intermediate materials needed by industry.

In general, as the processing of raw materials and intermediate products generate more pollutants than does the final production of goods, pollution has become increasingly problematical. Since the 1960s and 1970s the Latin American countries have experienced a large increase in the production of basic metals, metal working and finishing, organic and inorganic chemicals, and petroleum production and processing. Almost without exception, these developments have occurred with the minimal or no attention accorded to the environment. It is important to indicate that most of the industries were located in or close to large urban human conurbations, on the coastings, within the water catchment areas of major rivers, or above important underground water resources (Gajraj, 1984).

Extraordinary advances in chemical technology and production have been made throughout the world in the last half a century. The average annual growth rate of the chemical, petroleum and plastic products sector (1976–1989) has been one of the highest compared with those of other industrial and manufacturing sectors (UN, 1991). World production of chemicals (including solvents, fertilizers and non-ferrous metals) has in the past been located mainly in North America and Europe, but within the last two decades, the newly industrializing countries of East Asia and Latin America produced an increasing proportion of many chemical commodities on a global scale (UNEP, 1992 and UNIDO, 1993). As it shows in Tables 1–4, on one hand, some of the Latin American countries, in particular Brazil, Mexico and Argentina, and to a lesser extent, Venezuela, Chile, Colombia, Cuba and Peru have concentrated most of the industrial output of this region. On the other, it is also quite clear that over the 1980–1990 period the manufacturing capacity of these countries has declined as a result of a sharp deterioration of economic conditions in the region, precipitated by a combined outcome of growing external debt; the decline in the international price of many basic export commodities, unfavorable trends in international commerce, as well as the failure of the economic policies implemented by several of the Latin American countries (IDB, 1991). Only recently, some of the countries of the region have been able to stabilize this downward trend of their economies, and industrialization growth is regaining some strength.

In terms of employment creation and income generation, small-scale industry (SSI) is an increasing important subsector of local and national economies in developing countries. Small enterprises also serve as the incubators for industrial growth (WB, 1992a). While the majority of the SSIs do not work with hazardous materials or generate hazardous wastes, there are a number of subcategories that many create significant problems and thus require urgent attention, such as: tanneries, textile dyeing plants, metal working and electroplating shops, foundries, automobile repair shops and gas stations, battery production/recycling, pesticide formulation, paint shops and printing.

In Latin America the SSI subsector is heterogeneous, differing in size and composition from city to city and country to country. Significant variation exist in number of employees, production, and waste generation, levels of capitalization, degree of spatial concentration, and technological processes employed. Thus, two priority environmental health and chemical safety problems are associated with inadequate hazardous materials handling and hazardous waste management by SSIs:

(a) occupational exposure due to the large total employment in many of the troublesome SSIs, as well as exposure to family members and others living in the same premises or the immediate neighborhood; and
(b) pollution impacts of uncontrolled hazardous waste discharges, affecting especially surface and ground water, air, soils, and some times the food chain.

Table 1
Selected/countries among the 15 world leading producers in major manufacturing branches 1980–1990

1980		1990	
Country	Share (%)	Country	Share (%)
Food products (311/12)			
1. USA	18.2	1. USA	18.8
7. Brazil	3.8	7. Brazil	3.6
8. Mexico	3.4	8. Mexico	2.7
9. Argentina	2.7	9. Argentina	2.2
10. Canada	2.2	12. Canada	2.0
Textiles (321)			
1. USA	15.9	1. USA	17.0
8. Brazil	3.7	10. Brazil	3.0
10. Mexico	2.8	12. Mexico	2.5
11. Argentina	1.9	14. Argentina	1.6
		15. Canada	1.6
Wearing apparel (322)			
1. USA	24.2	1. USA	25.8
10.Canada	2.3	11.Canada	2.3
11. Brazil	1.9	13. Mexico	1.9
12. Mexico	1.9	14. Brazil	1.5
Leather and fur products (323)			
1. USA	13.6	1. Italy	13.8
8. Mexico	3.6	9. Mexico	3.6
9. Brazil	3.2	10. Brazil	2.5
10. Argentina	2.6	11. Argentina	2.3
13. Canada	1.4		
Footwear (324)			
1. Italy	18.5	1. Italy	17.1
6. Mexico	5.1	4. Mexico	6.1
8. Brazil	3.8	10. Brazil	3.6
13. Canada	1.3	15. Canada	1.4
Paper (341)			
1. USA	30.2	1. USA	31.0
3. Canada	7.0	5. Canada	5.6
11. Brazil	2.1	11. Brazil	2.0
12. Mexico	1.5	12. Mexico	1.5
14. Argentina	1.0		
Industrial chemicals (351)			
1. USA	25.3	1. USA	25.6
8. Brazil	2.4	7. Mexico	2.8
10. Mexico	2.2	11. Brazil	2.4
12. Canada	1.8	14. Canada	2.0

Table 1 (*continued*)

1980		1990	
Country	Share (%)	Country	Share (%)
Other chemicals (352)			
1. USA	26.0	1. USA	26.2
7. Brazil	3.5	7. Brazil	2.7
8. Mexico	2.5	9. Mexico	2.4
9. Argentina	2.3	12. Canada	1.5
10. Canada	1.9	13. Argentina	1.5
Rubber products (355)			
1. USA	17.6	1. USA	21.1
7. Brazild	3.5	8. Brazil	3.1
8. Argentina	2.9	10. Canada	2.5
9. Mexico	2.6	12. Mexico	2.2
10. Canada	2.4	13. Argentina	1.9
Iron and steel (371)			
1. Japan	22.7	1. Japan	23.6
6. Brazil	3.1	6. Brazil	3.8
10. Canada	1.7	8. Argentina	2.5
11. Argentina	1.7	13. Canada	1.5
12. Mexico	1.6		
Non-ferrous metals (372)			
1. USA	30.2	1. USA	27.1
6. Canada	4.3	5. Canada	5.0
9. Chile	2.1	9. Chile	2.3
11. Brazil	1.6	10. Brazil	2.1
13. Peru	1.3		
15. Mexico	1.2		
Metal products (381)			
1. USA	27.6	1. USA	27.9
8. Canada	2.7	8. Canada	2.3
9. Brazil	2.0	11. Brazil	1.6
10. Argentina	1.9	15. Mexico	1.4
Electrical Machinery (383)			
1. USA	27.7	1. Japan	29.7
9. Brazil	1.7	12. China	1.1
10. Canada	1.5	14. Brazil	1.0
15. Mexico	0.9		
Non-electrical machinery (382)			
1. USA	30.9	1. USA	33.3
7. Brazil	2.5	8. Canada	1.4
10. Canada	1.3	9. Brazil	1.4
Transportation equipment (384)			
1. USA	28.7	1. USA	30.7
8. Canada	2.1	8. Canada	2.4
9. Brazil	1.7	13. Mexico	1.0
10. Argentina	1.6	14. Brazil	1.0
12. Mexico	1.3		

Source: UNIDO, 1993.

Table 2
Latin American and Caribbean countries among 15 leading developing countries in major manufacturing branches 1980–1990

1980		1990	
Country	Share (%)	Country	Share (%)
Food products (311/12)			
1. Brazil	15.0	1. Brazil	13.9
2. Mexico	13.5	2. Mexico	10.5
3. Argentina	10.6	3. Argentina	8.5
5. Cuba	4.1	6. Cuba	3.7
8. Colombia	3.0	9. Colombia	3.2
11. Venezuela	2.4	14. Venezuela	2.3
13. Chile	1.7		
Sum of above	50.3	Sum of above	42.1
Textiles (321)			
2. Brazil	11.5	3. Brazil	8.3
3. Mexico	8.5	5. Mexico	6.9
4. Argentina	6.0	7. Argentina	4.5
13. Colombia	1.9	15. Colombia	1.8
Sum of above	27.9	Sum of above	21.5
Wearing apparel (322)			
3. Brazil	9.1	5. Mexico	7.2
4. Mexico	8.7	6. Brazil	6.0
7. Argentina	5.1	9. Colombia	1.7
10. Cuba	2.2	1. Argentina	1.5
12. Colombia	1.5		
13. Venezuela	1.3		
14. Chile	1.2		
15. Uruguay	1.0		
Sum of above	30.1	Sum of above	16.4
Leather and fur products (323)			
1. Mexico	14.3	2. Mexico	11.9
2. Brazil	12.8	3. Brazil	8.4
3. Argentina	10.3	4. Argentina	7.7
8. Uruguay	2.8	9. Uruguay	2.1
10. Colombia	1.9	10. Colombia	2.1
14. Peru	1.3	14. Venezuela	0.9
15. Chile	1.3	15. Chile	0.8
Sum of above	44.7	Sum of above	33.9
Footwear (324)			
1. Mexico	20.3	1. Mexico	18.9
2. Brazil	15.0	3. Brazil	13.8
5. Argentina	4.8	7. Cuba	3.7
6. Cuba	4.4	9. Chile	2.3
8. Venezuela	2.3	11. Venezuela	2.0
9. Chile	2.1	12. Argentina	1.9
Sum of above	48.9	Sum of above	42.6

Table 2 (*continued*)

1980		1990	
Country	Share (%)	Country	Share (%)
Paper (341)			
1. Brazil	18.3	1. Brazil	15.9
2. Mexico	13.6	2. Mexico	11.7
3. Argentina	8.9	7. Argentina	6.1
7. Venezuela	4.2	10. Chile	3.3
10. Chile	3.5	11. Venezuela	3.3
11. Colombia	2.3	12. Colombia	2.7
12. Peru	1.8	13. Cuba	2.5
13. Cuba	1.8		
Sum of above	54.4	Sum of above	45.5
Industrial chemicals (351)			
1. Brazil	16.5	1. Mexico	14.2
2. Mexico	14.8	4. Brazil	12.3
5. Argentina	7.8	7. Argentina	5.0
12. Venezuela	1.4	10. Venezuela	2.1
13. Peru	1.3	13. Colombia	1.2
14. Colombia	1.2		
Sum of above	43.0	Sum of above	34.8
Other chemicals (352)			
1. Brazil	16.7	1. Brazil	12.7
2. Mexico	11.7	3. Mexico	11.4
3. Argentina	10.8	5. Argentina	7.2
10. Venezuela	2.6	11. Venezuela	2.0
14. Chile	1.8	13. Chile	1.7
15. Peru	1.6	14. Colombia	1.6
Sum of above	45.2	Sum of above	36.6
Rubber products (355)			
1. Brazil	16.4	2. Brazil	13.3
2. Argentina	13.7	4. Mexico	9.2
3. Mexico	11.9	5. Argentina	8.2
11. Venezuela	2.2	13. Venezuela	1.9
Sum of above	44.2	Sum of above	32.4
Iron and steel (372)			
1. Brazil	23.6	1. Brazil	20.1
2. Argentina	12.7	2. Argentina	13.4
3. Mexico	12.3	6. Mexico	7.0
9. Venezuela	2.4	9. Venezuela	2.3
11. Chile	1.1	13. Colombia	0.8
12. Peru	1.1		
15. Colombia	0.9		
Sum of above	54.1	Sum of above	43.6

Table 2 (*continued*)

Non-ferrous metals (352)			
1. Chile	16.5	1. Chile	14.8
2. Brazil	13.1	2. Brazil	14.1
3. Peru	10.6	5. Mexico	6.9
4. Mexico	9.4	8. Peru	5.5
7. Argentina	5.8	10. Cuba	4.5
10. Venezuela	3.3	11. Venezuela	3.8
13. Cuba	2.3	13. Argentina	2.3
Sum of above	61	Sum of above	51.9
Metal products (381)			
1. Brazil	16.6	1. Brazil	12.4
2. Argentina	15.3	2. Mexico	10.6
4. Mexico	9.7	4. Argentina	7.2
10. Venezuela	2.0	12. Venezuela	1.6
14. Chile	1.3	14. Chile	1.3
		15. Trinidad Y Tobago	1.2
Sum of above	44.9	Sum of above	34.2
Electrical machinery (383)			
1. Brazil	18.0	4. Brazil	8.3
2. Mexico	9.7	10. Mexico	2.7
7. Argentina	5.8	11. Argentina	1.5
14. Venezuela	1.2	14. Venezuela	1.0
15. Colombia	1.1		
Sum of above	35.8	Sum of above	13.5
Non-electrical machinery (382)			
1. Brazil	33.8	2. Brazil	20.6
2. Mexico	10.6	6. Mexico	6.0
4. Argentina	9.4	8. Argentina	3.7
13. Peru	0.8	14. Colombia	0.6
15. Chile	0.7		
Sum of above	55.3	Sum of above	30.9
Transportation equipment (384)			
1. Brazil	18.2	3. Mexico	10.7
2. Argentina	16.6	4. Brazil	10.5
3. Mexico	13.5	8. Argentina	5.9
13. Venezuela	1.6		
14. Oeru	1.4		
Sum of above	51.3	Sum of above	27.1

Source: UNIDO, 1993.

Table 3
Selected countries among the 15 largest producers of pharmaceutical preparations 1975–1990

1975	Share (%)	1990	Share (%)
2. USA	19.8	1. USA	24.4
10. Brazil	2.0	10. Argentina	1.5
12. Mexico	1.6	12. Canada	1.5
13. Argentina	1.5	13. Mexico	1.3
15. Canada	1.2	14. Brazil	1.3

Source: UNIDO, 1993.

Besides the large petrochemical refineries and industry, which quite often are located in low density populated areas, (but frequently these sites are fragile areas from the environmental point of view) most of the chemical plants in Latin America are placed in or nearby large and middle size cities. For instance, over 2000 chemical plants are located in Mexico City (SEDESOL, 1992). As shown in Table 5, in Colombia (UNIDO, 1993) of 414 chemical plants in operation in the country, 238 employ 50 or less workers. Also as in most of the Latin American countries these industrial establishments are placed in highly populated urban areas.

Chemical safety and environmental pollution issues and problems are often so closely inter-related that it is not easy to make a clear distinction between both. Therefore, for practical reasons, when chemical substances are involved the risk reduction approach should consider analyzing the problems from both perspectives. As a chemical safety one, and as an environmental pollution problem alike.

As indicated in Chapter 19, of Agenda 21 of UNCED (UNCED, 1992) chemical safety has to involve the hazard identification (based on the intrinsic properties of chemicals), the risk assessment (including assessment of exposure), the risk acceptability, and the risk management.

In a wider context the risk reduction has to consider alternatives to toxic chemicals, as well as the establishment of pollution prevention procedures and setting standards for chemicals. The entire life cycle of the chemicals has to be considered. Such approaches could encompass both regulatory and non-regulatory measures, such as promotion of the use of cleaner products and technologies, emission inventories, product labelling, use limitations, economic incentives, procedures for safe handling and exposure regulations, and the phasing out or banning of chemicals that pose unreasonable and otherwise un-

Table 4
Latin American and Caribbean countries among the 15 largest producers of pharmaceutical preparations in developing countries 1975–1990

1975	Share (%)	1990	Share (%)
2. Brazil	9.5	2. Argentina	8.4
3. Mexico	7.6	3. Mexico	7.0
4. Argentina	7.4	4. Brazil	6.9
8. Venezuela	2.9	8. Colombia	2.9
11. Colombia	2.0	12. Venezuela	1.8
15. Peru	1.3		
Sum of above	30.7	Sum of above	27.0

Source: UNIDO, 1993.

Table 5
Selected characteristics of chemical industry branches by size of employment Colombia 1982–1987

Number of Employees	No. plants		(%) employment		Value added	
	1982	1987	1982	1987	1982	1987
Basic chemicals (351)						
< 50	55	70	8.1	10.7	7.0	7.7
50–99	19	22	7.5	9.9	8.9	11.9
100–199	10	6	9.2	5.8	8.3	4.8
> 200	20	23	75.2	73.7	75.8	75.7
Other chemicals (352)						
< 50	138	168	11.7	15.0	5.5	7.2
50–99	49	47	13.5	12.6	7.5	9.7
100–199	32	38	19.1	21.2	19.4	19.9
> 200	40	40	55.8	51.2	67.5	63.1

Source: UNIDO, 1993.

manageable risks to human health and the environment, and those that are toxic, persistent and bio-accumulative and whose use cannot be adequately controlled.

In other areas, risk reduction may include the prevention of chemical accidents, prevention of poisonings by chemicals and the undertaking of toxicovigilance and coordination of clean up and rehabilitation of areas damaged by toxic chemicals.

2. Urbanization and air pollution

Since 1930, the population of Latin America and the Caribbean has quadrupled (PAHO, 1990a). The current population of 438 million is projected to increase by 23% by the turn of the Century and by 74% by the year 2025. Rapid urbanization growth is likely to continue because of two factors: (a) fertility rates in many countries have not declined as steeply as mortality rates; and (b) the large proportion of young people (38% of the region's population is under age 15) ensures that population growth will continue for some time even if lower fertility rates are achieved. Thus, it is important to remember that the next generation of parents—and job seekers and consumers—has already been born.

Two-thirds of Latin Americans living in urban areas, compared with an average of 34% for the developing world as a whole (WHO, 1992c). By the turn of the century, the developing world will have 37 cities with populations over 5 million; five of them are already that size in Latin America and three more will join their ranks during the next 10 years (PAHO, 1990b) Table 6.

According to the World Bank (WB, 1992b) developing countries account for about 10% of the world's cars, 20% of the trucks and buses, and a little over 20% of the worldwide transport energy consumption. Latin America accounts for 60% of the developing world's share of cars and 30% of its buses and trucks. To put this into perspective, however, the US alone consumes about 35% of the world's transport energy, and all the developing nations together contribute about 29% to the global emissions of fossil carbon dioxide.

The number of cars in the cities has also grown dramatically over the past 50 years. Mexico City, for example, had 48 000 cars in 1940, 680 000 in 1970, 1.1 million in 1975 and 2.7 million by 1990 (SEDESOL, 1992). This sharp increase in the number of vehicles, plus the fact that a substantial industrialization process is also taking place in and around the large urban centers of the region has resulted in significant increase of air pollutants. Figs. 1 and 2 present the summary of the annual geometric means of total suspended particulates (TSP) and sulfur dioxide (SO_2) for

Table 6
Total, urban and rural population, estimated and projected, by regions and zones 1970–2000 (millions)

Region or Zone	Category	1970	1980	1990	1995	2000
World total	Total	3693	4450	5246	5678	6122
	Urban	1371	1764	2234	2525	2854
	Rural	2322	2685	3012	3153	3268
Americas	Total	510	613	726	785	844
	Urban	330	423	530	586	642
	Rural	180	191	197	199	201
Latin America	Total	283	361	451	499	546
	Urban	163	236	325	372	420
	Rural	121	125	126	126	127
Central America	Total	68	92	119	134	149
	Urban	37	56	79	92	105
	Rural	31	36	41	42	44
South America template	Total	36	42	49	52	55
	Urban	28	35	42	46	49
	Rural	8	7	7	7	6
South America tropical	Total	154	198	248	275	301
	Urban	86	130	184	211	266
	Rural	68	67	64	63	62
Caribbean	Total	25	30	35	38	41
	Urban	11	16	21	24	27
	Rural	13	14	14	14	14

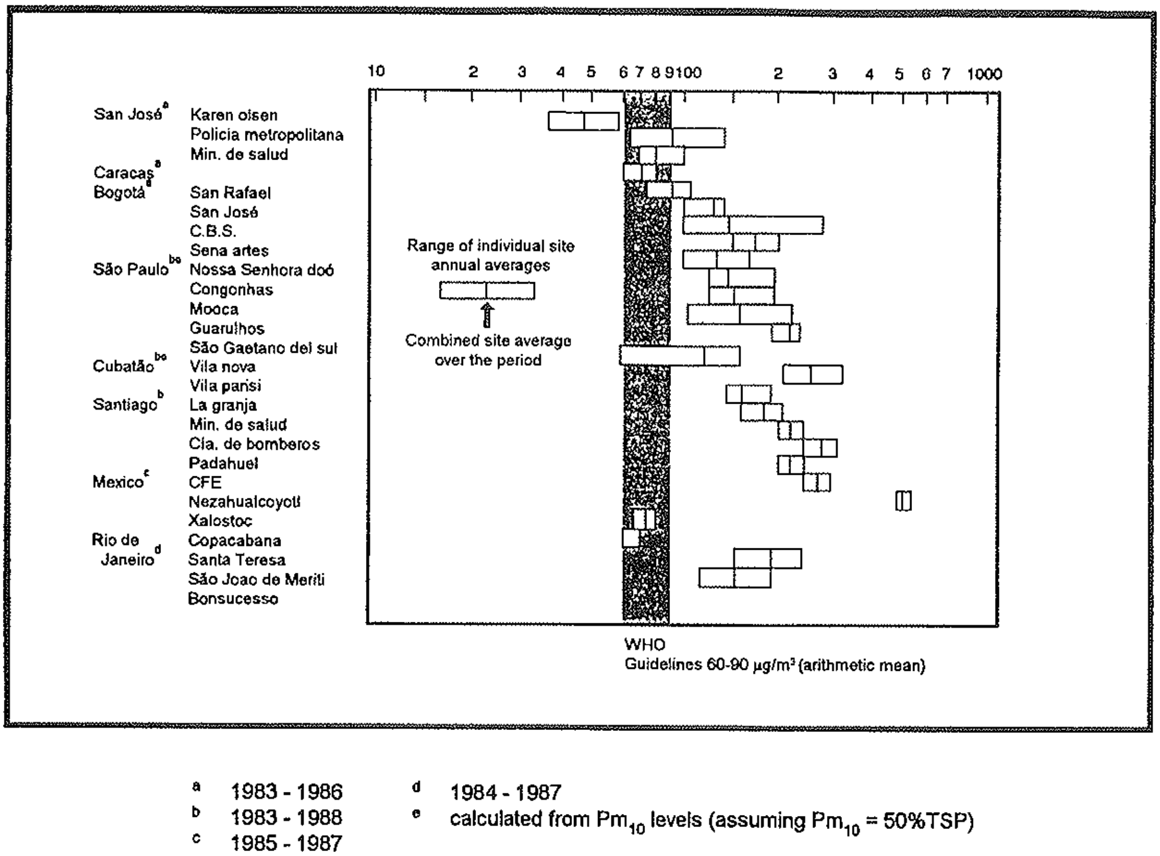
Source: Naciones Unidas. The prospect of world urbanication (revisado en 1984 y 1985). Nueva York: UN; 1983. (Estudios Demográficos, 101; ST/ESA/SER.A/101).

some Latin American Cities. These concentrations may be compatible with health damage, in particular among children and the elderly (WHO 1987).

It is estimated that 81 million of the Latin American population is living in cities which currently exceed the WHO recommended threshold limits for air pollutants (26% of the total urban population and the region). Due to the rapid population urban growth and the concomitant industrialization in progress, and despite all the pollution control efforts already under way there is a significant chance that the population at risk may increase.

Various chemicals are emitted into the air from both natural and anthropogenic sources. The quantities may range from hundreds to millions of tons annually. The increase in air pollution as a consequence of the expanding use of fossil energy sources and the growth in the manufacture and use of chemicals has been accompanied by mounting public awareness of and concern about its detrimental effects on health and the environment. Moreover, knowledge of the nature, quantity, physicochemical behavior and the effects of air pollutants has greatly increased in recent years (WHO, 1987). Nevertheless, more needs to be known and certain aspects of the health effects of air pollutants require further assessment.

The impact of air pollution is broad, and so are the number and types of pollutants with potential health effects. In Latin America most of the air quality monitoring programs are basically re-



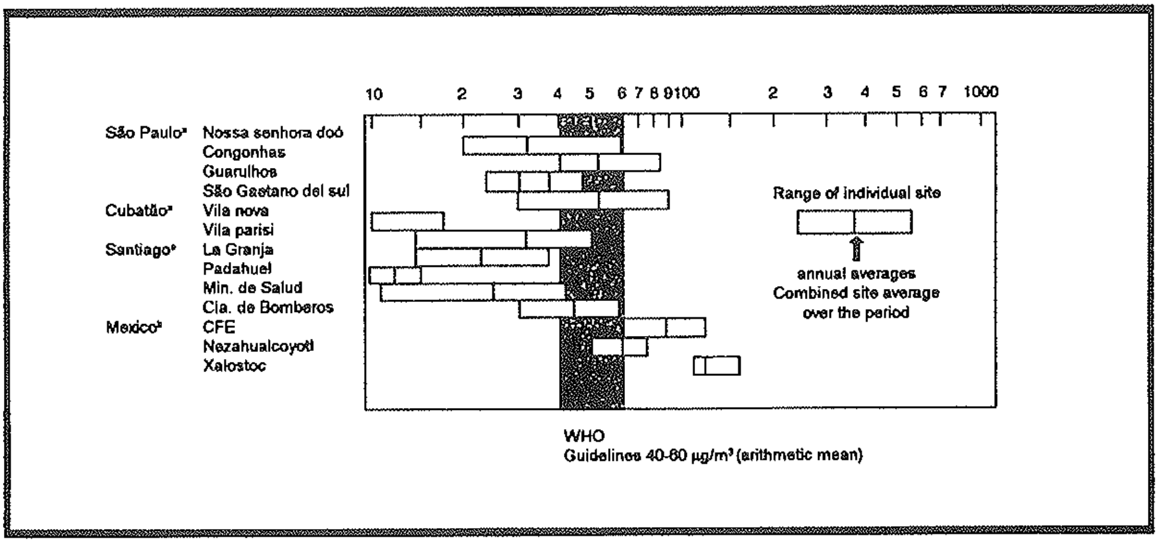
Source: Romieu I, Weitzenfeld H, Finkelman J. Urban air pollution in Latin America and the Caribbean. *World Health Statistics Quarterly.* 1990; 43:153-167. With recent information for Santiago, Chile from the Decontamination Commission.

Fig. 1. Summary of the annual geometric average of total suspended particulates (TSP) in some Latin American cities.

stricted to the traditional, most common air polutants, namely carbon monoxide, nitrogen oxides, sulfur dioxide, ozone and particulates (Finkelman, 1993). Also, only a few epidemiological studies on the health implications of air pollution have been conducted in countries of the region. Nevertheless, by extrapolating the findings cited in the international literature, it may be expected that these levels of air pollution could be associated with an excess number of 2.3 million cases of respiratory illness and reduced ventilatory capacity among children which may be impaired as adults by an increased risk of developing chronic obstructive lung disease. Among the elderly living in cities where the TSP limits have been exceeded, we may expect that the excess number of cases of chronic bronchitis on a yearly basis may be well over 100 000. Also based on international published scientific data, the current pollution levels experienced in some of the most heavily contaminated cities, could account for as much as 6% of the mortality. However, this estimation is approximated since population structures differ between Western and Latin American countries (Romieu, 1990).

3. Petrochemical industry

Despite the economic instability which has affected over the last decade the Latin America's development, the chemical and petrochemical industry continued its growth and expansion programs (ANIQ, 1988). The primary Latin American players, Argentina, Brazil, Mexico and Venezuela, are trying to develop their national petrochemical industries to meet domestic needs and export any surpluses available. Figs. 3–6 include some data on the production capacity of basic petrochemicals for the period 1990–95 (Quijada, 1990).



Source: Romieu I, Weitzenfeld H, Finkelman J. Urban air pollution in Latin America and the Caribbean. *World Health Statistics Quarterly*. 1990; 43:153-167. With recent information for Santiago, Chile from the Decontamination Commission.

Fig. 2. Summary of the annual SO_2 averages in some Latin American cities.

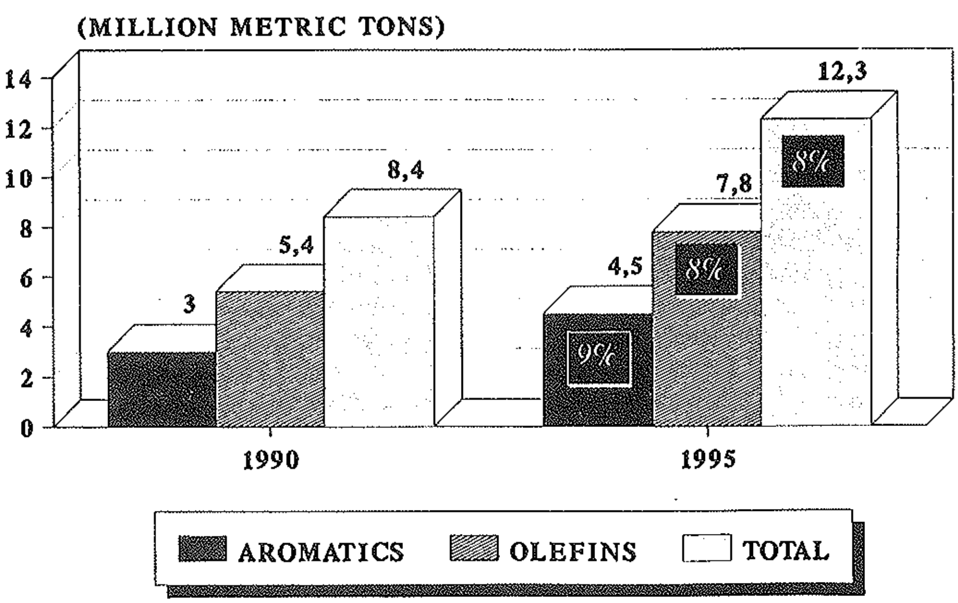


Fig. 3. Latin American Major Capacities.

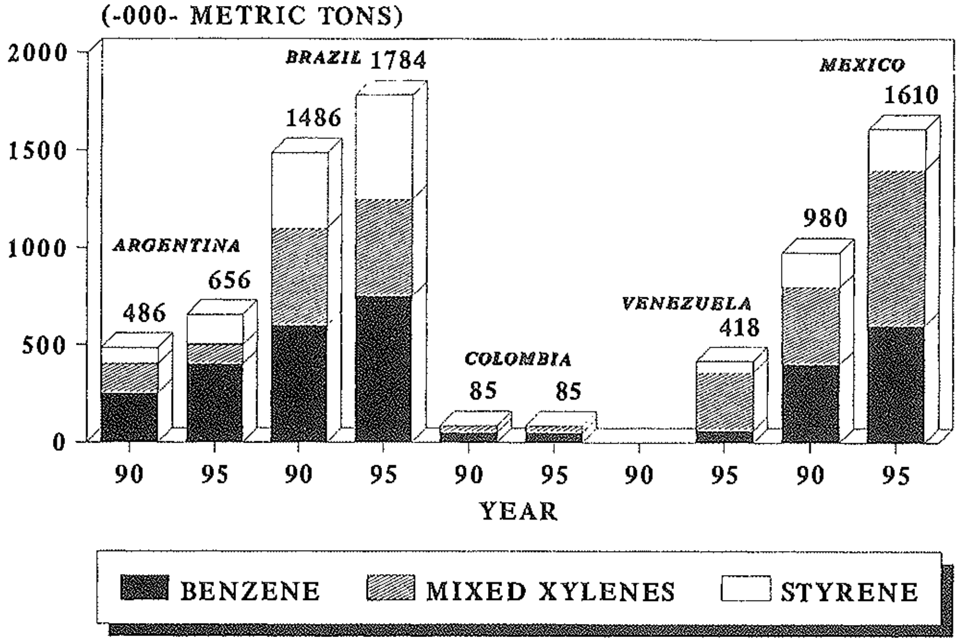


Fig. 4. Main aromatics capacities.

In 1990, Latin American's olefins (ethylene, propylene and butadiene) capacity represents approximately 5.4% of the world's capacity: this participation is expected to increase to 6% by 1995. In the case of aromatics (benzene, mixed xylenes and styrene) currently the Latin America's capacity is about 3% of the total global output, and may increase to 7.8% by 1995 (Quijada, 1990).

In Venezuela the annual consumption of benzene is approximately 36 000 metric tons, which until 1990 had been imported almost exclusively from the USA. A new benzene plant was constructed in the late 1980s and began production (59 000 metric tons annually in 1990). With this new plant, Venezuela has now exceeded its own domestic demand and has begun exporting benzene to other Latin American countries. A second benzene-producing facility is currently under construction. It should be noted that in most of the countries of the region there is no general awareness of the deleterious health effects of solvents. Only a few and very limited studies on the health effects of exposed workers have been conducted in Brazil (Augusto, 1984), Mexico (Torres, 1983; Muñoz, 1988; Ramíez, 1988) Cuba (Hernandex, 1983; Cedillo, 1987) and Venezuala (Escalona, 1993).

Another important source of exposure to solvents is the deliberated inhalation of a variety of solvents for their psychotropic effects. This practice has been documented throughout Latin America, especially in Mexico (Medina-Moro, 1982, 1986).

Oil is one of the most important sources of energy in the world. It is also one of the major causes of environmental problems. Latin America's oil pollution problems fall into two categories. Firstly, pollution arising from the production process (drilling, transport, refining and the petrochemical industry), and secondly, from the consumption of oil associated with the 'greenhouse effect' or global warming. Latin America (as the rest of the developing world) is not a significant contributor to the carbon dioxide emissions (WHO 1992d).

The two principal causes of pollution in the transportation of crude oil come from oil spills and from the accumulation of basic sediment and

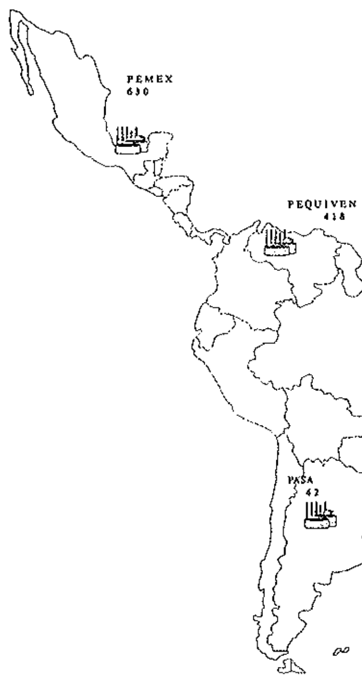


Fig. 5. 1995 Mexico and South American major aromatic expansions.

water (known as BSW) which must at some point be discharged. The problem of the BSW can to some extent be lessened since this material, if saved can be used for synthetic fuels. Oil companies maintain a guarded silence about how they are dealing with this problem in Latin America (Latin American Newsletter, 1992).

Oil spills are common in all the oil-producing countries in the region. Perhaps the following cases may illustrate the problem: (a) the Caribbean Basin; (b) Venezuela; (c) Colombia; and (d) Mexico.

(a) Everyday some 5 million barrels of oil are transported through the Caribbean, and every year an average of about 7 million barrels of oil are dumped there (Latin American Newsletter, 1992). Around half of this amount is discharged by tankers, dumping oily wastes and tanker slops. Another large amount comes from off-shore oil drilling. This pollution is affecting severely the Caribbean's mangrove swamps, seagrass meadows and coral reefs.

(b) A large proportion of Venezuela's oil production is concentrated in the west, around Lake Maracaibo. On the bottom of the Lake, which has a surface area of 1.2 million hectares. Thousands of oil wells have been drilled and a network of pipelines built. Some of these pipelines are 20 years old and they constantly leak oil. It is worth noting that in accordance with OPEC oil pipes have a lifespan of approximately 25 years, provided they receive proper maintenance.

(c) Attacks by the Ejército de Liberación Nacional (ELN) on Colombia's main oil pipeline have overshadowed any damage the state owned oil company, ECOPETROL, may be causing to the environment. Since 1986, when the ELN sabotage complaint on the oil industry began, they dynamited the Cañon Limón-Puerto Covéas pipeline around 150 times, causing over 650 000 barrels to be split.

(d) Mexico City's 18 de Marzo refinery in Atzcapozalco is one example of the extent of the environmental damage refineries can cause.

This plant was shot down in March 1991. According to the government's figures (SEDESOL, 1992), this refinery alone accounted for 2% of the air pollution in the city; it bleached out over 100 000 tones of pollutants a year.

Also in Mexico, in April 1992 when a succession of 15 explosions in the sewage system rocked Guadalajara, the countries second biggest city. The explosions which tore up streets and demolished buildings, left over 200 dead, 1500 injured and 4000 homeless. A Government inquiry concluded that the immediate cause of the explosions was a leakage from an oil pipeline from PEMEX's La Nopalera refinery (SSA, 1992).

4. Water pollution

As environment-watchers focus most of their attention on air pollution, the gravity of Latin America's water pollution is often overlooked. Most of the water pollution comes from three sources: (a) domestic waste water; (b) industrial effluents; and (c) land run-off.

(a) Pollution from domestic waste water is

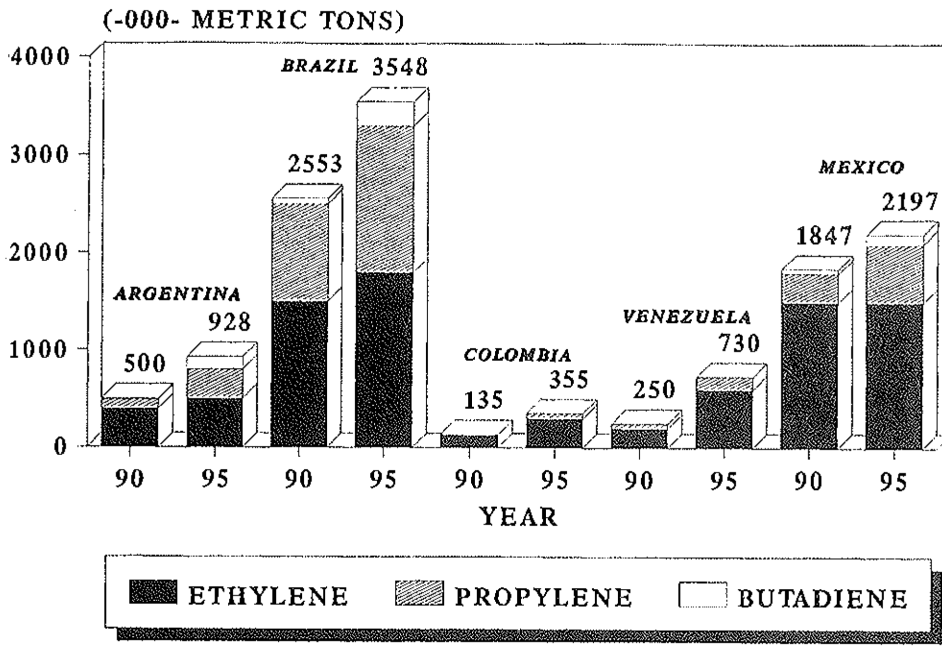


Fig. 6. Main olefins capacities.

caused by human waste contaminating water sources after passing through the sewage system. PAHO estimates that less than 2% of urban sewage in the region is treated (De Koning, 1992). The consequences of this lack of infrastructure is clear. The current cholera pandemic affecting most of the Latin American countries is a direct outcome of decades of negligence and lack of vision on making the needed investments to improve local water supply systems and basic sanitation.

(b) Industrial effluents include heavy metals, synthetic organic compounds which reach the water bodies through direct discharge, by leaching from waste dumps or from sedimentation processes of air contaminants. The extent of the problem has not yet been systematically evaluated. Nevertheless, numerous examples illustrate the complexity of the problem (CEPIS, 1988).

(c) Most of the water pollution associated with run-offs are linked with deforestation and the use of agrochemicals. Deforestation causes soil erosion which, after rainfall, shifts land into the rivers, filling them with sediment and degrading the quality of water. The use of fertilizers and pesticides, however, is the most pressing concern (Henao, 1993).

5. Pesticides

The estimated amount of money spent by the Latin American countries on pesticides has doubled, or tripled in some cases during the decade 1980–1990 (Burton, 1988) Table 7. If the public health problems associated with the use of pesticides are directly related to the amounts used, extrapolation of this trend may indicate the extent of future problems, unless measures are taken to avoid or reduce the adverse health effects.

In Brazil (Almeida, 1993), about 60% of all the pesticides applied for agricultural purposes were highly and moderately toxic. Nevertheless in general, there is a tendency in the region to move away from the highly persistent organichlorine pesticides to the use of less persistent, but gener-

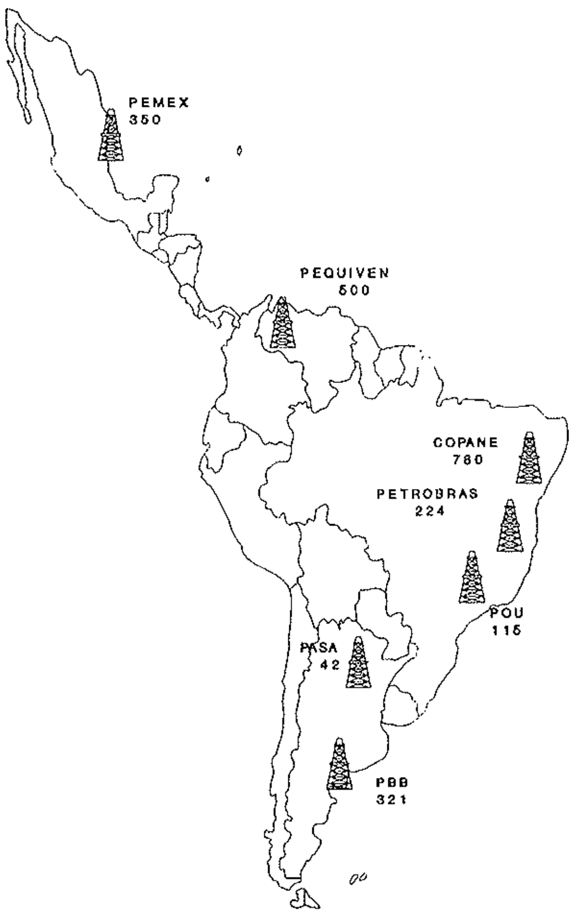


Fig. 7. 1995 Mexico and South American major olefins expansions.

ally, more acutely toxic compounds, such as carbamates and organophosphates. It is likely, however, that the more toxic of these chemicals will slowly be phased out (Henao, 1993).

In all Latin American countries there are chemical plants that formulate pesticides. Mexico and Brazil, stand out particularly where almost 50 pesticides are being synthesized.

A fact of special importance from the agronomic and toxicological point of view, is that in some countries like Costa Rica (Wesseling, 1988), Brazil (Almeida, 1986) and Mexico (Albert, 1990) the concentrations of the active ingredients indicated on the labels some times do not correspond with the concentrations actually present. Some times there are surpluses and in others, deficiencies.

The population exposed to pesticides in the Latin American region is potentially very large. Some of the groups at particular risk are described in Table 8.

With respect to exposed workers, there is a great complexity in the patterns of use for pesticides; hence, a great variety and intensities of exposure are taking place. Also, in some activities such as in the cut flower industry, mostly women are employed and exposed. There is not the least doubt that the economically active population in the agricultural sector, where 85% of the pesticides are utilized, has the highest potential of exposure. Table 9 shows some of the indicators of exposure for populations in some selected countries in Latin America (Henao, 1993).

Levels of morbidity and mortality among workers and populations not occupationally exposed, are not just the reflection of a simple relationship between the agent and the exposed person. Such levels also indicate the interaction of numerous other factors, such as the duration of the exposure, susceptibility, nutritional status, educational and cultural aspects, and the general social and economic conditions under which the pesticides are being applied.

Data on health effects in Latin America are relatively limited. Especially with respect to the great quantities of pesticides that are currently being used. Information from areas where these pesticides are being applied are not always completely reliable. Moreover, the data have often been obtained by different methods, which makes their comparison difficult and does not always allow correct evaluation of the adverse impact of pesticides on health.

Under-registration of pesticide poisoning cases is frequent. As an example, in Costa Rica, where the National Poisoning Center (CNK) had a record of 423 poisoning cases for the period from 1978 to 1980, while in a single hospital, in Guápiles, located in a banana plantation area, 374 cases were reported in 1980 (88% of those reported to the CNI in two years) (Henao, 1993).

Nevertheless based on some of the available

Table 7
Pesticides Expenditures[a] in some Latin American countries

Country	1980	1985	1990
Argentina	102	164	241
Bolivia	9	13	18
Brazil	695	1225	1993
Chile	8	12	17
Colombia	96	155	250
Ecuador	41	60	86
Peru	14	21	30
Uruguay	7	11	18
Venezuela	22	38	61
Mexico	199	351	565

[a]Millions of $US.
Source: Burton et al., 1988.

studies, Table 10 shows some of the reported acute poisoniug cases. From the results of these studies, however, the following estimates can be made:

- in the smaller countries, at least 1000–2000 acute pesticide intoxications occur on a yearly basis. In the larger countries proportionately more. Under-registration of acute intoxications renders precise estimates difficult;
- the number of pesticide intoxications has increased every year during the 1980s;
- the case fatality ratio due to pesticide intoxications ranged from 1.5 to 12%. This wide range probably results from the variation in the type of pesticide used, the number of applications per season, and other variables;
- the proportion of women among the poisoning cases ranged from 1.5 to 30%, with most values falling in the 20–30% bracket;
- the proportion of occupational pesticide intoxications among individuals less than 18 years old ranged from 10 to 20% (quite a few of the minors involved were less than 14 years old) with most percentages centering near 20%;
- of the hospitalized cases, it is estimated that 3.0–8.5% died; and,
- it is estimated that roughly 70% of the intoxicated individuals were agricultural and/or livestock workers.

Despite the fact that many studies have demonstrated a decreased activity among exposed Latin American workers to organophosphates and some carbamates (López, 1988; McConnel, 1990; Henao, 1991) only a few countries, mainly some regions in Colombia, Brazil and Nicaragua have established regular active surveillance programs. Cholinesterase measurements satisfies good screening criteria at low cost, and decreased activity indicates risk of development of disease for which appropriate intervention is available and acceptable to the exposed population (Henao, 1993).

Table 8
Population exposed and degree of exposure

Workers
- In factories that manufacture active ingredients and/or formulate them
- In various modes of transportation and sale
- In the agricultural sector (field applicators, mirex, pilots, storage personnel, flagmen, and laborers that are involved in the various stages of the harvest)
- In activities related to the livestock sector
- In the forest industry
- Those working with ornamental plants, particularly in greenhouses
- Applicators in public health campaigns, in urban fumigation companies, and those working on cash crops for export
- Applicators in urban fumigation companies

Communities
- Rural communities located near fields where there are aerial or land application activities
- Families of agriculture workers, especially children and pregnant women
- Urban and rural communities where there are residential applications or public health campaigns
- In general, through pesticides residues in food and water

Information on long term effects is very limited. Only recently have analytical epidemiologic studies been performed, or are currently in progress. These studies suggest that chronic central neurological damage is persistent after poisoning. Thallium poisoning are still being seen among individuals intentionally or unintentionally in Mexico (L. Pérez Lucio, Instituto Mexicano del Seguro Social, Mexico City, personal communication). Organophosphate induced delayed polyneuropa-

Table 9
Demographic information, pesticides utilized, and degree of exposure in some countries in Latin America

Country	Total population (millions)	Economically active agricultural population	Pesticides used (millions of kg)	Pesticides used in agriculture (millions of kg)	Degree of exposure (kg/person)	
					Total population	Economically active agricultural population
Brazil	144.0	23.0	64.0	54.0	0.44	2.34
Mexico	85.0	10.0	53.0	45.0	0.62	4.50
Colombia	30.0	3.0	21.0	17.8	0.70	6.00
Costa Rica	3.0	0.5	8.8	7.0	3.00	14.00
Ecuador	10.5	2.0	6.0	5.0	0.57	2.50
Panama	2.5	0.5	6.0	5.0	2.40	10.00
Honduras	5.0	0.6	4.0	3.4	0.80	2.12
Guatemala	9.0	3.0	6.0	5.1	0.66	1.70
El Salvador	5.0	1.0	3.0	2.5	0.60	2.50

Source: WHO, 1989; Associação Nacional de Defensivos Agricolas, 1989; Secretaria de Agricultura y Recursos Hidráulicos, 1988; Instituto Colombiano Agropecuario, 1990; Confederación Universitaria Centroamericana, 1989; Bolaños, 1991; Rahea et al., 1989.

thy (OPIDP) associated with exposures to methamidophos are currently being investigated in Central America (McConnell, 1990). Although potential teratogenic effects of maternal exposures are a common concern, the highest risk of adverse reproductive effect has been seen among male production workers in banana plantations in Costa Rica heavily exposed to the nematicide dibromochloropropane (DBCP). Continued use of this pesticide is reported to have produced high rates of sterility after it had been removed from the USA market (Thrupp, 1991; Ramírez, 1980).

In one of the few female reproductive studies published in Latin America, a case control study of birth defects was conducted in Colombia among children of women exposed to multiple pesticides (especially fungicides) used in cultivation of flowers for export. An increased risk was observed for birth marks, in particular hemangiomas, in children of mothers exposed to pesticides during pregnancy (Restrepo, 1990).

Considering the acute and chronic toxicity associated with these products; the increasing quantities that are utilized, their broad availability, and the precarious conditions under which they are used, the low priority that governments, in particular Ministries of Health have assigned to this type of concern. Also evident is the lack of research to analyze the prevailing conditions by specific regions, including the ones with the highest rates of pesticide usage.

Pesticides residues are also found in human mother's milk. A few studies conducted in Guatemala (De Campos, 1987), Mexico (Albert, 1981), Colombia (Vargas, 1990), Uruguay (Burger, 1987) and Costa Rica (Wesseling, 1990) indicated that levels of organochlorine compounds, particularly DDT and DDE were high, even exceeding some time the threshold values set for cow's milk. Although with lower frequencies DDD, BHCH, dieldrin, heptachlor epoxide and hexachlorobenzene were also found.

In general, throughout Latin America and based on the published studies in Brazil (CIENTEC, 1982; Ungaro, 1983, Carvalho, 1984) Chile (Ministerio de Salud, 1987) Costa Rica (Wesseling, 1990) and Mexico (Albert, 1990) the community is exposed to significant amounts of pesticides through the contamination of food with residues of these substances, which very often exceeded the tolerance limits recommended by FAO and WHO.

In addition to the bioaccumulation of pesticides in the food chains, there are other forms of contamination. Excessive use of pesticides in the agriculture and livestock sector, harvesting of the

Table 10
Reports on pesticide poisoning cases

Country	Time period	Poisining cases	Fatalities	Population studied	Reference
Guatemala	1986–87	2534	82 (3.2%)	— Health Care Centers of the Ministry of Health and Guatemalan Social Security — 69% of poisoned were farmers and 22% female — 700 cases were hospitalized 45 died (6.4%)	Samayoa et al., 1988
Honduras	1987	274	23 (8.4%)	— Hospital discharges — 30% female	Aguilar, 1988
El Salvador	1986–1987	9803	267 (2.7%)	— Emergency hospital discharges — 23% female	Lopez et al., 1988
Nicaragua	1986–1988	1913	86 (4.5%)	— Hospital discharges	Molina, 1990
Mexico	1978–1984	226	26 (11.5%)	— 20 pesticide poisoning accidents	Eco, 1984
Uruguay	1983 1987	378 739	? 10 (1.4%)	— Poison Control Center data — Poison Control Center data	Fogel, 1987
Brazil	1986–1989	13277	?	— Poison Control Center data	Pronitox/Sict/Fiocruz, 1991
Brazil	1982–1983	1500	?	— State of Parana. Cotton agricultural workers	Lopez et al., 1983
Colombia	1978–1989	5618	660 (11.7%)	— Department of Antioquia	Nieto, 1990
Peru	1985–1987	770 ??	?	— Huasa–Hasi: Potato agricultural workers Poisoning cases were recorded by workers	Nijmegen, 1989
Brazil	1986–1987	812	?	— 3488 agricultural workers in 7 states in Brazil — 192 (5.5%) were hospitalized — 232 incidence rate per 1000 workers	Garcia, 1987

products without the safe waiting period and contamination during storage, transport, and even before sale, are contributing factors to the high degree of contamination of food of plant or animal origin.

The rejection of food export products by the developed countries, generates not only economic problems, (Table 11) but also public health dilemmas for the general community, since on several occasions there have been reports that rejected food for export has been locally marketed (Henao, 1993).

6. Chemical safety

Chemical production has grown significantly in the region, and so are many of their uses. Consequently the storage, transport and trade of chemical products also increased, placing a significant number of people at risk of being exposed to chemical hazards, both workers in industry settings and public at large. In the Latin American region the improper handling of chemical substances has been recognized as a major threat to the human well-being (PAHO, 1987).

Table 11
Pesticides that caused the retention of foods coming from Latin American countries by the United States during 1990

Pesticide	MEX	GUA	GUY	COL	ECU	PER	CHI	ARG
Methamidophos	X	X		X				
Pirimiphos-methyl					X	X		
Monocrotophos	X	X	X					
Chlorothalonil	X	X						
EDB		X						
Fenitrothion								X
Parathion							X	
BHC	X							
Permethrin	X							
Acephate	X							
Daconil	X							
Dimethoate	X							
PCNB	X							
Guthion	X							
Omethoate	X							
Monitor	X							
DDT/DDE	X							

Source: Department of Health and Human Services, 1991.

While the industrialized countries have established an extensive body of law to protect the public from occupational, environmental and consumers hazards, many of the developing countries have not yet done so. The disparities in national regulations and other factors controlling hazardous products, processes and wastes have had some undesirable consequences. Pesticides, drugs, and consumer products banned or highly restricted in some countries have been exported to others (Castleman, 1987).

Toxic waste disposal pose another threat to Latin America's environment and human well-being. Only until recently some of the countries are trying to collect information on the type and amounts of residues produced. As an example, in Mexico, according to official figures in 1990 (SEDESOL, 1992), 450 000 tons of industrial wastes are generated daily. Of those 337 500 are residues of the mining activities; 81 000 are associated with the manufacturing of chemicals and 31 500 with agroindustrial activities. Of the above, 14 500 tons/day are considered hazardous. Of those, 5.784 tons/day are generated by 39 000 manufacturing plants located in Mexico City. For the safe handling of all the hazardous wastes generated by the country, only 18 recycling facilities, three incinerators and seven industrial waste dumps were operational. Thus, only a fraction of the hazardous wastes were properly handled.

Also, there is increasing evidence that over the last years there have been a number of attempts to bring large quantities of hazardous waste into the Region (GREENPEACE, 1993).

Over the last few years, with the aim of protecting the environment and the human well-being, there has been an international attempt to reduce the illegal export of potential harmful chemicals. A number of international treaties have been signed by a number of countries, industrialized and developing ones, in particular de Basel Convention (UNEP, 1991).

In particular, on pesticides, since the beginning of the 1980s, the constant voice of alarm of various groups concerned about the misuse of these chemicals has sounded. Within this context, the International Code of Conduct on the Distribution and Use of Pesticides was prepared by FAO, with the collaboration of WHO, UNEP and several NGO's, including the pesticide industry through the International Group of National Associations of Manufacturers of Agricultural

Chemicals (GIFAP). This Code consists of twelve articles by which, ethical standards of conduct are established for all the public and private entities that intervene or are involved in the distribution and utilization of pesticides. The Code was unanimously approved by FAO's Council in 1985 (FAO, 1986).

To support technically these international agreements a number of guidelines have been developed, addressed to Governments with the view of assisting them in the process of increasing chemical safety in all countries through the exchange of information on chemicals in international trade. Such is the case of the Prior Informed Consent (PIC) principle and the London Guidelines for the Exchange of Information on Chemicals in International Trade (UNEP, 1989). The PIC refers to the principle that in order to protect human health and the environment, international shipments of chemical that are banned or severely restricted in a given country should not be exported without the agreement, (where such agreement exists), or contrary to the decision, of the designated national authority of the importing country. This principle has been developed on the basis of common elements derived from relevant bilateral, regional and global instruments as well as existing national regulations.

As indicated by UNEP, although the guidelines have not been prepared specifically to address the situation of developing countries, they nevertheless provide a framework for the establishment of procedures for the effective use of information on chemicals in these countries. Implementation of the guidelines should thus help them to avoid serious and costly health and environmental problems due to ignorance about the risks associated with the use of chemicals, particularly those that have been banned or severely restricted in other States (UNEP, 1987).

The implementation of the PIC procedures has been entrusted to the International Registry of Potential Toxic Chemicals (IRPTC) to UNEP and to FAO. In order to familiarize the national designated authorities with the PIC procedures, a number of subregional workshops have been already held in Latin America (UNEP/UNITAR, 1993). Most of the national designated authorities belong to the agricultural sector. Thus, of 25 countries where the PIC is in progress, only eight countries are in the process of implementing additional import controls over other chemicals different then pesticides.

In 1984, and later in 1989, the Pan American Health Organization (PAHO, 1990) assessed the capacity of the Latin American and Caribbean countries to cope with some of the emerging environmental health issues, including those related with the national chemical safety programs. These assessments included information on normative, resource and organizational capabilities. About two thirds of the countries, scored as having 'few requirements', as well as 'lack of significant capabilities'. This applied both to countries undergoing moderate-to-rapid industrialization. No country was scored as 'adequate'. By comparing data from the 1984 and 1989 surveys, it appears that:

- changes have taken place within this relatively short span of years. Although most changes are of small degree, they indicate the feasibility of making further positive changes, especially in a period of heightened sensitivity to environmental issues.
- these changes in capability have been insufficient to raise any country into the 'most requirements met' category, although a few countries have advanced from the category of 'few requirements met' into the category of 'some requirements met'.

The 'right to know' and 'responsible care' issues are still vague in the Latin American region. Most of the time workers, employees and community are not properly informed about the potential health and environmental hazardous associated with the handling and/or disposal of the chemical substances produced or generated by industry. Important questions such as what are acceptable levels of risk to employees, customers, the public, or the environment are not addressed. Although labeling practices in the region have improved over the years, industry rarely provides additional information on the hazards of chemicals to customers, or on how to dispose safely of the products.

Since chemical plants are often located in or around metropolitan areas, large quantities of hazardous or toxic chemicals are transported through the cities, by road or rail tanker, increasing substantially the potential of chemical accidents in large urban communities. Yet very few countries have legal standards (or real enforcement whenever available) for the transport of such goods, nor have they appropriate or effective emergency plans for dealing with the inevitable accidents.

Some of the chemical accidents in the region listed in Table 12 may be associated with the implementation on the 'right to know' and 'responsible care' vague policies. With the intention of improving lcoal awareness and response processes to potential chemical accidents, with the support of UNEP and PAHO/ECO a number of workshops have been held in the APELL methodology (Awareness and Preparedness for Emergencies at Local Level), with the direct involvement of industry, local government, first responders, health services and concerned civil organizations (ECO, 1992).

The conference held in Rio de Janeiro, Brazil, 3–14 June 1992, recognized the need to ensure the environmentally sound management of toxic chemicals, within the principles of sustainable development and improvement of quality of life for mankind (UNCED, 1992). In order to achieve this objective, a significant strengthening of both national and international efforts was demanded, including a careful review of priorities and budgets the aim of internalizing progressively into the local economies the cost of the chemical safety and the protection of the environment. Even so, a consensus was reached that despite all local efforts to internalize the costs there was a need for making available fresh additional funds, as means to support the capacity building in the countries, in particular in the developing ones.

By the time of the Rio conference, most of the Latin American countries were optimistic and shared great expectations. Now a year and a half

Table 12
A historical overview examples of chemical accidents in Latin America

Chemical involved	Type of accident	Consequences		Place/country and year
		fatalities	injuries	
Phosgene		22	320	Poza Rica, Mexico 1950
C5 Hydrocarbons	Ignited/fire	1	2	Peurto Rico, 1976
Ammonia	Explosion	30	22–25	Cartagena, Columbia 1977
Ammonia	Release	2	102	Mexico 1977
Vinyl chloride	Release	—	90	Mexico 1977
Methane		52	—	Santa Cruz, Mexico 1978
Water treatment chem	Leakage	—	2000	San Juan, Puerto Rico 1981
? Ammonia	Derailment (evacuation of > 5000 people)	28	1000	Cerritos, Mexico 1981
Ammonia	Release	—	1000	Guadalajara, Mexico 1983
Hydrocarbons	Ignited/fire	100	NK	Cubatao, Brazil 1984
LPG	Explosion	650	5000	Mexico City, Mexico 1984
LPG	Explosion	NK	NK	Brazil 1988
Gas/methane	Gas release	NK	NK	Mexico 1988
Pesticides	Release/explosion	NK	300	Cordoba, Mexico 1981
Methane gas	Explosion	202	1500	Guadalajara, Mexico 1992
Benzene	Release	2	1	Buenos Aires, Argentina 1992
Chloride	Release	—	1	Pilar, Argentina 1992
Sulfur Dioxide	Release/explosion	4	80	Rio Segundo, Argentina 1992
Sulfuric Acid	Release	—	40–50	Lima, Peru 1992
Sulfuric Acid?	Release	6	15	McQueena Tacna, Peru 1993

later, there is less excitement. Most of the countries and agencies are moving very slowly towards the proclaimed UNCED objectives, and the additional international fresh funds needed to support the process have been downscaled. Nevertheless, it is important to mention that some international channels are open for negotiating limited funds in support of local, country driven projects, aimed at incorporating the sustainable development concept into the national development policies and strategies, including those related with chemical safety issues. One of the funding mechanisms is Capacity 21, under the leading role of the United National Development Program (UNDP, 1993).

Most of the countries in the region have general legislation on chemicals, especially on water quality and liquid effluents. Air standards are less frequent (Weitzenfeld, 1992). Most of the countries also have permissible limits for occupational exposures. Quite often all these regulations, environmental and occupational have been copied or adapted from foreign legislation, not necessarily applicable or relevant to local conditions. This issue is critical because it severely reduces the compliance with these regulations by all parties involved.

As the globalization of the economies and markets is becoming a reality, a number of countries in the region are negotiating among themselves, or with other external stronger economics, as it is the case of the North American Free Trade Agreement (NAFTA), possible partnerships in the so called 'free trade agreements'. The potential implications of rapidly increasing the trade of products, including the chemical ones, plus the potential for creating new open markets and production sites in countries with different chemical safety and environmental standards, with all its discrepancies is one of the critical issues under consideration by the countries involved.

It is important to stress the point that only a few countries have some regulations on hazardous wastes, and therefore no clear distinction is being made between a 'chemical product' and a 'chemical waste'. This has important practical and legal implications in the international trade of chemical substances.

Countries in the region, in general, have chemical and toxicological anlaysis laboratories, but these facilities are not always properly equipped or staffed with qualified personnel. The laboratories often function in isolation; not responding properly to institutional needs or programs. Quality assurance and quality controls are poorly implemented.

Although access to relevant and timely information has improved in some of the Latin American countries, quite often local authorities lack the expertise to make the best possible use of the data.

In some of the Latin American and Caribbean countries, environmental risks statements are required by law for large development projects, particularly those financed through international loans, and on a more selective basis for obtaining construction or amplification operational permits of some of the high risk industries. Even so, when these requirements are fulfilled, often these environmental risk statements are not subject to any real audit or follow up action.

Health risk assessments are not yet a part of the decision making process. When conducted, these studies are of an academical nature. Despite all the efforts undertaken by PAHO/ECO and other national and international agencies, the number of scientists and professionals acquainted with these methodologies is still very small (ECO, 1992).

Chemical safety cannot be seen in a vacuum. It is closely related with development—expressed as the need to bring not just economic growth but an improvement in the standard of living, particularly of those who are the poorest—Within this context, the principles of universality, solidarity, and equity are to be upheld, especially in societies that are characterized by poverty, indigence, and tremendous inequalities, where the active presence of the State is indispensable.

It is an irrefutable fact that the State in Latin America and the Caribbean has undergone a serious and dangerous process of deterioration. Growing centralization and bureaucratization, alienation and indifference to the needs and demands of the population, indiscriminate intervention in the ownership, management, and operation of systems and services, have contributed to the inefficiency of the State and, to a certain extent, to a loss of legitimacy. As a result, the State needed to be recognized and modernized and its role redefined at each of the levels at which it acts.

Such a redefinition is particularly essential in the area of responsibility for the systems that provide direct health care for the populations, and those who protect and control the environment, including the chemical safety.

7. Conclusions

1. In most of the countries of the region, the environmental health and chemical safety related problems are growing at a faster pace than the local capacity to deal with them.
2. The improper handling of chemicals accumulated over decades constitute a serious environmental problem that may potentially affect a vast number of individuals in the region. Although not enough is known about the real magnitude and nature of the problem, the emerging picture, though highly diverse, is unfavorable everywhere.
3. The primary impediments to the implementation of effective national chemical safety programs is resulting from a combination of lack of a political will and the limited allocation of resources of all kind.
4. In most of the countries there are no clear cut policies under which to harmonize the activities of the different sectors, leading to limited prevention and control programs.
5. Regulations, although present, are frequently irrelevant to local needs, and therefore compliance is limited.
6. On the whole, the population, including workers are ignorant of the substances to which they are exposed as well as the potential consequences of these exposures.
7. Chemical accidents are happening more frequently, particularly in urban areas and the preparedness and contingency plans to cope with them are in general inappropriate.
8. The UNCED has raised great expectations, even so, countries and international agencies are still slow in pursuing tangible results.
9. Some of the specific chemical safety problems often referred by countries as highly problematic are those associated with the improper use of pesticides, petrochemical production, urban air pollutants and exposure to heavy metals.
10. The practical implementation of risk assessment/management methodologies is still very poor, and are not yet part of the decision making process.

8. Recommendations

1. Increase public awareness and a proactive community participation by:
   (a) concentrating in a few relevant problems, instead of an across the board type of strategy;
   (b) improving risk communication; and
   (c) promoting the 'right to know' and 'responsible care' strategies.
2. Improve the capacity building at country and local level by:
   (a) concentrating prevention and remedial actions on top priority problems and issues;
   (b) promoting and implementing an effective coordination and joint work among different sectors and agencies;
   (c) training personnel on relevant chemical safety issues at all levels;
   (d) improving access, interpretation and use of relevant and timely technical information;
   (e) improving reference national laboratories, as the support unit to an extended network of laboratories and the local level;
   (f) implementing risk assessments to technically support the risk managements strategies and the decision making process; and
   (g) improving preventive strategies to reduce chemical accidents, including the formulation of preparedness and contingency plans.

3. Implementing risk reduction as well as clean up actions of contaminated sites, with special consideration on those ecosystems where human health and well-being might be compromised.
4. Internalizing into the local economies the costs of chemical safety and prevention programs.
5. Fighting inequity and poverty by implementing effective actions to promote sustainable development strategies.
6. Demanding and making a better use of the technical support provided by international agencies.

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The current state of pesticide management in Sub-Saharan Africa*

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1. Introduction

One of the most serious problems facing the countries of Sub-Saharan Africa is the need to increase and sustain food production for their fast growing populations. The last two decades have witnessed a rapid population growth and urbanization; the net effect has been that population growth has outstripped food production leading to serious food shortages. In 1975, Africa produced 85 percent of the food it consumed, but by the year 2000 it is predicted that it will only produce about 61 percent (Toure, 1989). While some of the food shortages can be attributed to normal vagaries of the weather, there are indications that in most of the African Countries, governments have not allocated sufficient resources, infrastructure and policies designed to support agriculture despite the importance attached to this sector in the overall strategy for food and socio-economic development.

Small-scale farmers make up over 80 percent of the rural population and are mainly responsible for the production of almost all the basic food crops—sorghum, maize, millet, beans, cassava and rice as well as the bulk of the cash crops. In addition, nearly all livestock production is in the hands of the small-scale farmers. The relatively few large scale farms to be found are engaged in commercial production of food and cash crops utilizing modern agricultural technologies. Small-scale farmers, being constrained by limited resources are constantly faced with crop losses due to pest estimated to be as high as 50 percent (Odhiambo, 1985). In addition, vector-borne livestock and human diseases constrain further the productivity of the farmers. With limited agricultural land available increased agricultural production by the small-scale farmer is only possible through adoption of improved agricultural technologies including the use of chemical pesticides for the control of pests of crops and vectors of human and livestock diseases.

2. Pesticide usage in the region

The African region has more than its share of the common pests: insects, plant diseases, weeds, rodents as well as most of the devastating plagues known to man — the African armyworn, locusts, grain-eating birds and droughts (Jansen, 1985). With the exception of droughts, pesticides are the obvious choice of control measures for these pests and plagues.

The bulk of pesticides which are used in Sub-Saharan Africa are imported from Europe, America and Japan. Most of these pesticides are offered as finished ready-to-use products, while only

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Table 1
Expenditures on agro-chemicals in Sub-Saharan Africa

Country	US $ Million
Sudan	52.7
Tanzania	31.8
Zimbabwe	29.4
Cameroon	24.2
Ivory Coast	19.4
Kenya	12.0

Source: Bryant 1984

a few products are locally formulated from imported technical grade concentrates. The marketing of these pesticides is also usually undertaken by agro-chemical companies who may be principals or subsidiaries of overseas manufacturers with a distribution network of wholesalers and retailer outlets.

Accurate statistics on pesticides trade and usage are scanty in many of the African countries, thus reflecting the level of understanding of the hazards of pesticide use. The leading African agro-chemicals consumers are those countries with a well developed cash crop sector, especially those where the bulk of production is on plantations, large farms or in centrally administered irrigation and other schemes. A study done in 1981 (Jensen, 1985) to evaluate agrochemical use in Sub-Saharan Africa, the following countries emerged as the large pesticide users (Table 1) on the following main crops (Table 2).

Pesticides usage is more applicable mainly to the large scale cash crop production rather than the smallholder food crop or subsistence farming. The smallholder sector especially in Eastern Africa, is however currently undergoing fast changes towards a cash crop economy especially in horticultural crops production resulting in greater use and demand for agrochemicals. This sector is expected to grow steadily over the next few years as large farms are sub-divided. In Kenya, the nse of pesticides has steadily increased from about Kshs. 400 million in 1985 to over Kshs. 700 million (US$30 million) in 1989. (Source: Pest Control Products Board, Kenya). This reflects a large expenditure of foreign exchange (Tables 3 and 4).

Table 2
Expenditure on agro-chemicals by crops in Sub-Saharan Africa

Crop	US $ Million	% of Total
Cotton	108.7	40
Coffee	40.8	15
Cocoa	35.7	13
Maize, Tobacco, Bananas	11.0	4
Sugar	10.0	3
Rice	7.0	2

Source: Bryant 1984

Of the major plagues that frequently hit the Africian Continent, locusts and grasshoppers represent the biggest threat not only in crop and vegetation damage, but in the cost of control operations as well as environmental pollution due to a wide coverage of insecticidal applications. In the recent locust plagues that Africa experienced from 1985 to 1989, it is estimated that control operations in 23 countries of the region was US$275 million of which about US$100 was for pesticides (Brader, 1989).

3. Health and environmental concerns

Pesticides are an essential component of modern agriculture, and their importance cannot be underestimated especially in Third World Countries where the majority of the populations are undernourished and the demand for food production will grow due to increased populations. Pesticides are also extensively used for public health particularly in the developing countries where human disease vectors abound.

World pesticide sales have nearly doubled since the mid- 1970s to US$18 billion a year, and much of this growth has taken place in the Third World (Rama, 1989). The World Health Organization (WHO) estimates that as many as one million people suffer acute poisoning from pesticides every year, among them many farmers in the Third World, leading to nearly 20000 deaths a year. (Grossman, 1993).

The impact of pesticides on human health and

Table 3
Value of importation of different pesticides into Kenya, 1986–1990 in million Kshs. (Kenya Shillings)

Year	Acaricide/ Insecticides	Herbicides	Fungicides	Others	Total
1986	134.9	121.3	281.3	42.6	580.1
1987	182.3	173.4	357.3	28.1	741.1
1988	158.9	145.2	329.9	28.5	662.5
1989	208.1	154.2	328.2	30.7	721.2
1990	260.3	159.4	169.2	55.6	644.5

the environment shows two different scenarios in the developed and developing countries. In the former, environmental contamination, pesticides residues and the protection of users are the main pesticides issues; but in the developing countries, the main concern is the misuse of pesticide resulting in acute poisoning arising from occupational exposure. In Africa, health experts relate instances of acute poisoning of farm workers to exposure to pesticide due to lack of protective clothing because of the hot climatic conditions, use of contaminated water and food through use of empty pesticide containers, and the general lack of knowledge on how to use pesticides.

Over the years, the extent of acute pesticide poisoning has been observed and the trend shows that it is a problem of immense magnitude especially in the developing countries. In Kenya, many farmers and farm workers in the coffee growing areas risk slow and painful death due to application of various pesticides. Kenyan coffee farmers must mix several pesticides to effectively fight pests and diseases, and spraying of coffee trees has become an all year round operation. A recent report in Kenya (Daily Nation, September 9, 1993) quotes the Ministry of Health estimate of 700 deaths a year due to pesticide related poisoning. In Zimbabwe, cotton farmers apply pesticides 8–12 times in a period of six months to control bollworms, and six times against spider mites (Grossman, 1993). Surveys conducted in a population of five villages in Zimbabwe have demonstrated high residue levels of DDT far in excess of the 0.007 ppm set by WHO (Mpofu, 1986). Case studies of organophosphate poisoning in rural and urban population in Zimbabwe show high poisoning rate, both accidental and attempted suicide (Nhachi, 1988).

Table 4
Importation of Pesticides 1986–1990 in % Total value

Year	Insecticides/ Acaricide	Herbicides	Fungicides	Others
1986	23.2	20.9	48.6	7.3
1987	24.6	23.4	48.2	3.8
1988	24.0	21.9	49.8	4.3
1989	28.9	21.4	45.5	4.3
1990	40.4	24.7	26.3	8.6

Massive pesticide spraying especially in a crisis atmosphere is costly in monetary terms, and in the long term is a potential health hazard and leads to serious environmental damage. Aerial applications of fenitrohion insecticide have been reported to be phytotoxic to sorghum thereby reducing yields (Schaeffers, 1986) and at the recommended dosage for locust control cause immediate mortality to birds (Steedman, 1988). The widespread use of pesticide in Sub-Saharan African Countries has resulted in serious environmental pollution. It has been shown that in some national parks in the Sudan, deaths of wildlife has been attributed to contamination by pesticide containers used during the locust campaigns.

In Zimbabwe (Rama, 1989), evidence exists to suggest that in the effort to control tsetse fly and mosquito, wildlife contamination with DDT has affected such species of animals as crocodile, birds, bats and fish (Mahiessen, 1985; Phelps et al. 1989), and in Kenya, long-term routine applications of copper fungicides in coffee have resulted in high concentrations of copper in plants, litter and soils (Dickinson and Lepp, 1983, 1984). Perhaps the biggest threat to environmental pollution is the inadequate pesticide storage facilities in most African countries, especially the old stocks remaining for future use but are now left leaking.

4. Pesticide regulation and legislation

In view of the complexity of the pesticide industry and trade, it is important for the developing countries to enact laws to regulate the importation, distribution and use of such pesticides so as to ensure that they pose little hazard to man and the environment. Governments must play a leading role in legislation on pesticide use and ensure that every pesticide product is registered for use in accordance with the existing laws. A Food and Agriculture Organization (FAO) survey (Rama, 1989) indicate that very toxic pesticides were widely available in at least 85 developing countries, and that eighty of these countries had no adequate system to approve, register or monitor the material. In addition, these countries lack information about pesticide hazards and have no trained manpower to evaluate them.

In Sub-Saharan Africa, at present, very few countries operate an efficient pesticide regulatory service. In many instances the laws to regulate pesticide use hardly exist, and where such laws have been enacted, there are numerous obstacles to their efficient operations. The major obstacles in the enforcement of the regulations include: lack of suitable and comprehensive pesticide legislation, competent and well trained manpower, and inadequate resources for operations.

A major stumbling block to the efficient operations of any pesticide legislation is the current practice of some donor nations providing commodity aid in the form of pesticides, some of which are either out-dated or are banned in the countries of origin. In many instances such donations result in excessive supply of unwanted pesticides which eventually remain unused and pose problems in disposal and when dumped lead to environmental pollution. It is recommended that all nations, both developed and developing, strictly adhere to the recently introduced International Code of Conduct on the Distribution and Use of Pesticides which was unanimously adopted by all FAO Member countries in 1985 as an important instrument for the better management of pesticides. Pesticides and other hazardous chemical wastes are also being dumped in some African countries at a fee to the consenting government.

5. Need for alternative pest control strategies

During the period 1940–60 in Europe and America, spectacular successes were achieved in pest control through the use of persistent pesticide to the detriment of other pest control strategies. These pesticides, including DDT, were reasonably cheap and were therefore extensively used whenever pest control was thought to be needed. Soon, however, pesticide-resistant pests developed and became widespread leading to even more damaging secondary pests. In addition, problems associated with pesticide residues and environmental pollution stimulated a renewed interest in alternative pest control methods.

It has now become evident that a more effective approach to pest control is the adoption of the integrated pest management (IPM) concept. IPM is a strategy which integrates appropriate control measures that will reduce or maintain pest populations below the economic threshold. These methods include cultural practices resistant varieties, biological control, physical methods and selective use of appropriate pesticides. Since pesticides are an important component of an IPM strategy, the impetus of any pest management programme should include the judicious use of suitable pesticides that will selectively control the pest but not harm beneficial insects; and at the same time be safe to the user while being environmentally friendly. Lately, there has occurred a shift from the use of chemical pesticides to biological pesticides or biocides which are considered more appropriate.

As the majority of the African farmers are resource poor, their overriding concern is to minimize their losses. Pest control methods that involve the use of expensive pesticides are generally considered inappropriate for these farmers who lack the resources and the skills required in their applications. It would therefore be necessary to develop and introduce IPM strategies that are technically appropriate, economical and environmentally sound for adoption by these farmers. The International Centre of Insect Physiology and Ecology (I.C.P.E.) is one of the institutions currently involved in the development of appropriate low input pest control strategies which require little or no pesticide use.

6. Conclusion

A large and varied group of pests attack crops of the African farmer, and carry various disease-causing vectors to him and his livestock. The control of these agricultural pests and disease vectors has relied mostly on chemical pesticides. However, as a consequence of pesticide poisoning to humans and pollution of the environment reported from many parts of Africa, there is need for cautious use of the pesticide in order to avoid further injury and environmental pollution. The need for using pesticides within the framework of integrated pest management should be encouraged. As pesticide usage increases, there is need to carry out a thorough training of farmers and other users in the proper use and handling of such products.

Finally, the need for comprehensive regulatory controls of pesticides in the African countries should be strengthened. The current status of pest management indicate that major constraints exist within the countries, in the availability of skilled manpower, resources and facilities to generate information on pest management. International organizations such as the FAO and GIFAP as well as donors should be encouraged to play an even bigger role in the support to pest management in general and in the regulation of pesticides use in particular.

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Part II

Ecotoxicology in Developing Countries

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The international mussel watch: a global assessment of environmental levels of chemical contaminants*

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1. Introduction

As a consequence of increasing population and intensifying industrial development on a global scale, it is inevitable that the world ocean will continue to receive societal waste. The goal of the International Mussel Watch Project is to quantify the sources and rates of input of these wastes so that the current status of environmental health can be assessed and that trends may be determined.

The International Oceanographic Commission (IOC), in collaboration with the United Nations Environment Program (UNEP) and the US National Oceanographic and Atmospheric Administration (NOAA) have supported the creation of the International Mussel Watch Project and initiated an initial monitoring program in Central and South America in 1991–92. The program has been directed by the International Mussel Watch Committee and administered by the Project Secretariat office based at the Coastal Research Center of the Woods Hole Oceanographic Institution.

The genesis of the International Mussel Watch

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Project can easily be traced to the 1975 Marine Pollution Bulletin editorial where Professor Edward Goldberg of Scripps Institution of Oceanography called for a global marine monitoring program to serve as a 'spring board for action'. In his editorial, Dr. Goldberg outlined a global scale monitoring program based on the sentinel organism concept that is capable of detecting trends in concentrations of several important marine contaminants. Since the mid-1970s, scientists of several countries have been using bivalve filter-feeding mollusks to monitor for selected chemical contaminants in coastal marine waters. Such contamination of coastal waters might result in chemical changes that are deleterious, over the long term, to both the integrity of the coastal environment and to human health. Because of their sedentary habits and their ability to bioconcentrate the pollutants of interest, mussels and other bivalve species appear to be appropriate sentinel organisms. This approach to marine monitoring has been successfully applied in several national and regional programs in Europe, Taiwan, Canada and the United States and an extensive scientific literature has been generated from this work. The mussel watch approach has been adopted as one of several coastal environmental quality monitoring strategies by UN programs and the International Mussel Watch Project is working to build on this cumulative experience.

Particularly important among the monitoring programs that were established during the 1970s were those of the Organization of Economic Cooperation and Development and of International Council for the Exploration of the Sea. The United Nations Environment Program has also created its Regional Seas Program which has placed a major emphasis on the development of host country capabilities for measuring the levels of pollutants in coastal and marine environments. The Intergovernmental Oceanographic Commission of the UNESCO sponsored the formation of a Task Team on Marine Pollution Research and Monitoring in the West Pacific region. National governments in many countries have initiated their own programs to provide for longer-term protection of coastal zones from the deleterious effects of chemical contamination. In the United States, the 'Mussel Watch' program was begun by the US EPA in the mid-1970s and involved academic scientists from Scripps Institute of Oceanography, Moss Landing Marine Laboratory, University of California Bodega Bay Laboratory, University of Texas and Woods Hole Oceanographic Institution. This program used mussels and oysters as indicators of the local levels of several classes of pollutants, principally synthetic organics, fossil fuel compounds and their derivatives, several trace elements, and the transuranic radioactive elements produced in the nuclear fuel cycle and by fallout from nuclear weapons tests. Mussel Watch became an operational contaminant monitoring program in the United States in 1986 and is directed by NOAA as a part of the Status and Trends Program.

In December, 1978, the members of the US Mussel Watch Program joined with scientists of other countries to hold an international workshop in Barcelona, Spain. This workshop assessed the methodologies employed for the detection and measurement of pollutants in coastal zones through the use of indicator organisms. The participants at the Barcelona workshop decided that continuing international collaboration and communication would be worthwhile, and elected a committee charged with the task of planning for the initiation of a global monitoring program. Communication at the international level was continued at a second meeting held in Honolulu, Hawaii in November of 1983. Participants at the Hawaii meeting examined the conceptual approaches used by the Mussel Watch programs and assessed the potential for expansion of this approach to a global scale. The International Mussel Watch Project had its genesis at the Hawaii meeting. Planning momentum was maintained by the International Mussel Watch Committee under the leadership of Prof. Edward Goldberg who received substantial support from a planning office base at the University of Maryland and directed by Dr. Rodger Dawson. The Project has been initially implemented in the Central-South America region and due to resource limitations, has focused exclusively on organochlorine contaminants. Financial support for the Project is coordinated by the Intergovernmental Oceanographic Commission and includes financial contributions from IOC-UNESCO, UNEP, US-NOAA, the Woods Hole Oceanographic Institution and in-kind contributions from host countries.

In May, 1991 members of the International Mussel Watch Committee and representatives of three regional monitoring programs (i.e. CASO, CPPS, CEPPOL) met in Costa Rica to organize the Initial Implementation Phase of International Mussel Watch. In this initial phase, samples were collected throughout the region by the IMW Field Scientist, with the assistance of host country scientists. These host country scientists form the nucleus of an international marine monitoring network through which the results of the project will be disseminated. The International Mussel Watch Project will complement regional and national monitoring programs where they are established.

Field sampling, host-country scientist analyses and data interpretation has been coordinated by the Woods Hole-based Project Secretariat, under the guidance of the IMW. Executive Officer. All sampling and sample logistics have been carried out by the IMW Field Scientific Officer, who was supervised by the IAEA Marine Environmental Laboratory. The host-country scientists will work directly with the Field Scientist. Samples were distributed by the Project Secretariat and analyzed at two contract laboratories, which also participate in data review and interpretation. Preliminary data interpretation has been undertaken by the Project Secretariat but the active participation of the central lab analysts and the host-country scientists is essential. All data will be made available to participating host-country scientists. The International Mussel Watch Committee, in concert with the Project Secretariat and the Field Scientific Officer, will provide final data interpretation, taking into account comments from host-country scientists and the analytical laboratories.

For those scientists with analytical expertise, tissue samples have been made available for in-country analysis and interlaboratory comparison. Data from this work is not included in the draft final report but will be included in the final report. Host-country scientists have also been asked to determine production and use data from available sources in their respective countries. This information will be summarized in the final report as well.

This initial implementation phase will:

- generate high quality data on chlorinated pesticide and PCB concentrations in the Central-South America coastal region
- serve as a 'field-test' of a large-scale international marine monitoring program for chemical contaminants
- create a western hemisphere international network of coastal environmental scientists
- provide a forum for training and for discussion of analytical results
- create the institutional structure for a global scale coastal monitoring program

The Initial Implementation Phase provides direct experience for introducing this program to other global regions. Continuation (and expansion) will be considered when the program is assessed at the conclusion of this phase. Host-countries and the entire UN family will benefit from the scientific results generated during this initial phase and will have an opportunity to expand local monitoring activities with technical support from the project as well as to integrate these activities into regional and global-scale programs.

2. Discussion of results and preliminary interpretation of data

2.1. Quality assurance and quality control

The initial plan for the Implementation Phase included a Quality Control and Quality Assurance Check (QA/QC) prior to entering the phase of extensive analyses of the field samples. The plan had to be revised to accommodate funding constraints. However, a good series of QA/QC analyses have been carried out and the final data are still being received.

Trace analyses for organic contaminants in this program can be difficult because of the low concentrations of many of the target analytes and the several different types of species or different physiologic states of the same species collected in the wide geographic range of this program.

There were two principle components to the QA/QC program in the Initial Implementation Phase. The first component was the routine QA/QC internal to each Analytical Center (IAEA Marine Environmental Laboratory [MEL], and Texas A&M University Geochemical and Environmental Research Group [GERG]). The laboratories will report on these procedures in their final reports. The second component was coordinated by the Project Secretariat and consisted of two sub-components: (1) The analysis of two check samples and one Working Reference Material (WRM); and (2) the analysis of field replicate samples for several stations. The preliminary results of the QA/QC component coordinated by the Project Secretariat are presented in this section of the report.

The QA/QC samples used were as follows:

(A) **Deer Island.** A freeze dried (lyophilized) sample of *Mytilus edulis* tissue from a large batch of samples collected several years ago from a coastal site near the Deer Island sewage treatment plant, Boston, Massachusetts USA, homogenized, and kept frozen until distribution to the Analytical Centers. Each laboratory received three sub-samples chosen by random number routine.

(B) **Staten Island.** A batch of mussels collected from Staten Island in the harbor of New York, New York, USA, shucked to obtain tissues, homogenizcd, stores frozen (wet), and distributed to the Analytical Laboratories. Each laboratory received one sub-sam-

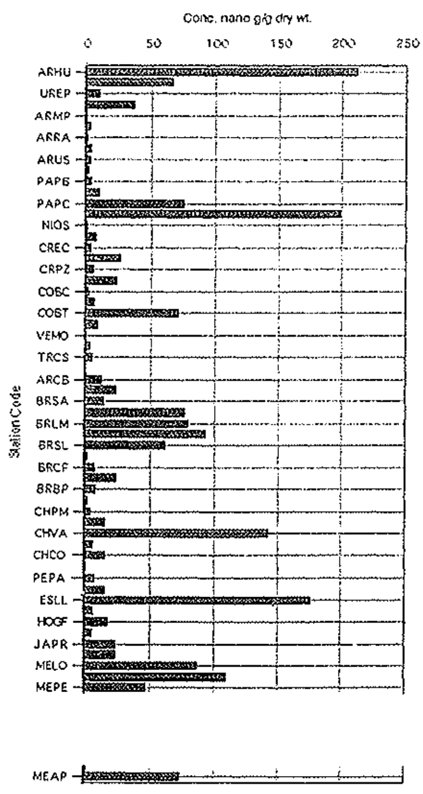

Fig. 1. Total DDT group concentration in South and Central America.

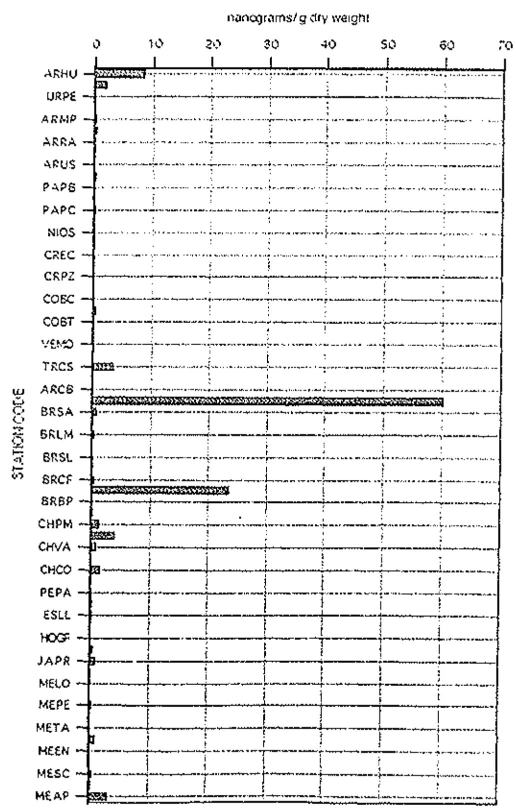

Fig. 2. b HCH concentrations in South and Central America.

ple for triplicate analysis. These samples were prepared by Dr. Roger Dawson and colleagues of the Center of Estuarine and Environmental Studies, University of Maryland, USA for the GESRM Program of IOC.

(C) NOAA-NIST. Samples prepared for the US National Oceanic and Atmospheric Administrations Status and Trends Program by the US National Institute of Standards and Technology as a working reference sample (soon to be a Standard Reference Material) were distributed to the Analytical Laboratories by US NOAA at the request of the Project Secretariat. Each laboratory received several samples.

(D) Splits of samples from 11 field stations were analyzed by both Analytical Laboratories.

All data resulting from the analyses of these QA/QC samples were sent to the Project Secretariat and were not available to the other Analytical Laboratory until this report was distributed for the São Paulo meeting.

In addition to the Analytical Laboratory QA/QC program, participating national laboratories have received splits of field samples, Standard Reference Materials and a working reference freeze-dried tissue sample for analysis. The Project Secretariat has organized a small interlaboratory comparison exercise with these materials and will report this data in the Final Report if available.

2.2. Summary of QA/QC results

Some of the analytes, for example hexachlorobenzene (HCB); *o,p*-DDE; and *o,p*-DDT were present in concentrations at, or approach-

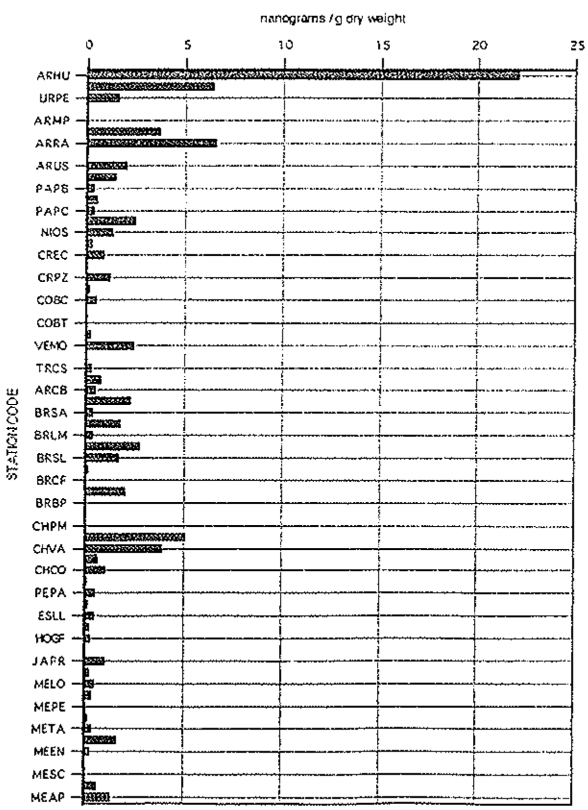

Fig. 3. Lindane concentrations in South and Central America.

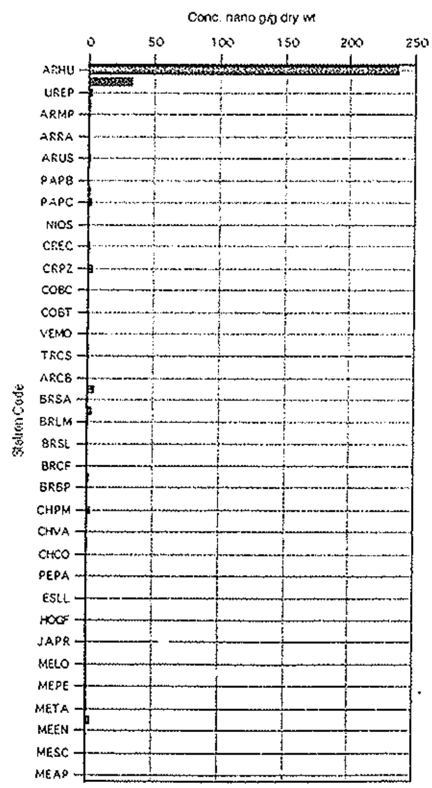

Fig. 4. Gamma chlordane concentration in South and Central America.

ing, the detection limits for GERG. The data for dieldrin; *o,p*-DDD were not within an expected range of agreement. Otherwise, the agreement between the two laboratories for the Deer Island samples seemed to be within state-of-the-art limits for these types of challenging analyses.

The NOAA-NIST sample results indicate significant differences between the two Analytical Laboratories for trans nonachlor and dieldrin, and several of the DDT family compounds. Some aspects of the results for the PCB congeners also require further discussion to ascertain why there are such large interlaboratory differences for reported concentrations of CB 28, and CB 52. Perhaps this is related to the fact that these compounds are more volatile and might be lost during sample concentration prior to gas chromatographic analysis. Data for other CBs agree within a factor of two which is acceptable for the survey purposes of this stage of the IMW Program.

Several factors could be the cause of interlaboratory differences and a detailed discussion of each analytical method is needed to reduce these differences. There is excellent agreement for the dry weight determination which eliminates this factor as a cause of any significant discrepancies between laboratories for the pesticide and CB analytes. For those samples where analyte concentrations are significantly above the detection limits, the agreement between laboratories is usually very good, and generally within a factor of two or better. This is as expected. Samples of particular concern and requiring discussion are samples 1153, 1154 for *p,p*-DDE, or *o,p*-DDD and *o,o*-DDT; samples 1175, 1176 for *o,p*-DDD, *p,p*-DDD and *p,p*-DDT; samples 1279, 1280 *o,p*-DDD. Also, there is a need to discuss the data for gamma chlordane for several samples, specifically: 1059, 1060; 1153, 1154; 1193, 1194.

Overall, given the low concentrations of the analytes in several of the field-collected samples, the results of the QA/QC are encouraging. Of course, the natural ambition is to attempt to improve agreement between laboratories and this will be a topic for all National Laboratories participating in the IMW Program. The issue of interlaboratory QA/QC is an essential one for any regional program involving multiple analysts and cannot be overestimated.

3. Results and discussion of IMW data

Many of the analytes are present at, or below detection limits, in a large portion of the samples analyzed thus far in this Initial Implementation Phase. This is good news in an environmental quality sense, but we must keep in mind that the program is designed to make a broad geographical assessment only. Local 'hot spots' of pollution may not be detected. This initial survey should be followed by a more detailed assessment of specific embayments by participating national scientists.

One factor to keep in mind when reviewing this set of data is the large number of species represented. There will be a discussion of the multiple species issue at the São Paulo meeting. The IMW Project has collected more species throughout the region than is the case, for example, in the US NOAA Status and Trends Program (primarily

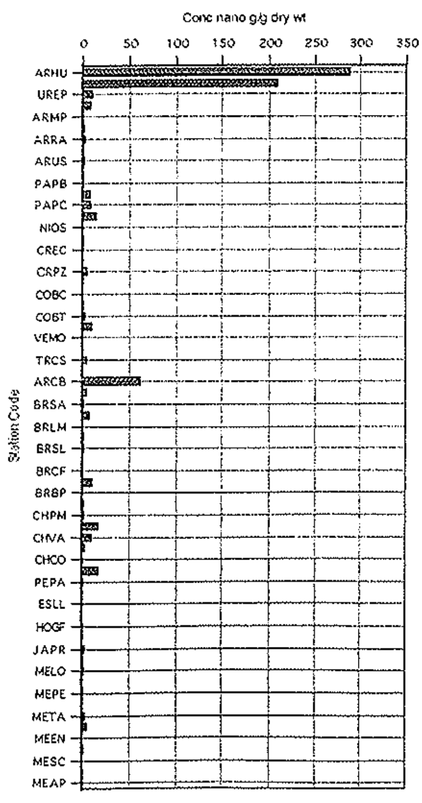

Fig. 5. CB 138 concentration in South and Central America.

Fig. 6.

three species) or for other national programs for which there are one of three species. This may be inevitable for any monitoring program which covers a broad tropical-subtropical-temperate area. There are few coastal areas in the IMW South and Central America and Caribbean set of data where the same species was present in more than four to five stations in sequence. This creates the problem of understanding how species differences can influence comparisons of data between and among stations. Fortunately, the sampling strategy made provisions for collection of multiple species at several stations and we have sufficient data from this and other programs to begin to address this issue in São Paulo. The results of this discussion will be summarized in the Final Report.

Total DDT concentrations (sum of DDD, DDE, and DDT) for the samples analyzed to date (Fig. 1) indicate that concentrations are within the range found for mussels and oysters reported for the US National Status and Trends Program for the US coast during the years 1988–1990. The elevated concentrations at the seven stations with concentrations > 100 nanograms/g dry weight need to be assessed with respect to potential sources for inputs of DDT group compounds at those locations (Station Codes ARHU, NIIA, CHVA, ESLL, MELV, MEPM, META). This is an example of how a broad regional survey can lead to a more detailed future assessment of specific areas or specific contaminants.

Beta HCH is generally present in concentrations at, or below, detection limits with the exception of about 10 to 12 stations (Fig. 2). In particular, stations ARHU, ARAT, TRCS, BRSB, BRGB, CHPA, and MEAP deserve our particular attention for elevated concentrations in comparison to the other stations. Similarly, lindane concentrations (Fig. 3) appear to be elevated in stations ARHU, ARAT, ARRA, and CHPA. Gamma chlordane is present in elevated concentrations at only two stations, ARHU, and ARAT (Fig. 4).

Concentrations of PCBs are elevated in only two of the IMW stations, ARHU and ARAT as indicated by the plot of a representative chlorobiphenyl congener – CB 138 (Fig. 5). A comparison of the DDT distribution (Fig. 1) with the CB 138 concentrations (Fig. 5) indicates that PCBs are found in detectable concentrations less often in the IMW sampling in comparison to similar sets of data for the US coast in the NOAA Status and Trends Program. This possibly reflects a lower overall use of PCBs in the Central and South American regions but this hypothesis can be investigated in greater detail if requested. Production and Use data is available for review.

Overall, the good news is that there are no samples in the present set of data for which contaminant concentrations in the bivalve tissues approach or exceed the various national and international recommended action limits for these individual chemicals in seafood for human consumption. However, the various stations identified above as having elevated concentrations of specific chemicals do require some discussion about reasons for the elevated concentrations and perhaps some follow-up work at the regional and local level.

Much more interpretive work and comparative work with other data sets are needed prior to completion of a final report. However, the issues raised in this draft will initiate the discussions in São Paulo and provide an opportunity for all IMW participants to comment on the results to date.

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Contamination by persistent chemicals in food chain and human health

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Abstract

Persistent polluting chemicals are, by definition, substances which have long half-lives or disappearance rates in the environment, mainly due to their chemical stability, but often also caused by unfavourable conditions for environmental/biological mineralisation processes to take place. DDT, lindane, dieldrin, HCB, and PCB are well known examples of chemicals which can be found in various parts/compartments of the environment, and in living organisms including man.

The early findings in 1950s and 1960s of the persistent chlorinated pesticides in birds and fish populations in North America and Europe were obviously the results of deliberate and extensive use of these chemicals in agriculture and industry. The findings were confirmed and substantiated by national and international monitoring programmes, and it became clear that many field observations of threatened species convincingly could be correlated to the increasing levels of contamination.

Still more man-made chemicals have been drawn into the field of interests as widespread pollutants, and the geographical areas in which contamination takes place have become ever larger. The threat to groundwater ressources from infiltration of pesticides into soils, and the alarming reports on contamination of mothers milk are to-day well-known examples. They are described from many parts of the world. Similarly, the food chain biomagnification of several pesticides and of PCB which were already described from Great Lakes region in North America in the 1960s and from the Baltic Sea area in Europe in the 1970s has since then been followed by identical observations in the Danube basin in Eastern Europe and in Indian provinces during the 1980s.

Scientifically, we are to-day able to describe many of the fundamental processes, including environmental transport and transformation, as well as exposure, uptake and metabolic patterns for many of the persistent man-made chemicals.

Accordingly, we are reasonably well informed of the most obvious cause-effect chains which govern the process of increasing pollution. We understand and can often for most of the chemicals predict the hazards of the enviroument as well as to man. In spite of this experience, and contrary to belief created by our scientific knowledge, the problem of contamination is still increasing. This includes the frequency of reported accidents and damages from all over the world. It is obvious, therefore, that the question becomes a matter of concern for the global society and a call for world-wide attention through internatioual bodies develops iuto a matter of urgency.

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1. Introduction

It is presently about 30 years ago the Presidential report "Use of Pesticides" [25] was published from the White House, U.S.A in response to the massive interest created by Rachel Carson's "Silent Spring" [6] and thereby directly urged the scientific community all over the world to focus on chemical pollution of man and environment.

More specifically this report pointed to the increasing presence in our environment of what was then called **persistent chemicals** as the result of agricultural, industrial or other human activities. Without any precise definition, this term was meant to cover any man-made (or natural) chemicals that could remain - *or persist* - chemically unchanged for long time in soil, water, air, or in living organisms. The reason was that they were only slowly (or not at all) mineralised, metabolised, or otherwise eliminated by physical-chemical, microbiological or biological processes. In practise, however, the attention at that time was mostly given to a few chemically stable, chlorinated pesticides - the so-called *dirty dozen.*

The discussion was clearly focusing on the chemical entities *per se*, and on their intrinsic stability, but obviously the term could not be handled operationally unless a number of conditioning factors were included, *e.g.* the location or the species in which the chemicals persist, or the surrounding, environmental factors and conditions which may influence and ultimately determine the degree of stability of the chemcial concerned.

The immidiate background for the presidential as well as for the public concern was some examples of DDT pollution, examples which are now historical, but at that time had just been uncovered. This was, for instance, the case:

- in the nature reserve at Clear Lake, California in which a grebe population was practically eliminated due to accumulation of DDT in the eggs of the nesting birds [10],
- in a number of fish and fish eating birds near the shores of Lake Michigan in Green Bay, Wisconsin, and - not to be forgotten -

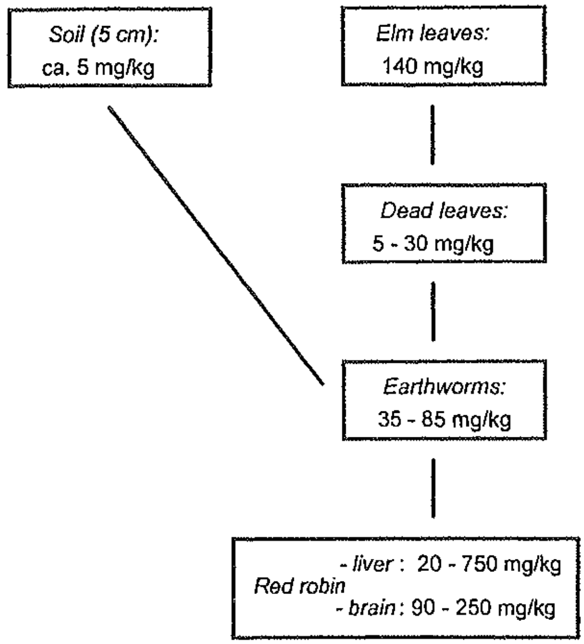


Fig. 1. Silent Spring in Urbana, Ill., U.S.A. (1958). DDT-treatment towards elm disease, 1 kg a.i. per tree. (Found: ca. 1 kg/ha in soil; 140 mg/kg on leaves)

- in the red robin populations living in residential areas of Urbana, Illinois [6].

The last of these three examples formed the background for the symbolic title of "SILENT SPRING". By this was referred to the observations of a decreasing number of songbird populations in the surburban surroundings of American cities, allegedly due to DDT-sprayings, and substantiated by the findings of DDT in a simple food chain of leaves/soil → earthworms → birds.

2. Persistent chemicals in the environment: some case studies

In the other examples, similar phenomena were observed concerning accumulation of DDT. They were confirmed as the result of deliberate uses of DDT, followed by a transfer with food and subsequent increasing concentrations of the chemical in the eating organisms. The process of accumulation was followed by analyses of the predator-prey chains in the ecological systems, and a tendency

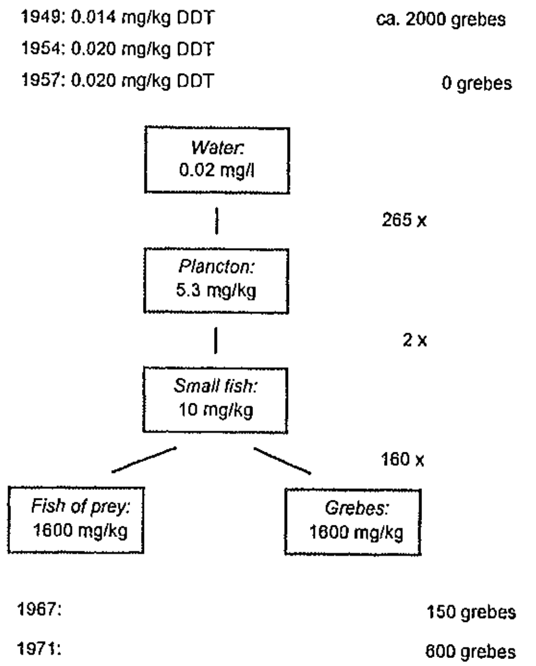


Fig. 2. The mosquito eradication programme at Clear Lake, California (1949–57).

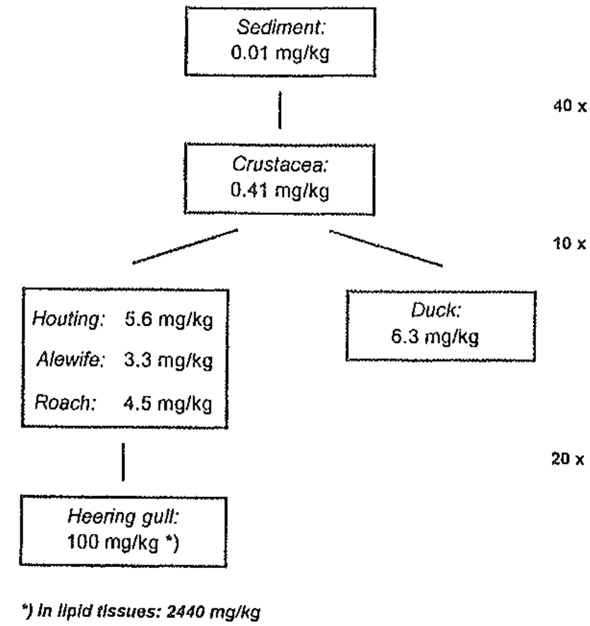


Fig. 3. DDT-food chain in Green Bay, Wisconsin resulting from agricultural uses of: 30 tons a.i. per year in Door County (1949–64).

to somewhat higher rates of accumulation in the aquatic systems may be noted.

It was a well-known result of these observations, and — of course — of the publicity given to them via the world media, that scientists all over began to analyse and describe the distribution and the fate of DDT, but also of several other, similarly persistent plant protection chemicals, such as aldrin, dieldrin, heptachlor, lindane, and chlordane.

A few further studies are worth-while mentioning as examples of these investigations concering environmental distribution of persistent chemicals resulting from food chain transfers. They may serve as illustrations of the wide-spread geographical distributions and of the fast timely development which we have experienced since the early observations in the 1950s.

1) The *Brookhaven National Laboratory study* [27] of the complex food web network in a Long Island estuary was a forefront study from the 1960s. This excellent field study has served as a reference and a model study for a number of following analytical programmes all over the world. In such studies, the persistent chemicals were traced at the lowest levels in water and in planktonic organisms, while fish and carnivorous birds, *e.g.* sea gulls, herons, cormorants etc. could contain concentrations which were higher by a factor of 1000 or more over the organisms at the base of the network.

2) A series of *Baltic Sea studies of persistent chemicals in fish*, especially heering, cod and salmon, and in *fish-eating predators*, such as fish eagles, sea birds, otters and seals were developed in Scandinavian countries, especially Sweden in the late 1960s and in the 1970s, and often in close exchange with montoring programmes in the U.S.A. and Canada, and also in some European countries [9, 16, 19]. Without going into details it will suffice to note, that some of these studies are still being followed-up, and generally they have confirmed the early American observations. But they also extended the scope of the studies as well as the understanding of fundamental processes.

(a)

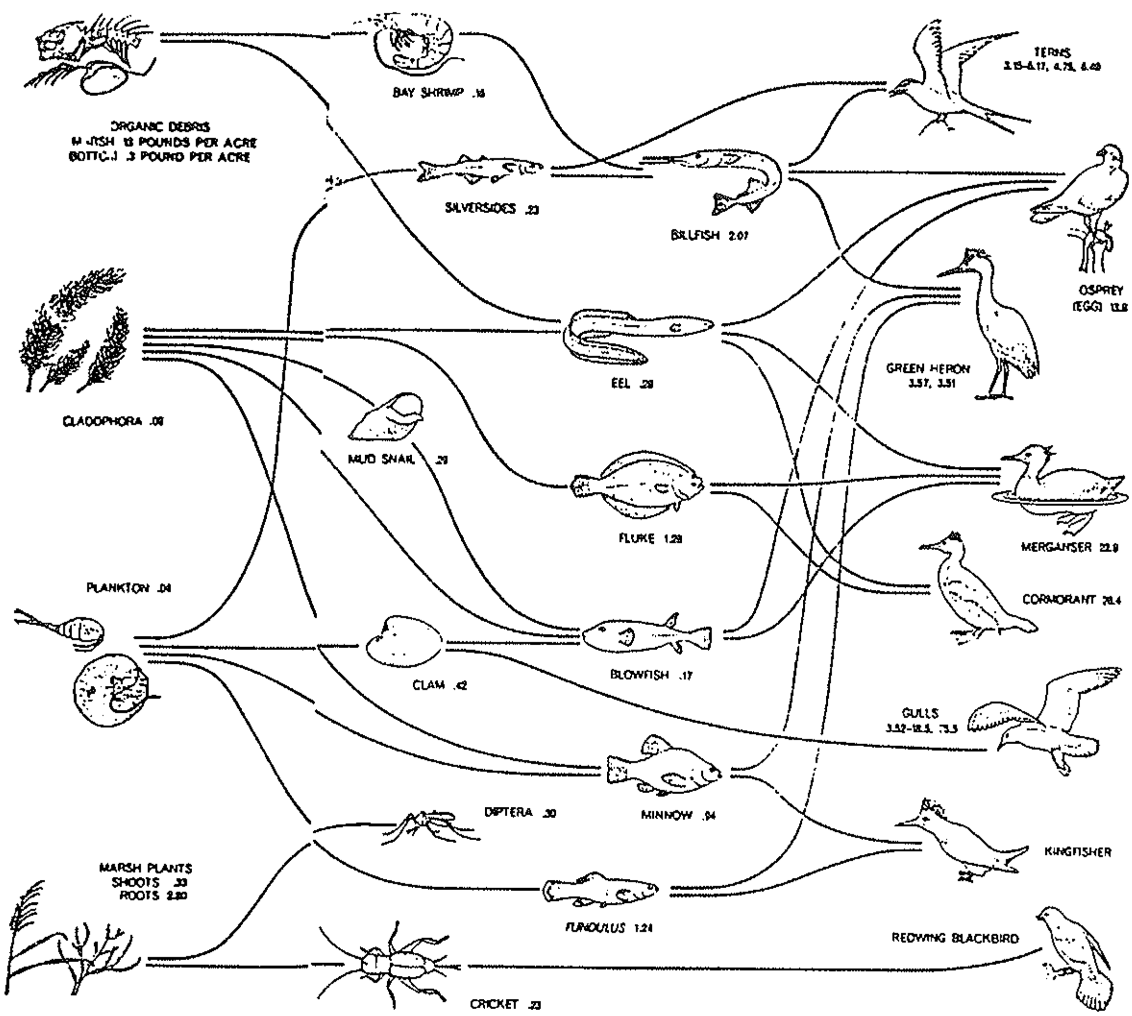

BAY SHRIMP .16
ORGANIC DEBRIS
MARSH 13 POUNDS PER ACRE
BOTTOM .3 POUND PER ACRE
SILVERSIDES .23
BILLFISH 2.07
TERNS
3.15–6.17, 4.75, 6.40
OSPREY
(EGG) 13.8
CLADOPHORA .08
EEL .28
GREEN HERON
3.57, 3.51
MUD SNAIL .26
FLUKE 1.28
MERGANSER 22.8
PLANKTON .04
CORMORANT 26.4
CLAM .42
BLOWFISH .17
GULLS
3.52–18.5, 75.5
DIPTERA .30
MINNOW .94
MARSH PLANTS
SHOOTS .33
ROOTS 2.80
KINGFISHER
FUNDULUS 1.24
REDWING BLACKBIRD
CRICKET .23

Fig. 4(a).

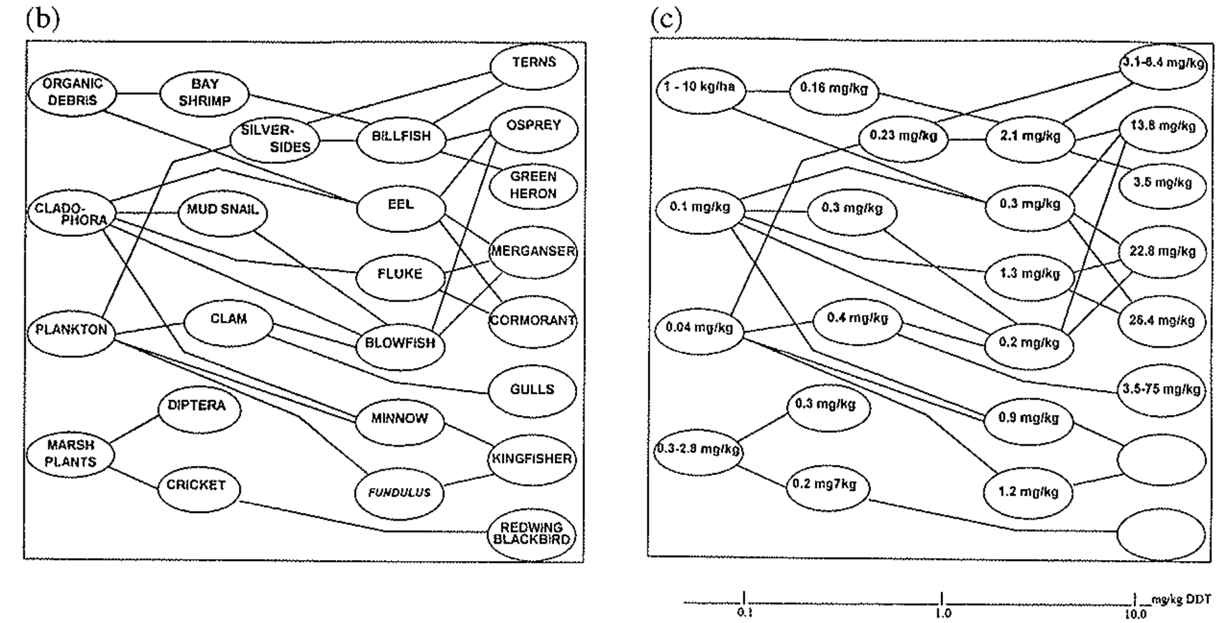


Fig. 4. (a) Residues (mg/kg) in plants and animals of an estuary food web; (b) Plant and animal food web in a Long Island estuary (ref. Woodwell et al., 1967); (c) ΣDDT residues in plants and animals of an estuary food web (ref. Woodwell et al., 1967).

Especially mentioned is the inclusion in regular monitoring programmes of PCB, i.e. the polychlorinated biphenyls which were first identified as environmental contaminants by Søren Jensen in Stockholm (ref. 12 and 13) and also of organic mercurials (ref. 24)

It became important parts of the studies to analyse and to collect evidence for the direct cause-effect chain of events leading *from* the discharge or dissipation of industrial and agricultural chemicals *to* the situation of contamination. The aims, of course, were to establish sufficient evidence for the cause-effect connections between the increasing contamination and a continuous number of observations of environmental deterioration.

3) In the years after this, i.e. the 1970s and especially the 1980s this was followed by numerous individual field studies, laboratory experiments, and coordinated monitoring programmes from all over the world, including the third world's developing countries. Although scattered and hardly ever presenting a full picture, these investigations were *legio* in numbers, and in character they mostly followed the pattern already indicated in the examples above—the obvious difference being that the results of the later studies emerged 20, or rather 30 years after those already known from the industrial countries.

- As an example is shown some DDT findings from India. They were reported in 1982 (or 1983) from the North Indian plains stretching towards the North and East of Delhi clearly resulting from agricultural uses of the DDT [1], and they are presented here in *figure 7* in a direct comparison with the Brookhaven Laboratory results reported from Long Island.
- In *figure 8* is similarly given an overview of DDT levels found in the ecosystem of Lake Kariba, Zimbabwe as published in 1992 by Nils Kautsky and his group from the Askö Laboratory in Stockholm and sponsored by the Swedish Development Agency SIDA/SAREC [4]. In that study the well-known patterns of food chain transfer were found, including the well-known metabolism of DDT into the dominating DDE metabolite,

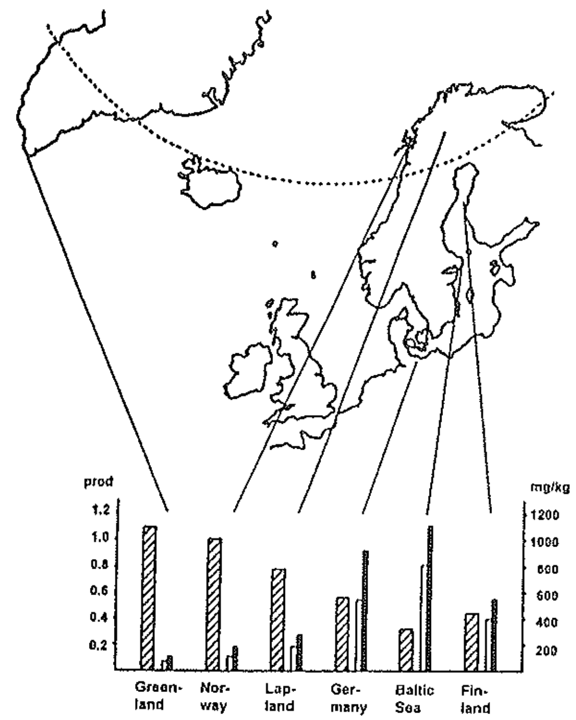


Fig. 5. Reproduction of white-tailed eagle (*Haliaëtus albicilla*) related to contents of DDE and PCB (after Helander et al., 1982).

and also the simultaneous observation of other chlorinated chemicals such as HCH, HCB, and aldrin (or rather dieldrin),

- Unhappily, but in this case not unexpected, the findings were supplemented with information on egg-shell thinning in birds, decline of birds populations, and distortion of insect and insect larvae populations, i.e. exactly as it was seen in the U.S. and Europe in the years of 1955/60. Further, the presence of these chemicals in human fatty tissues, including mothers milk was reported. This is an obvious consequence of the fact that the small fresh water fish, the Kapenta is one of the important stable foods in Central African countries, such as Zimbabwe and Zambia.
- As a further and final example is in *figure 9* tabulated some of the reported monitoring results which resulted from a surveillance of the environmental pollution situation in the Danube river and its vast delta region towards the Black Sea [23]. This study contributed to the initiation of the intensive UNDP/UNEP monitoring programmes that are still in progress in this region which is one of the best

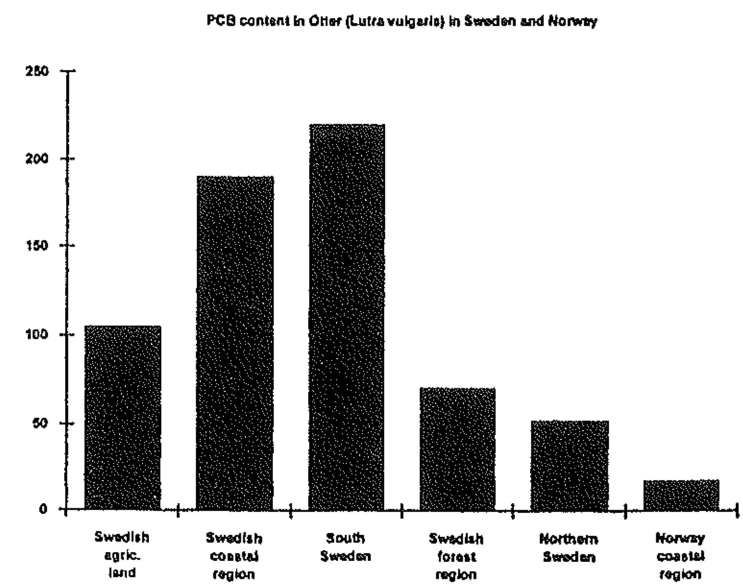


Fig. 6. At PCB-values above 40–50 mg/kg reproduction failures are likely to occur.

nesting areas in the world for a wide range of species of aquatic birds.

It is some of the results from the early 1980s which are given here. They clearly indicate the differences in accumulation rates which may develop between individual species dependant on different dietary and feeding habits. This is in the table exemplified by primary consumers, *e.g.* mallards, secondary consumers, *e.g.* glossy ibis, and other secondary consumers feeding on fish, *e.g.* the herons, and finally the tertiary consumers feeding exclusively on fish, *e.g.* the cormorants and the pelican.

3. Characterisation of persistent chemicals

The examples above are all tied to the traditional concept of persistent chemicals in food chains, and they illustrate a development over 3–4 decades. Obviously, the problem of persistent chemicals is as important now, as it was when the report of the American president in 1963 expressed that the use of persistent pesticides should be phased out [25]. To-day we know that this has not happened and simultaneously with our gaining new knowledge and establishing new regulations in the industrialised countries, we have further experienced that the persistent chemicals as a problem area has escalated geographically as well as scientifically. This has developed at a much higher rate than our imagination at that time permitted us to believe. Also, for many of our problems we do not seem to have moved closer towards a solution than we were 30 years ago—on the contrary.

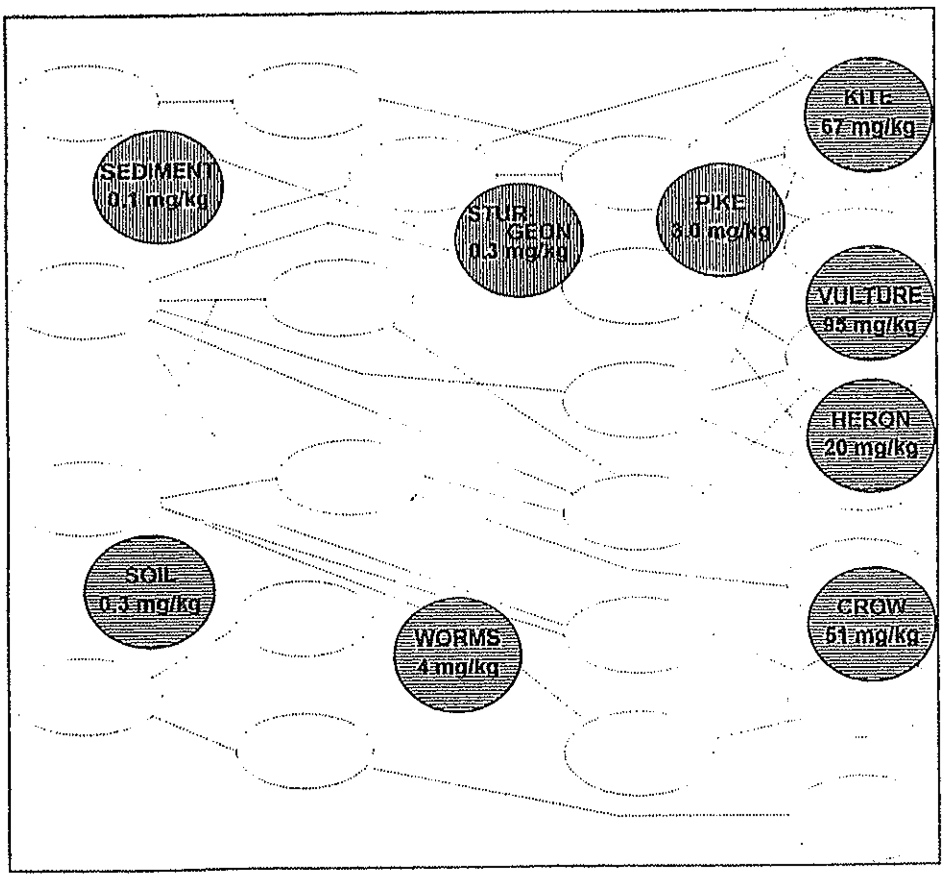


Fig. 7. ΣDDT in Indian terrestrial ecosystem — Long Island estuary food web as background

3.1. The number of persistent chemicals

In the early years (i.e. 1955–1965) persistent chemicals were merely referring to a limited number of chemically stable, chlorinated first generation insecticides. However, the identification of PCB as a wide-spread, ubiquitous environmental contaminant [12, 13], and the later extension of the list of persistent pesticides with several other chemical entities, has made it clear that we are confronted with a still increasing and an open-ended problem. Actually, already during the 1960s the *dirty dozen* chemcials were counted in more than one dozen.

Even if we limit the discussion to the organic chemicals, i.e. by not including any of the heavy

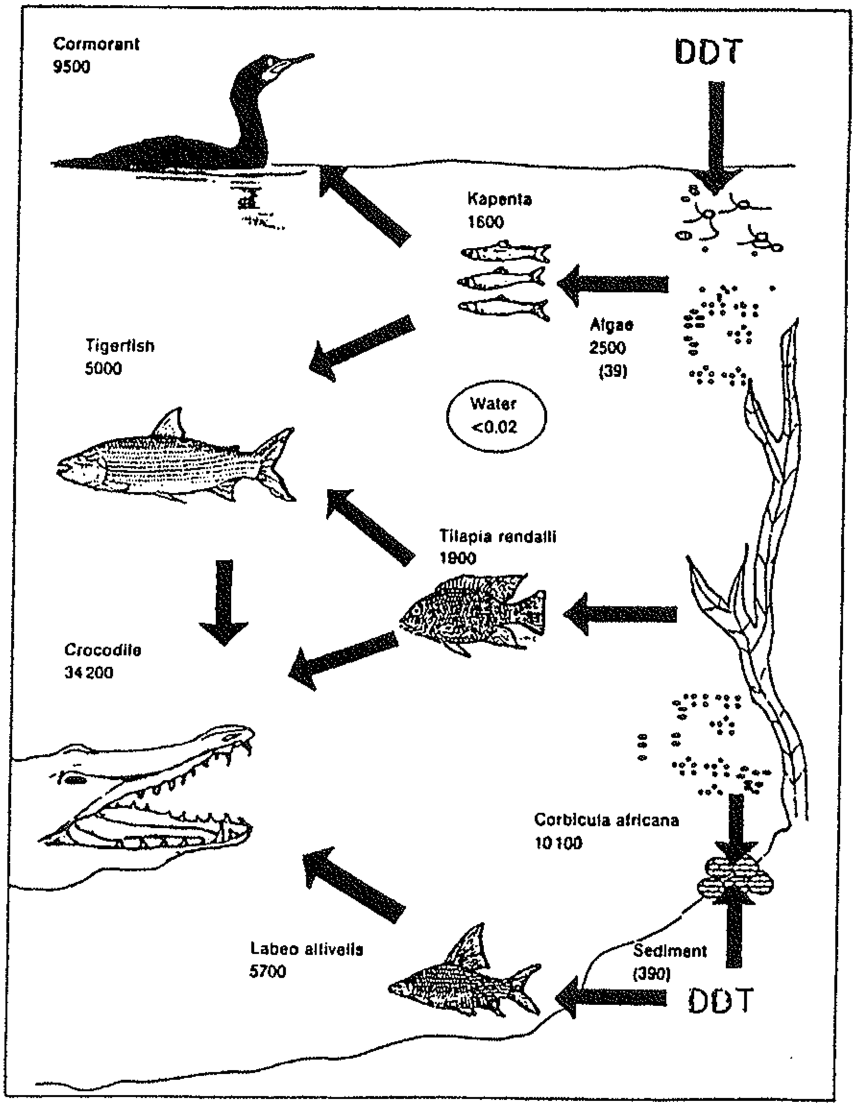


Fig. 8. Mean levels of ΣDDT (ppb in fat) in the ecosystem of Lake Kariba, Zimbabwe (Figures in brackets are in ppb dry weight) — from Berg, Kiibus & Kautsky (1992).

metals or other conservative, inorganic compounds, a list of persistent chemcials will to-day include:

- an increased number of both existing and new agricultural chemicals, in so far as we have learned the necessity to differentiate *e.g.* between low, medium and high stability and/or persistence,
- a considerable number of industrial chemicals, such as polyaromatic hydrocarbons from the petrochemical industry, PCBs, chlorinated phenols, organic solvents (often chlorinated and of low molecular weight),
- many chemical intermediates or high-volume end products which are shipped or marketed all over the world,
- and many so-called household chemicals which can be identified as persistent among detergents, dry-cleaning agents, pigments etc.

Thus, we are now counting persistent chemcials in hundreds, and a considerable number of these —but definitely not all—may now be found among the so-called 'Priority, or List 1 chemicals' or other chemicals registered as hazardous in National administrations or International organisations [ref. 8, 14].

3.2. Properties and environmental fate of persistent chemicals

The persistence is not a hazardous property *per se* such as chemical or biological stability, and it is definitely not sufficient to characterise persistent chemcials simply as being recalcitrant against chemical or biological breakdown processes. It is rather a characteristic which varies depending on the chemical as such and on external circumstances, and it is a feature that becomes important in combination with other properties. It thereby conditions persistence to become a mat-

Type of feeding		*SPECIES*	*HCB*	*γ-HCH*	*ΣDDT*	*PCB*
Primary consumer:		*Mallard*	0,18	0.27	1.27	0.98
Secondary consumer: (invertebrates)		*Glossy ibis*	0.16	0.28	4.00	2.40
Secondary consumers: (invertebrates + fish)		*Grey heron*	0.17	0.65	7.35	2.04
		Night heron	0.19	0.52	6.25	2.33
Tertiary consumers: (fish)	*In delta*	*Pygmy cormorant*	0.47	0.46	19.31	14.95
	At surface	*White pelican*	0.32	1.15	18.75	5.38
	At bottom	*Common cormorant*	1.30	2.01	59.9	23.6

Fig. 9. Chlorinated hydrocarbons in eggs of water birds collected in the Delta on Danube river ($\mu g\ g^{-1}$ dry wt) (ref. from Walker and Livingstone, 1992).

*) ALDRIN
AMINOTRIAZOLE
CAMPHECHLOR
*) CHLORDANE
CIPC / IPC-CARBAMATES
*) DDT / DDE / DDD
*) DIELDRIN
*) DINITRO-HERBICIDES
¤) ENDRIN
*) HCB
HCH
*) HEPTACHLOR / -EPOXIDE
LINDANE (or γ-HCH)
¤) MIREX
¤) TELODRIN
*) TOXAPHENE

*) Included in PIC procedure
¤) To be included in PIC procedure

Fig. 10. Rachel Carson's 'Dirty dozen'.

ter for concern. Especially important in this context is

- The possibility for *food chain transfer* which already at an early stage was found to be determined by the *lipophilicity* of the individual chemicals. The bioaccumulation potential leading to an increasing bioconcentration in living organisms is closely correlated to the lipoid character of the chemicals, because the lipoid chemical will tend to follow the pathways—and possibly also interfere with the metabolic patterns of natural fats.
- However, we also know that there are limitations to this correlation in so far as it may be affected by the presence of particulate matter due to adsorption on to a surface. The degree of uptake and the pathway of movement of persistent chemicals in a food chain will vary according to trophic levels. For aquatic organisms, for instance, there are marked differences between the uptake and bioavailability of persistent chemicals directly from the water or via the food intake. Further, it seems reasonable to believe that chemical entities of high molecular weight, such as the highly chlorinated PCB congeners may be hindered or even blocked in their penetration of and transfer through biological membranes, even though the lipophilic character would indicate a high degree of accumulation [7].
- The *mobility* of persistent chemicals is similarly a matter of increasing concern. It is expressed as the potential of a chemical for

Mercury	Hexachlorobenzene	Fenitrothion
Cadmium	Hexachlorbutadiene	Fenthion
Copper	Carbontetrachloride	Malathion
Zinc	Chloroform	Parathion
Lead	Trifluralin	Parathion-methyl
Arsenic	Endosulfan	Dichlorvos
Chromium	Simazine	Trichloroethylene
Nickel	Atrazine	Tetrachloroethylene
-drins	Tributyltin-compounds	Trichlorobenzene
HCH	Triphenyltin-compounds	Dichloroethane 1,2-
DDT	Azinphos-ethyl	Trichloroethane
Pentachlorphenol	Azinphos-methyl	Dioxins

Fig. 11. List of priority hazardous substances (3rd North Sea Conference, 1990; cf. ref. no. 11).

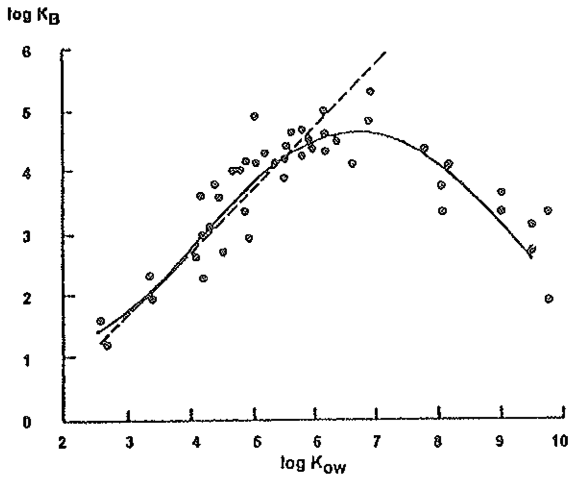


Fig. 12. Relationsship between bioconcentration and lipophilicity. (Comparison of experimental data against regression line (dotted) obtained by extrapolation from data for chemicals with values of log K_{OW} between 3 and 6 (ref. 6).

transport or transfer between and/or within the environmental compartments. Mobility has for a long while mostly been connected to the process of *volatilization*, a situation which is recognised as important all over the world, but which on the other side probably is of greater

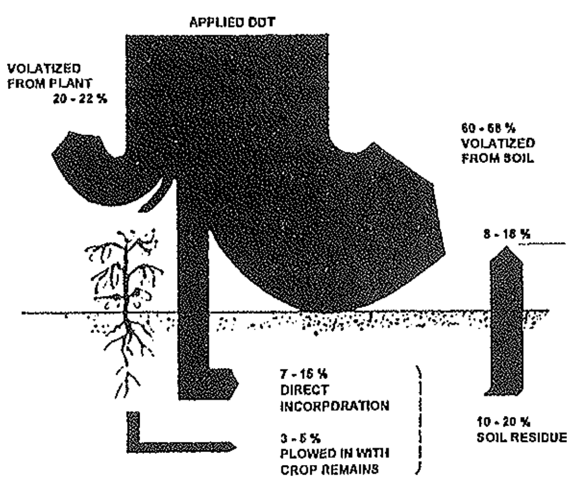


Fig. 13. Schematic representation of the fate of DDT applied to a crop of cowpea. Figures summarize data collected during four-year experimental period in Nigeria (ref. J. Perfect, 1980).

significance in tropical and subtropical countries [17] than the case is in more temperate climate zones.

- The transfer of a chemical, *e.g.* by volatilization from plants, water or soil is succeeded by an atmospheric transport and the persistenee will then be determined by the process of photodegradation in the atmospheric compartment. This is in fact relevant for many of the traditional persistent chemicals, *e.g.* when DDT or PCB are the objects of long-range transport - often called the fastest way of pollution - even as far as remote polar regions of the globe. But it is also important as a background for our understanding when we are dealing with the more recent problem areas of ozone depletion in the upper atmospheric regions, and of the potential for climate change connected to persistent halogenated chemicals being released in to the global atmosphere.
- The *retention* of persistent chemicals in soil and sediments is a further problem area which has become significant and attracted scientific as well as official interests in more recent years [15]. Physically it is primarily determined by the potential for a chemical to be adsorbed to soil or sediment surfaces. The process of terrestrial run-offs, of infiltration or leaching into soils are incrasingly found to take place in and around chemical produtions sites, from pesticide treated agricultural lands, and from chemical waste dumps/deposits.
- The adsorptivity of the chemical is under the circumstances determining whether a contamination will develop as a threat to groundwater or drinking water ressources, or whether the adsorption will result in a retention of chemicals for a prolonged period of time. This latter situation may have the character of a geo-accumulation, i.e. a binding or holding back polluting chemicals in soil and sediments, with the risk of a delayed release under changed circumstances, as it has frequently been seen in connection with dredging of lakes and coastal waters, or as a result of restauration of marine or fresh water ecosystems [21].

3.3. Potential hazards and toxic effects of persistent contaminants

In general, polluting chemicals cause concern because they may have effects in the ecosystems. The persistent chemicals cause particular concern because of

- their chemical stability, as it is the case *e.g.* for ozone-depleting CFC-gases, or contaminants leaching in to groundwater or other drinking water supplies.
- their biological long half-lives which determines the presence of them as exogenic chemicals in tissues, including their transfer between animals, and
- the possibility of being recycled back to the base of the food chain.

Adding to the concern is the fact, that the toxicological/ecotoxicological interests have to be attached not only to the parent compounds, but also - as we now know for many of the traditional persistent chemical still in circulation - to possible metabolites, to free radical derivatives of the chemical, and to the enhanced production of reactive oxygen species or oxyradicals. These are to a great extent chemical entities which are often connected to the induction and/or involved in the development of genotoxic and carcingoenic effects.

As far as the potential for effects are concerned, we have to deal with the possible hazards connected to reproduction disturbances, cf. the egg-thinning and direct embryo toxicity in birds, including teratogenic and immunological disturbances in all species. We have experienced this with fish, birds, seals and other mammals [23], and it is increasingly being raised as a question whether epidemiological studies will be able to trace the same effects on domestic animals and in man [20].

The mechanistic understanding of the many symptoms and harmful effects known to be connected to be persistent chlorinated chemicals are still limited. The toxicity, however, is often exerted via the metabolites, and several of them *e.g.* PCB and PCB congeners are known to be effective tumour promotors in liver. This is an ability which is correlated to their ability to inhibit or to

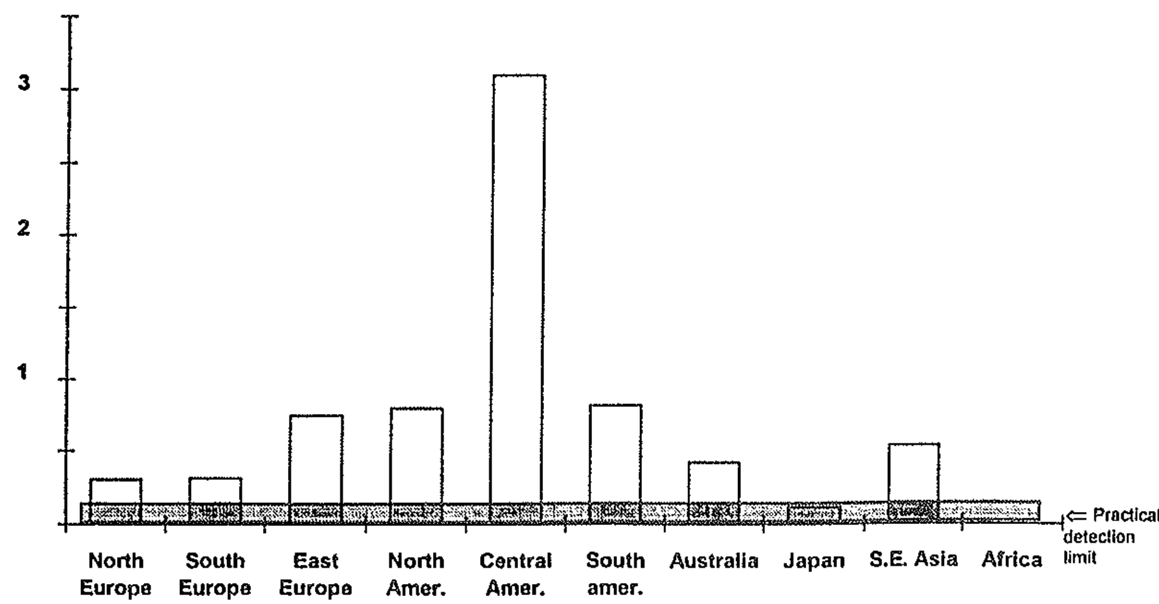


Fig. 14. ΣDDT in human in $\mu g\ l^{-1}$ — High-values (mostly pooled). (data from ref. no. 9).

Cook Islands	Animals killed by oil spill in streams
Fiji Islands	Dogs poisoned by metaldehyde
French Polynesia	Fish kills in rivers by pesticides
Mariana Islands	Cattle by organoarsenate herbicide
Micronesia	Fish kills by Endrin - large scale kills of fish, wildlife & domestic animals by endrin and sodium arsenate leakage into lagoon
New Caledonia	Dogs poisoned by organophosphate
Papua New Guinea	DDT & Lindane killing of fish - cats died after DDT spraying in village - cattle killed by dimethoate and diazinon
Tokelau	Fish kills by DDT & Lindane - Coral reef damaged
Tonga	Horse poisoned by drinking water contaminated with Benomyl
Western Samoa	Dogs poisoned by paraquate

Fig. 15. Reports on poisoning of domestic animals, fish and wildlife in South Pacific Islands (J. Perfect, 1980).

induce enzymes, among which the P 450 enzyme complex is particularly important, and which may in turn provoke alterations of the metabolism of other initiating chemicals. Such phenomena have been extensively studied and described for mammals [18] but they are also observed in fish [3] and in birds [5].

When dealing with the persistent chemicals, it is important to note that for the majority of these we mostly have to consider the chronic and sub-lethal effects.This is in contrast to the more acute toxic effects which are known and well-described for many less persistent chemicals, such as the organophosphate insecticides. Differences among the manifest symptoms are reflected in the chemical hazards between the persistent organochlorine compounds and other types of pesticides, although the hazards often become evident at the same low concentration levels. The polluting impact on individuals of the persistent organochlorines is possibly greater at the early life-stages, compare for instance, chickens after hatching and juvenile birds when they start flying, and the interaction of persistent chemicals with organisms may be significant also from an evolutionary point of view - at which stage, however, we have to admit that our further assessment still have to be substantiated by more factual knowledge and experience than we have at hand to-day.

This is, however, still a matter of utmost importance because we are faced with an obviously uncontrolled pollution of the environment and an increasing impact on man, i.e. human beings who may be considered the top-predators and who also being occupationally exposed, are likely to be

1965	**ca. 1 mill. tonne/year**
1980	**ca. 2 mill. tonne /year**
2000*)	**ca. 4.5 mill.tonne /year**

Consumed in 3rd world countries:

In 1980:	**ca. 15%**
In 2000*):	**35-55%**

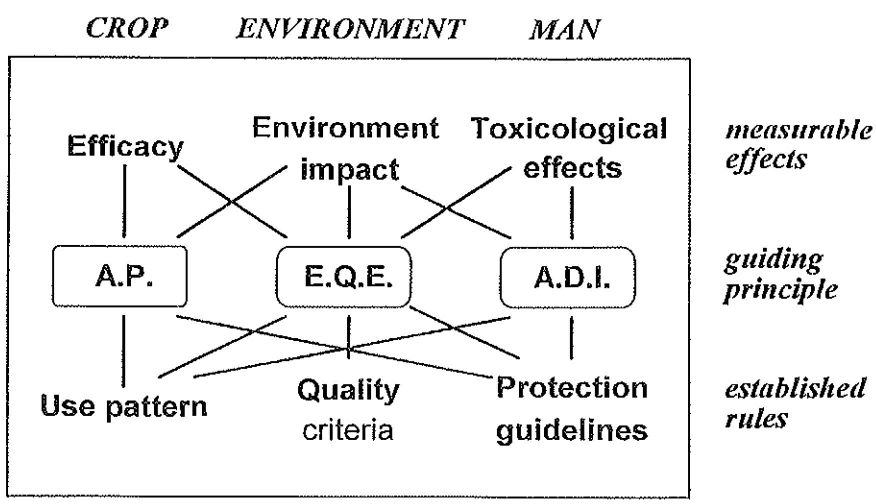
*) Forecasts: ref. from UN/ECETOC, 1982)

Fig. 16. World Production of pesticides (WHO, 1990).

	India	Indonesia	Malaysia	Pakistan	Peoples Republic of China	Philippines	Republic of Korea	Thailand
Aldrin/dieldrin	⊠	⊠	⊠	⊠	⊠	⊠	■	⊠
Aldicarb	□	⊠	□	□	□	⊠	⊠	⊠
Azinphos-E & -M.	■	□	□	□	■	□	□	□
Carbaryl	□	⊠	□	□	□	⊠	□	□
Chlordane	⊠	⊠	⊠	⊠	⊠	⊠	■	⊠
DBCP	■	■	■	■	⊠	■	■	■
DDT	□	■	■	⊠	■	■	■	■
2,4 - D	□	□	□	□	□	□	□	□
2,4,5 - T	■	■	□	□	□	⊠	□	■
Endrin	■	■	■	■	■	■	■	■
Ethylene dibromide	□	■	□	□	□	⊠	□	■
Heptachlor	⊠	⊠	⊠	⊠	⊠	⊠	■	⊠
Lindane (γ-HCH)	□	□	□	□	□	□	□	⊠
Mephosfolan	■	□	□	□	□	□	□	□
Monocrotophos	□	⊠	⊠	□	⊠	□	□	□
Other Organochlo.	□	⊠	⊠	⊠	⊠	⊠	⊠	⊠
Paraquat	□	⊠	□	□	□	⊠	□	□
Parathion	■	■	■	■	⊠	■	⊠	□
Toxaphene	■	■	□	□	□	■	■	■

■ Banned - out of use ⊠ Restricted - only specified uses □ Unrestricted

Fig. 17. Pesticides banned or restricted for agricultural uses in some Asian countries.



Problem areas: Lack of control, Hazardous chemicals, Lack of knowledge ⇒ Code of conduct ⇒ ???

Fig. 18.

the species primarily threatened by the persistent chemicals - through food, through drinking water and through mothers milk. The question and the heavy pressure we are facing, therefore, is rather: Can we afford to wait and to await that future knowledge will develope and experiences will build up to unsurmountable hights?

4. Perspectives and concluding remarks

Overviewing the development and experiences which we have gained concerning the use of persticides and other chemicals, the picture of to-day becomes gloomy when we deal with persistent chemicals. It is the unforeseen consequences, the mistakes and the evils which have become evident. They are to some extent a repetition of our mistakes and errors as they now flourish with 20–30 years delay in the economically and socially less fortunate third world countries.

But it seems to be more than that. In summing up, and at the same time attempting to draw up some concluding remarks it is undoubtedly justified to make the following observations:

- The **number** of chemicals and the **total amounts** being produced and marketed is continuously increasing—see for instance the overall world statistics for pesticide production and use during the period from 1950 to 1980/85, including a forecast for year 2000.
- This increase is dominantly - or possibly even solely - expected to take place in the developing countries from which we to-day hear about **rates of increase** in the order of 5–7% per year and in which we already know that the number of **chemicals available** is comparable to that seen in the industrialised countries.
- And among those chemicals which are officially accepted and in practical use **persistent chemicals are frequently seen although they are banned or restricted elsewhere.**
- It is these ehemicals which are now found in **mothers milk**, in **surface waters**, and in **staple food,** and which are building up **in ground water ressources** in most parts of the world.

In most official statistics, *e.g.* from WHO or from National aid programmes, we learn much about accidents and damages caused by pesticides, especially those which are acutely toxic such as organophosphates, weed-killers or fungicides. What we do not hear, however, is the still untold, or only partially known story, about the long-term effects, the gradually deteriorating environmental qualities, and the chronically developing damages on animals as well as man - These are most likely to be caused by the more persistent and the chronically more hazardous chemicals which *we know are dirty*, and *also know how dirty they are* - but which we up till this very moment have not mastered to control.

The threats towards man and the environment from these chemicals, therefore, are likely to increase also in the years to come, unless a radical change in priorities and measures is initiated and implemented on a global scale.

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Threats by heavy metals: human and environmental contamination in Brazil

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Abstract

An overview of some aspects of the current situation in Brazil, as regards environmental and human contamination by chemicals is presented. Special attention is given to those problems caused by heavy metals (mercury, cadmium, zinc, arsenic and chromium) used in industrial activities and in goldmining. Social and economical influences are also briefly discussed.

1. Introduction

In general, most of the 'Third World' or 'Developing Countries' faces the same problem in relation to social, environmental and human health; no importance is given to these issues.

The dream of a rapid passage from underdeveloped to developed status, reinforced and catalysed by the mass media, makes it easy to ignore important processes particularly those related with the social, human and environmental aspects of life.

It is a common belief that in such circumstances economic interests should prevail over other social, environmental or political interests which can be later addressed. The peculiarities of such nations and/or societies are ignored in 'the interest of development'.

It is easy and sometimes very convenient to forget that development can not be achieved by economic growth alone without support of the other components of a developed society such as educated and healthy people or strong and up to date legislation.

The relations among these components are intricate and one can not be privileged above another; they must be in harmony. This is, in my opinion, the starting point for the economic crisis: the original sin.

The lack of a well organised and fully developed society to support desired economic growth, contributes to the dominance of the richest over the other social classes and enlarges the social and economical inequalities; the rich (strong) became richer (stronger) and the poor (weak), poorer (weaker). In such unorganised societies, the law does not protect all classes equally and the rich are treated with much more benevolence than the poor. This behaviour reinforces existing social inequalities.

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To implement 'forced development' foreign capital must be attracted; money becomes the essential fuel and must be borrowed from the developed world. To attain these objectives, sacrifices must be made; any nationalistic policy or protective law must be dropped in order to improve the economy. As money assumes immense importance to the borrowers as a force to the promotion of development, profit is the price that must be paid to the lenders.

In this model of unrestricted economic growth, industries must be attracted at any cost including relief from requirements protecting environmental and human health. Tax relief and other advantages are offered. Any technology even those recognised as obsolete or hazardous are welcome since they can be more profitable in short term.

To illustrate the different behaviour of industrial activities in developed countries when compared with developing ones the following data are useful (Freitas et al., 1991). Studying the industrial accidents occurring between 1974 and 1987 and causing more than 50 deaths, more than 100 injuries, more than 2000 evacuees, found that 68% of the industrial chemical accidents occurred in the developed countries and 32% in the developing ones. However when one takes into account the number of deaths or permanent injuries, these numbers change completely. Twelve percent of deaths and 6% of permanent injuries occurred in developed countries and 88% of deaths and 94% of permanent injuries in developing countries. Several causes can be pointed out as responsible for these differences, the use of obsolete and hazardous technology in association with insufficient safety information and training of workers in developing countries appeared to be the most important.

Pollution control is another example of the industrial double standard.

In order to attract industry, most developing countries do not require waste control measures which are expensive.

To avoid the spread of pollutants originating from such industries throughout urban areas, they are generally located in industrial parks, in the outskirts of the cities.

This practice, common in the past, created 'zones of pseudo-prosperity' and led to internal migrations. The absence of any counterbalancing policy to address social problems and develop basic infra-structure in the rural areas contributed further to the migratory phenomena.

Generally, the last skilled and/or poorest people from rural zones or small towns, those employed in the production of essential items such as foodstuffs are the first to be attracted by the easier life of the industrialised cities.

The need to reduce living expenses tend to locate these workers as close to the industrial complexes as possible. The outlying industrial park, therefore, soon evolves to become a part of the city in close physical contact with the poorest and most vulnerable segments of its population.

These migrations occur at such a high rate that is is impossible for government to provide basic requirements necessary for a decent life such as sanitation. The standard of living drops.

Economic problems further aggravates social, environmental and human ones.

This overall situation leads to:

(a) economical dependence, which facilitates economic pressures.
(b) weak or non-existent protective laws particularly those related to basic human rights and environmental health
(c) inexistence of legal accountability
(d) unemployment and low wages
(e) increasing in social tension
(f) environmental and human contamination
(g) sub-human living conditions (the fast rate of population growth is not followed by a corresponding increment in the economy and basic living standards).

Corruption also flourishes.

Several environmental 'accidents' which occurred in Brazil in the past were caused by these factors acting in isolation or in conjunction. A particularly serious accident was that which took place in Golania, when source used for radiotherapy containing cesium-137 was found abandoned in a semi-destroyed hospital by poor inhabitants scrouging for scrap metal and opened. This 'accident' was responsible for the spread of 19 g of this radioactive metal in the urban area of Goiania, which has 1.5 million inhabitants, and caused the deaths of four people and contamination of a number of others. An area of 15 hectares was heavily polluted. Decontamination of this area resulted in 3000 m^3 of radioactive wastes which are still deposited temporarily at Abadia, Goias, waiting to be transferred for a permanent deposit.

Irresponsible management of radioactive materials associated with ignorance and the need for survival were the underlying causes for this 'accident'.

This example emphasizes that environmental problems can not be divorced from social problems such as poverty, hunger, ill health and access to basic necessities such as housing among others.

In the midst of this chaos big international companies easily use double standards between their home country and developing countries. The following report published by 'The Sunday Times' on June, 18, 1989 is a clear example of what can happen. According to that article, British Petroleum promotes its 'green' image in England as a company which looks out for the environment; In Brazil, however, the same company is bulldozing and burning the rain forest at the Jamari National Forest, near Porto Velho, Rondonia, in search for cassiterite ore, a raw material used to manufacture tin. In these mining activities 'large amounts of soil are being dumped haphazardly, sitting up one of the main rivers in the forest being impossible to gauge precisely how much has been directly destroyed and how much adversely affected by road clearance, soil dumping or diversion of rivers. This is not an isolated case.

On Friday, May 29, 1992 at 6.30 pm a Bayer factory producing modified polyurethane, located on the outskirts of Rio de Janeiro was the cause of an environmental accident. This industry used toluene diisocanate (TDI) and a mixture of diethylenglycol and trimethylpropane as reactants in the process. On that day, one of its reactors exploded liberating a cloud of chemicals into the environment. This leakage continued out of control until midnight.

No emergency measures were taken by the industry in order to evacuate or protect the population living nearby. Over the following days several complaints were sent to the State Secretariat of Health by neighbors reporting allergic and respiratory problems. A survey carried out at the local hospitals showed a doubling in the number of people, mostly children, attending for respiratory problems.

Even facing this evidence Bayer refused to accept any responsibility and the government was technically unable to produce scientific and technical evidences to prove this link between the explosion and the community complaints.

Other cases related to heavy metal contamination and a brief discussion of some Brazilian internal problems may help to clarify some aspects of this intricate problem.

The following are some indicators of Brazil's socio-economic conditions (GIMA, 1991; Schilling et al., 1992; Padua et al., 1992):

Until 1964 Brazilian external debt was approximately US$3.2 billion. By 1985, at the end of the military government, it had increased to US$105 billion.

From 1980 to 1987 the Brazilian government paid US$121 billion external service debt. At the same time debt increased from US$64.2 to US$121.3 billion. This drainage of currency has aggravated the social crisis since the country has no money left to use internally and must export as much as it can in order to generate currency to continue the payments. As an example, in 1988 Brazilian exports generated a positive balance of trade of US$19 million. US$17 million were used to pay off part of the debt.

In 1991, the unemployment rate increased to the point where 13.3% of the economically active population is presently out of work as result of economic difficulties. (Dieese, 1991).

This situation is reflected in the distribution of income in the country (Table 1).

For comparison, in developed countries the 10% richest control about 20–25% of the national income.

Although the gross domestic product from 1940 to 1985 increased by 476%, the minimum wage during the same period decreased and now represents about 22% of its 1940 buyer power. World Bank data show an increase of 43% in the num-

Table 1
Income distribution in Brazil; comparison between 1981 and 1989 (IBGE, 1990)

Class	% of generated income	
	1981	1989
90% poorest	53.4	46.8
10% richest	46.6	53.2
50% poorest	13.4	10.4
10% poorest	0.9	0.6
1% richest	13.0	17.3

ber of people living in absolute poverty (income below US$370/year) between 1981 and 1989.

About 351 000 children under 5 years of age die in Brazil each year.

According to FAO (1985) 85 million Brazilians eat less than 2240 cal/day (considered to be the minimum requirement) and about 61% of child mortality in Brazil is caused by malnutrition and hunger.

During the 'Brazilian economic miracle', 1972, the Brazilian representative at the World Conference for the Environment held at Stockholm, held that 'a Country that has not reached a minimum satisfactory level in providing for the essential needs of its population can not give much financial support to environmental protection'. This was only partially true, at that time the government had access to funds, but they were not applied to social/environmental needs.

The military governments managed to obtain external credit to subsidize gigantic projects such as the construction of the trans-amazonic road, the Italpu dam, nuclear reactors, the 'steel railway'. Improvements in social or environmental conditions attributed to these projects, if they occurred, were very small. Several are completely ruined or abandoned today.

In Brazil, the rapid process of industrialization was accompanied by the development of some industries possessing new and advanced technologies, compared with the Brazilian ones, but with very weak, old or absent technological refinements in relation to environmental protection. In general, no treatment, recycling or reprocessing of the waste produced was required. Consequently, the profile of the Brazilian industry today is of high impact on the environmental resources owing to the characteristics of the processes used and their interaction with nature (GIMA, 1991).

As consequence of rapid industrialization, associated with the absence of any policy aimed at maintaining a stable rural population, great increases were observed in migratory processes towards large cities in Brazil. In 1940, 31% of the Brazilian population resided in urban areas. Fifty years later, in 1990, this percentage had increased to 75%, of whom 42.5% lived in cities with over 100,000 inhabitants. This rapid migration caused a clear fall in living standards with most migrants living under a precarious or even completely without basic infra-structure. About 60% of Brazilian population lives in nine metropolitan areas (São Paulo, Rio de Janeiro, Belo Horizonte, Salvador, Porto Alegre, Recife, Fortaleza, Belem e Brasilia).

In urban Brazil, about 20 million people do not have treated water; 75 million do not have waste collection and treatment. In the rural areas only 6.8% have public water and waste collection and treatment.

Only 3% of the domestic waste are correctly treated; 63% are launched into rivers and 34% deposited in open areas near the cities.

The lack of investments in basic sanitation is an important cause of hospitalization.

Only 10% of Brazilian countries have sewage plant treatment. As far as industrial contamination is concerned, the situation is worse. The Tiete river, for example, receives 250 000 tons of biochemical oxygen demand daily as it flows through the metropolitan area of São Paulo.

Analysis of sediment samples collected in Cubatão, a heavy industrialized area located approximately 40 km from São Paulo, showed high levels of contamination by arsenic, lead, mercury, zinc, and pesticides (HCH and pentachlorophenol).

Identical problems are found in other important rivers in the southeast of Brazil, such as the Paralba do Sul river.

The Paralba do Sul river is the most important source of water supply for the State of Rio de Janeiro and for northern São Paulo. Its importance for this region can be easily recognised since the State of Rio de Janeiro is called 'the one river State'. This river and it tributaries run through an economically important and highly industrialized region of Brazil. One hundred and thirty three cities are located along the valley of Paralba do Sul with a population of more than 5 million. Its water is supplied for more than 15 million inhabitants in these two States.

About 12000 small and large industries and 6000 agricultural and cattle ranches are located in this area. This industrial park was responsible for the production of US$3.3 billions in 1990 and for the employment of 600000 workers. Among the major industrial and potential polluting activities located alongside the Paralba do Sul, we can mention: (a) factories producing chemicals, dyes, pesticides, plastics, and others; (b) metal extraction and processing (refining, extraction, goldmining, etc); (c) food industries; (d) cement industries and paper and pulp manufacturing.

Despite its great importance as a water source, the Paralba do Sul river has been systematically polluted by domestic sewage and waste, chemical waste, hospital residues, pesticides and accidental contamination. In general all the sewage and the waste which originates in the cities near the river are disposed off without any prior treatment since the majority of the cities do not have sewage treatment plants or even sites for their solid urban refuse. Accidental contamination comes from the economically most important highway in Brazil (the Rio de Janeiro–São Paulo highway and railroad) which run alongside the river for the greater part of its course and constitute the most important route of travel of raw material and products of the companies located in this area, some of which are very hazardous. Spills of acids, bases and even highly toxic compounds are not uncommon. In 1982 the Rio de Janeiro State Foundation for Studies of the Environment (FEEMA) and the Rio de Janeiro State University carried out an investigation for the biological detection of some toxic compounds in this area. The results showed that after the great industrial park located in the city of Resende, about 46% of one bentonic Brazilian fish (Locarildase, gen, Hypostomus) caught in this area had some kind of tumour, generally in the digestive system. Similar levels were not observed in the areas located upstream from the chemical industrial park (FEEMA, 1983).

Significant chemicals already identified in the water and in the sediments of the Paralba do Sul include the metals manganese, cadmium, mercury, copper, lead, iron and nickel; polyaromatic hydrocarbons (benzo pyrene, etc), organochloride pesticides (aldrin, dieldrin, heptachlor, HGH, etc) phenols and cyanides. Some of these compounds are not completely removed by the water treatment provided and even in this case it must be considered that a large fraction of the population uses water collected directly from the river, without any previous treatment. To decrease the impact of this problem on human health, the Federal Government passed a law prohibiting the installation of chemical plants producing chlorine and soda using mercury cells, as well as preventing the introduction of non degradable, highly toxic or carcinogen containing effluents. To enforce these objectives a program for the registering industries was launched and more than 676 have been registered since then. The overall situation as regards water pollution has since improved but is still a matter of great concern.

2. Environmental aspects related to metal extraction

Mining is an important source of income to Brazil. From 1970 to 1980, a large increase was observed in this area. For example, the extraction of iron increased from 36 million tons in 1970 to 118 million tons in 1980; of bauxite from 510 thousand tons to 2.9 billion tons, of chromite from 73 thousand tons to 892 thousand tons and of gold from 5.8 to 22 tons. These increases were due mainly to the exploitation of the Amazon region.

In general the companies responsible for mineral extraction use obsolete technology which affects the original topography, accelerates erosion processes, causes emission of dust and atmospheric contamination, deforestation, sitting up of rivers and human contamination.

Taking into consideration only the environmental aspects, such exploitation has caused changes in the soil due to removal of topsoil and residue deposition, in the water by increasing turbidity and metal content, changing the pH, decreasing the oxygen content (increasing chemical demand) and modifying the original conditions for the life and in the air by increasing the particulated materials, gases, etc.

Particular attention should be paid to the poor understanding of the specificities of pollutant cycles under tropical conditions.

According to official data, about 1854 'garimpos' are operating in Brazil extracting gold, gems and other rare minerals. According to these data these operations employ 300 000 people directly. This activity started as a survival strategy for large numbers of workers originated from rural areas, generally unemployed or under-employed and has subsequently led to severe cases of environmental and personal contamination.

3. Mercury contamination

Among the heavy metals, mercury is a very important cause of environmental and human contamination in Brazil. This metal has been used in industry and in gold mining activities. From the industrial point of view, the chloralkali plants are the most important. Data from the Brazilian external trade commission shows that of 200 tons of mercury legally imported, 49.4% were used in goldmining activities and 7.6% in the production of chlorine/alkali. In these industries, atmospheric emissions of mercury can attain 45% of its consumption and this is the most important source of mercury contamination in the industrial sector (Bezerra, 1990). Most chlorine produced in Brazil comes from this kind of industry.

In a chloralkali plant located in Rio de Janeiro the amount of mercury lost to the environment was calculated to be about 350 kg/monthly. The calculated consumption factor of mercury was about 400 g Hg/ton chlorine produced, which is 400 times higher than the United States goal for the next decade of 1 g Hg/ton (Melo, 1993).

This plant is located in a heavily populated area and employs about 400 workers. Two hundred and sixty one of them work in the electrolysis sector, i.e., in direct contact with mercury.

Table 2
Urinary mercury levels (μg/l) in 98 workers of a chloralkali plant in Rio de Janeiro (CESTEH, 1992)

	Average	Max.	N
Group I (direct contact)	15.8	91.0	44
Group II (indirect contact)	9.7	45.8	26
Group III (no contact)	4.1	15.6	28

The results of a survey carried out among the workers of this plant is shown in Table 2. Cases of severe contamination (values of urinary mercury as high as 10 000 μg/L) were observed. Measurements of the levels of atmospheric mercury taken inside this factory showed, in several locations, values higher than that allowed by Brazilian legislation (tolerance limit = 0.04 mg/m^3). Values as high as 0.415 mg/m^3 were observed.

A questionnaire applied together with this survey showed that 17% of the exposed workers did not know anything about the health effects of mercury or the precautions that should be taken to avoid contamination.

Studies carried out in the Acari river showed levels of mercury in sediments of 0.09 μg/g upstream of the chloralkali plant and of 1.96 μg/g downstream. Values reported for the Guanabara bay showed values from 3.19 to 22.83 μg/g.

Other cases of industrial mercury contamination have also been reported. A study in workers from an electric lamp industry in Santo Amaro, São Paulo, showed that 85% had signs of chronic metallic mercury poisoning ((Zavariz, 1993). The available data did not allow us to assess the magnitude of the environmental contamination.

3.1. Mercury in the Amazon region

The Legal Amazon represents about 60% of the Brazilian territory occupying an area of 5 million km^2. It includes about 3.5 million km^2 of tropical forest and 'cerrados' possessing enormous biological diversity and high primary productivity.

Economically, this region is very important since it contains several mineral resources including iron, bauxite, gold, cassiterite and manganese as well as oil and gas. Its hydroelectric potential is on the order of 100 00 mol weight.

Since the 1980s this region has been the object of great transformations. The exploitation of its mineral resources and the building of dams has profoundly affected its social and ecological organization. Economic interests overcame ecological, biological and cultural values creating a series of negative impacts on ecosystems and populations. Deforestation and mineral exploitation associated with an extensive spread of goldmining activities has been causing serious pollution in this area.

According to unofficial data, goldmining activities involve an area of 16.7 million hectares and a massive workforce of 650 000 people.

The techniques used for gold extraction are in general very rudimentary and employ large amounts of mercury. As a consequence, extensive environmental contamination has been observed.

Despite its predatory and unofficial nature, goldmining is an important economic activity in Amazon. Workers in 'garimpo' do not have fixed hours nor do they enjoy the rights enjoyed by other workers. The great majority of these workers are peasants mainly from Northeast of Brazil. Because of the lack of any real agrarian reform, they cannot survive in their birthplaces and are forced to migrate. The distribution of wealth in the 'garimpos' follows the usual Brazilian pattern; 5% of the population receive 81% of the income whereas the remaining 95% receive 19%.

Mercury is used extensively in the process of gold complexing, either mechanically or manually. However, the amount of mercury used to extract gold depends on the technology employed. Losses of this metal can occur during the amalgamation process in pans and in rifles, both along the river banks and on the boats. Part of the mercury is lost directly into the rivers as metallic mercury (15 to 50%) and part is released into the atmosphere as elemental mercury vapor (65–83%).

It is almost impossible to calculate the total annual amount of mercury used in the recovery of gold because: (a) a major part of the gold produced is sold locally and then sent to unofficial gold dealers in cities such as Rio de Janeiro or São Paulo; and (b) most of the 'garimpos' are located in remote areas and the mercury used is sold freely or enters illegally from the neighboring countries (Paraguai, Bolivia and Venezuela).

Official figures show that goldmining in the Amazon region accounted for 94% of the total gold production in Brazil between 1980 and 1988.

The amount of mercury released into the environment to produce 1 kg of gold is quite variable depending on the site, the gold containing material and concentration and the extraction process. Emission factors calculated in these cases varied from 1.0 to 10.0. It is believed that a more realistic value would be from 1.3 to 1.7.

Taking into account these factors, one can estimate the average annual discharge of mercury into the environment as between 40 and 160 tons/year of which 10 and 100 ton is liberated into the atmosphere and 30 to 60 ton into the rivers.

The different mining processes used in the Amazon region to extract gold result in different wastes and mercury dispersal mechanisms (Lacerda et al., 1992). When gold is mined from bottom sediments, mercury is lost to the environment as metallic mercury directly into the rivers. Where the mining operations involve grinding of soils, mercury is concentrated in tailing deposits and can eventually be mobilized through leaching and particle transports during rains. Mercury lost to rivers as metallic mercury is preferentially accumulated in bottom sediments and generally presents very low mobility. In the Madeira river, mercury concentrations close to operating dredges can reach levels up to 2.6 $\mu g/g$, decreasing to background values ($< 0.2\ \mu g/g$) a few kilometers downstream. Similar behaviour has been observed in other areas.

The most contaminated river systems are those of the Amazon basin where goldmining is traditional and it takes place on a large scale. Contamination of rivers from the Southeast of Brazil such as Mogi-Guacu, Paralba do Sul, etc also have a strong contribution of industrial activities. Even in these cases, levels as high as 0.05–0.49 $\mu g/g$ in the sediments and up to 0.4 $\mu g/l$ in water has been found.

Organic mercury (methylmercury) has been

Table 3
Levels of mercury concentration in air (Malm, 1990)

Area	Mean(ng/m^3)
Porto Velho	
Gold reburning areas—outlets	292 000
Streets near reburning areas	3 200
Teotonio waterfall (20 km upstream)	500
Guajara-Mirim (250 km upstream)	80
Humalta (180 km downstream)	20
Background levels	
Remote rural areas	0.1–10
Urban areas	0.5–50

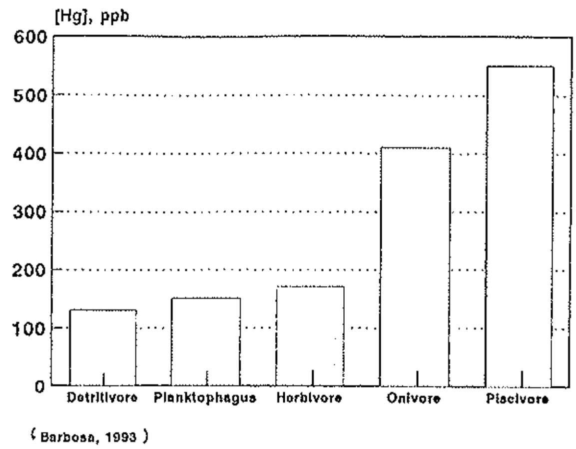

Fig. 1. Merecury concentration in fish samples by trophic level from the Madeira Basin (Barbosa, 1993).

Detritivore $n = 53$	130 ppb
Plankophagus $n = 8$	150 ppb
Herbivore $n = 26$	170 ppb
Onivore $n = 64$	410 ppb
Piscivore $n = 94$	550 ppb

found in sediments of rivers in the Amazon. In fact, methylmercury concentrations reached nearly 10% (0.2–0.6 μg/l) of the total mercury content in water and 2% (0.1–1.9 μg/g) in the sediments.

Atmospheric levels result mainly from the roasting of Au:Hg amalgam and from the purification process. Levels of atmospheric mercury measured in areas with goldmining is shown in Table 3.

Measurements carried out in Alta Floresta, Mato Grosso, an important center of gold production, shows that considerable amounts of mercury lost to the atmosphere are associated with particulated materials (Hacon et al., 1992).

The content of mercury in fish captured in contaminated rivers can surpass the maximum permissible concentration recommended for human consumption. Levels of mercury as high as 2.7 μg/g were found in carnivorous fish captured in goldmining areas (Lacerda et al., 1992). Higher levels were found in larger, older and carnivorous fishes (Fig. 1) following the pattern of mercury distribution typical of organic (methyl) derivatives which shows very slow excretion rates.

Studies on populations living along the Madeira river reported that mercury content in human hair reached levels as high as 26.7 μg/g (Malm, 1990).

The mercury levels in hair of Gorotire Indians (State of Para) was found to range from 3.4 to 6.4 ppm (Gouto et al., 1988). A study carried out with Kayapo-Gorotire Indians reported levels as high as 18.3 ppm of mercury in hair of pregnant women indirectly exposed to mercury. High relationship of organic to total mercury was also found in pregnant women (Ferrari et al., 1992).

Analysis of the mercury content in urine, blood and hair (Tables 4 and 5) of inhabitants of the Amazon region has shown strong correlations with diet and other exposure. As shown in Table 4, the highest average mercury levels were observed in the Munduruku Indians. However, it is difficult to say whether occupational exposure to mercury vapor or intake of mercury via fish consumption is the main factor responsible for this finding (Hacon, 1990).

Although the mercury contamination in the Amazon region has been studied for several groups in Brazil, little has been done to model the effects of the current situation or to forecast

Table 4
Levels of mercury contamination in human hair in different amazonian riverside communities (Hacon, 1990)

Sample origin	Mean	Range ($\mu g/g$)
Madeira river	9.2	0.22–40.0
Munduruku Indians[a]	18.7	10.0–31.8
Gorotire Indians	4.74	3.10–6.34
Carajas	2.89	0.25–15.7
Pocone	0.8	0.3–3.1

[a] Working in the Tapajós goldmining with a fish diet.

the fate of the metal in the region or to study local biogeochemical mechanisms.

4. Cadmium, zinc, arsenic and chromium contamination—Sepetiba Bay

Sepetiba bay is a semi-enclosed coastal lagoon located at about 100 km west of Rio de Janeiro. This bay has been contaminated by industrial activities including milling, metal smelting and plastic and chemical manufaeturing. The most important contaminants are: cadmium, chromium, lead, arcsnic and zinc. Studies carried out in the bay found that 1.6 tons of cadmium, 180 tons of zinc, 2.7 tons of copper, 11 tons of chromium and 4.5 tons of lead arc introduced per year. This represents a large input relative to the dilution capability of this body of water. High concentrations of these metals in sediments and in the marine biota has been found and suggests a possible risk to the local population through consumption of contaminated seafood (Barcellos et al., 1991).

The most important source of contamination is a zinc factory located nearby which dumps industrial waste in an adjacent area which is exposed to both rainfall and contact with seawater. It is believed that about 600 000 tons of waste containing an estimated amount of 50 000 tons of zinc and 200 tons of cadmium are deposited in this area (Barcellos, 1991).

Analysis of the sediment cores revealed significant enrichment in zinc and cadmium after the installation of the industry. In fact, enrichment of 8.1-fold and 15.1 fold were observed in

Table 5
Levels of mercury concentration in Amazonic populations (Barbosa, 1993)

Population	Hg/urine (ng/g)				
	< DL		DL–20		> 20
Goldminers ($n = 109$)	20.12%		42.20%		37.62%
Indians ($n = 194$)	44%		26%		30%
	Hg/Blood (ng/g)				
	< DL		DL–10		> 10
Goldminers ($n = 129$)	62%		5%		33%
Indians ($n = 132$)	39%		2%		59%
	Hg in Hair ($\mu g/g$)				
	< DL	DL–5	5–10	10–20	> 20
Goldminers ($n = 165$)	1.4%	85.5%	7%	6.1%	
Indians ($n = 419$)	0.8%	28.2%	47.5%	22.5%	1%
Riversiders ($n = 384$)	2%	23%	33%	27%	15%

DL = detection limit. Estimated as 2 ng/g for urine and blood and 1 $\mu g/g$ for hair.

the bottom sediments for zinc and cadmium respectively.

Arsenic (1500 tons/year) is used by the same industry in order to purify the electrolytic solution used to produce zinc and cadmium (eliminating nickel, cobalt and copper). Part of the used arsenic is recycled or recovered in the solid waste. The levels of this element found in sediments of the Sepetiba bay range from 0.1 to 80 g/kg in sediments, but the highly contaminated region is restricted to the bay adjacent to that plant (Barcellos, 1992).

Intoxications by arsenic have been reported in workers at this plant and a preliminary survey carried out among 30 workers revealed an average urinary level of 59 μg/l (15–109 μg/l) for the exposed group compared with 14 μg/l (5–28 μg/l) for the non exposed (administrative) group (Machado et al., 1992). A similar situation was observed in relation to cadmium contamination. In this case, levels as high as 93 μg/l were observed in workers working direct in the production of this metal (Pivetta, 1991).

Analysis of chromium, cadmium and zinc in seafood captured in Sepetiba bay show contamination mainly of the filter-feeding molluscs (oysters) with cadmium (from 0.07 to 3.32 ppm) and zinc (from 4.53 to 1258 ppm) and high concentration of chromium (from 0.1 to 9.24 ppm) in all analysed organisms (Pfeiffer, 1985).

Fish, particularly carnivorous, also show some degree of contamination but not as high as in the filter-feeding molluscs. In these fish levels ranging from 0.08 μg/g to 5.3 μg/g for chromium, from 0.02 μg/g to 0.15 μg/g for cadmium and from 0.75 μg/g to 20.0 μg/g for zinc (w/w) was found.

These values show, as expected, that the bulk of the heavy metals introduced into the bay is concentrated in the abiotic part of the marine ecosystem. In spite of this, continued monitoring is necessary in order to prevent health problems caused by an eventual mobilization of these metals.

5. Conclusions

Human and environmental contamination by heavy metals in Brazil, mercury in particular, currently represents a very serious problem and a major risk for future generations given that large amounts of these metals have already been introduced into the environment. Changes in the Brazilian environmental policy are improving the situation mainly by reducing industrial emissions. Tight control of goldmining activities is being implemented but since most of the 'garimpos' are located in remote areas, great difficulties persist.

The influence of the social and economical conditions on the processes of contamination of human and of the environment in Brazil is unquestionable.

Most people living in Developing Countries do not have a clear idea about the true meaning of 'full citizenship' or even of human rights. Their experiences and the history of these Countries do not reinforce these concepts. In this setting the existence of institutions with credibility is essential to overcome this problem. In Brazil a poll carried out some months ago appointed the Catholic Church as the most credible of all institutions. The importance of such institutions clarifying and disseminating the concepts of full citizenship and human rights for the ordinary people, and specially the poorest and the illiterate, is very great. Their work may be a starting point for a global solution to the problem described here.

Some segments of Brazilian society have already started to promote the development of such an 'environmental conscience'. Trade Unions and some political parties have recognised the importance of this subject and this change of behaviour has put some pressure on the government and on companies to decrease pollution and monitor their workers, particularly those working under 'unhealthy conditions'.

Changes in technology and research are needed to control or to eliminate the sources of contamination and to understand and minimize the impact of pollutants already present in the environment. Although the Brazilian government is improving environmental legislation much remains to be done to make it efficient. From the technical point of view, the lack of expertize, the absence of laboratories and of technical and scientific information are important obstacles. The powerful economic pressures associated with unemployment and other social problems makes these policies difficult to implement. Frequently popular or governmental pressure is overwhelmed by economic pressures.

As far as human rights are concerned, neither social class, colour, geography or degree of instruction can justify inequality. Health is a basic right for all. A high degree of economical or technical development of a Country does not constitute a reason for its prevelance over others; on the contrary its responsibility is even greater.

Since most environmental problems in developing countries are directly or indirectly caused by international (multinational/transnational) companies and the government and/or the people of these countries have no power to pressure them, it is likely that the solution of these problems will require international cooperation.

For this reason an international Forum should be created to facilitate the developing countries gaining access to clean and up-to-date technology as well as to all informations necessary to improve the quality of life and of the environment and to protect them against the voracity of economic trusts. Occupational and legal aspects should also be considered.

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Part III

Risk Assessment for Chemicals in Developing Countries

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Methods of risk assessment

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1. Introduction

Risk assessment is a general term used with increasing frequency by both scientists and regulators. Basically, risk assessment is supposed to provide a bridge between research and risk management. Risk assessments contain four more or less distinct parts: hazard identification, exposure assessment, dose-response assessment and risk characterization. All these parts contain elements that need advanced scientific judgement but there are also elements where subjective attitudes come into play. Risks may be expressed in different ways:

- Individual risk
- Population risk
- Unit risk
- Exposure related to given risk level
- No risk

Traditionally, an approach is used involving determination of no adverse effect levels (NOAEL) from studies in humans or animals and subsequently applying safety or uncertainty factors to that value in order to extrapolate from animals to man and to compensate for variations in sensitivity or incompleteness of the data base (for review, see Barnes and Dourson 1988). This approach assumes a threshold for the critical effect and is used for all non cancer endpoints and in most cases also for carcinogens that lack genotoxic activities. For genotoxic carcinogens, a non-threshold approach is used and a multistage linearized mathematical extrapolation is usually applied.

2. Traditional risk assessment assuming thresholds

$$\frac{\text{No adverse Effect Level (NOAEL)}}{\text{Uncertainty factor (Safety factor)}} = \text{Acceptable or Tolerable Daily Intake (ADI or TDI) US EPA = reference dose; rfd}$$

3. Risk assessment: carcinogenic chemicals

Non-genotoxic carcinogens:

- Safety factor approach

Genotoxic carcinogens:

- Linearized multistage
- Extrapolation

Virtually safe dose; Vsd)

- (Tolerable risk 1×10^{-5} or 1×10^{-5})

The overall safety factor can be divided into subfactors which represent the various parts of un-

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certainty and variability in the database (Dourson and Stara 1983).

4. Uncertainty (safety) factors

• Average to sensitive human	10
• Animal to human	10
• LOAEL to NOAEL	< 10
• Short term to long term exposure	< 10
• Minimum to complete data base	< 10
• Critical effects on teratogenicity	10

5. Traditional risk assessment assuming thresholds

Problems:

- Choice of critical effect
- NOAEL dependent on study design
- Choice of uncertainty factors

In the last few years, there has been a dynamic development of better and more advanced methods of risk assessments. An excellent review of the progress in this field is given by Paustenbach, 1989.

Examples of such new trends are: the bench mark dose approach, which is intended to replace the traditional NOAEL/Safety factor approach (Crump 1984, Kimmel 1990),

6. Bench mark dose approach – advantages

- All data from the whole dose-response curve are used
- The shape of the dose-response curve affects the evaluation
- The bench mark dose may be different from the tested doses
- No need to determine the NOAEL
- Allows for estimating the risk at a given exposure level

The physiologically based pharmacokinetic modelling (PBPK), which allows integration of diverse data and takes toxicokinetics into account so that interspecies dosimetric comparisons can be made (Anderson et al. 1993),

7. Physiologically based pharmacokinetic models – PBPK: advantages

- Allows integration and extrapolation using diverse data
- Predicts complex kinetic behaviour
- Enables interspecies dosimetric comparisons
- Allows parameter scaling across species
- Facilitates hypothesis generation
- Identifies areas of needed research

The application of molecular dosimetry, which makes possible the determination of a relevant dose at target organs (Bartsch et al. 1988),

8. Molecular dosimetry: advantages

- Determination of relevant dose at the target or a surrogate target
- Allows integration of relevant dose over time

The application of molecular biology, which is opening up a new arena of possibilities to incorporate mechanic aspects and also bring genetic variations in the populations into the risk assessment process,

9. Molecular biology: advantages

- May allow more mechanistic aspects to be considered
- May allow exposure analysis through changed patterns of mutated oncogenes and/or suppressor genes
- May allow aspects of genetic variability to be considered

Most of these methods are still in the process of development and need validation before they are generally introduced into the process of risk assessment.

It is important however, to remember that the risk assessment never can be made as a mechanical process, there will always be a need for a judgment by skilled experts.

10. Why use expert judgement?

- Scientific data may not speak for themselves; require careful interpretation
- Scientific data may seem conflicting or inconsistent; require judgemental synthesis
- In the abscence of data, assumptions are necessary; requires judgment about plausibility of assumptions
- Choice of and/or construction of models may require judgements that are beyond the expertise of the risk assessor

Recently, there has also been raised an increased interest in the risk assessment of early exposure during pregnancy, infancy and childhood and various attempts have been made to design special test systems to study that problem (ILSI Press 1992, NRC, 1993).

The risk assessment of exposure to chemicals in developing countries may present special problems.

11. Special aspects with regards to developing countries

Toxicity (both short and long term) is influenced by many environmental factors:

- Temperature
- Malnutrition
- Dehydration
- Infections

However, a situation with growing populations and shortage of food and a need for increasing use of agrochemicals may require more sophisticated risk assessment and risk management, both to reduce exposure to hazardous chemicals but also to make possible continued use of needed and beneficial chemicals.

12. Special aspects with regards to developing countries

- Need for more sophisticated risk assessment?
- Need for more exposure analysis?
- Need for more risk management?

Regulation (National and International)
Education
International support

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Pesticides hazards in developing countries

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1. Introduction

Pesticides are widely used throughout the world for the control of vectors of disease as well as for the protection of crops, foodstuffs and other agricultural products from pests.

The term 'pesticides' has been defined as any substance or mixture of substances intended for preventing, destroying or controlling any pests including vectors of human or animal disease, unwanted species of plants or animals causing harm during or otherwise interfering with the production, processing, storage, transport, or marketing, of food, agricultural commodities, wood and wood products, or animal feedstuffs (Food and Agriculture Organization (FAO) 1986). They may also be administered to animals for the control of insects, arachnids, or other pests in or on their bodies (FAO 1986).

Pesticides may be classified in several ways. They may be classified according to the target pests they destroy, for example, insecticide, herbicide, rodenticide and others. They may also be classified according to the chemical class they belong to, for example organochlorines, organophosphorus compounds, carbamates, pyrethroids, nitrophenols, etc. Another system of classification may be according to the degree or type of health hazard involved, such as that developed by the World Health Organization (WHO). Other classification systems, based on combined functional and chemical properties of the pesticide, have also been proposed (Hogstedt 1992).

2. Use of pesticides in the developing world

Developing countries use about 20% of the pesticides in the world (Mowbray 1988) (Fig. 1). However, its use in the developing world is increasing. From 1970 to 1980, the value of pesticides purchased in the Third World countries increased 6.5 fold in constant dollars (World Resources Institute 1986).

3. Exposure to pesticides

Exposure to pesticides occurs under different circumstances. It is therefore important to recognize these situations and vulnerable groups exposed to such situations for prevention of adverse health outcomes resulting from pesticide exposure. The WHO (WHO 1993), identified the different segments of the population and the manner in which they are exposed to pesticides (Fig. 2).

The size of the population exposed, according to the type of exposure, is shown in Fig. 3. The largest sector of the population is exposed to pesticides through exposure on a long term basis at low dose levels, whereas smaller segments of the population are exposed at high level of expo-

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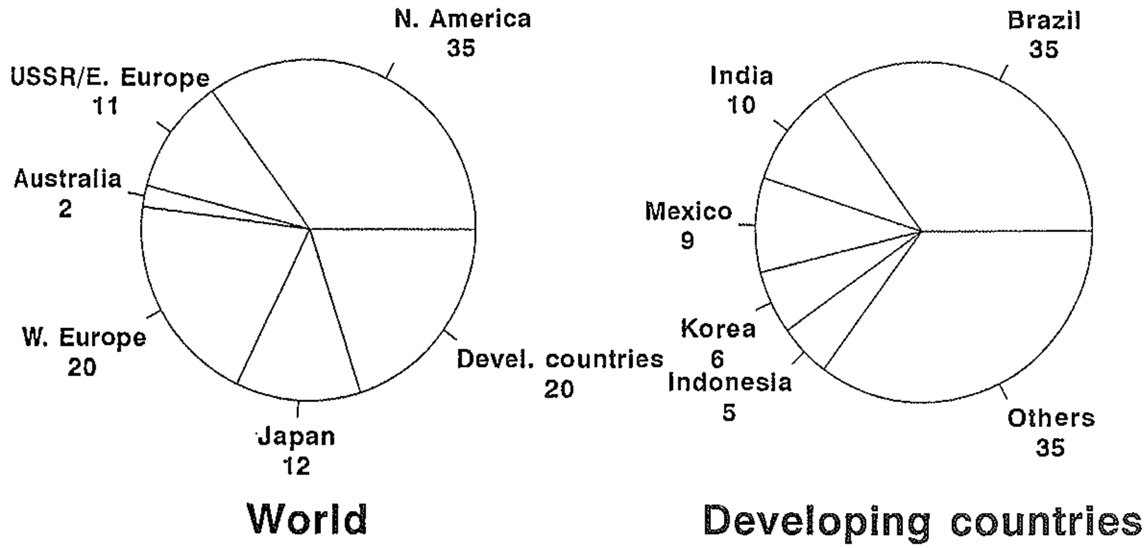

Fig. 1. World pesticide market based on 1981 value (excluding non-crop outlets). From Mowbray (1988), based on Wood McKenzie Agrochemical Services data.

sure either as a single dose or for short periods of time.

It must be recognized, however, that the persons with high level exposure are most likely to show the effects of pesticide poisoning, whereas those exposed to low doses over prolonged periods may not always suffer any adverse effects.

4. Types of poisoning

Pesticide exposure may result in either acute or chronic poisoning. Acute poisoning implies an incident where overt reactions follow closely upon exposure to an agent. In contrast, chronic poisin-

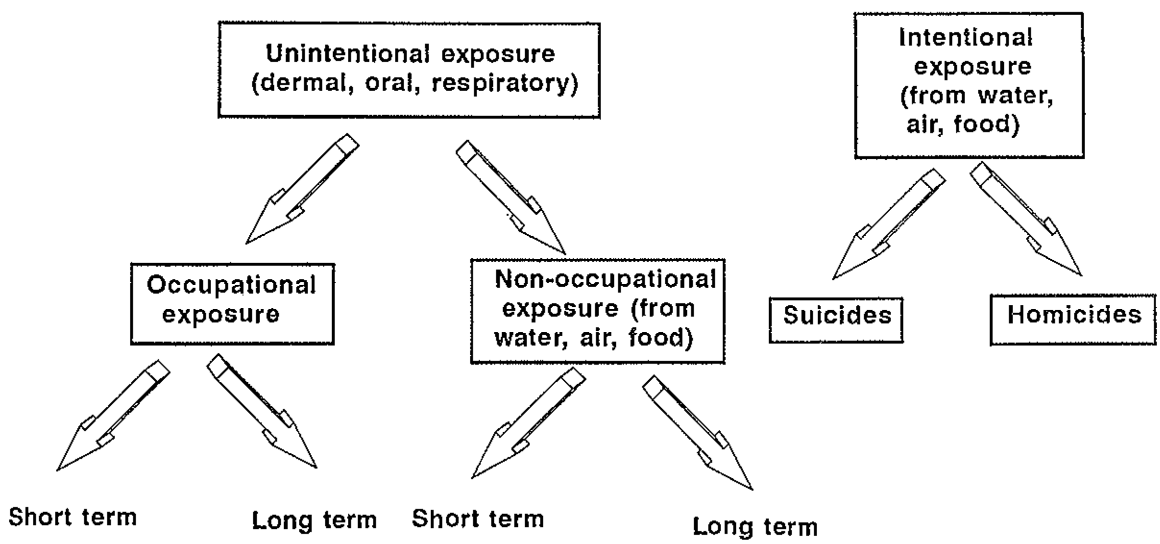

Fig. 2. Types of exposure of pesticides.

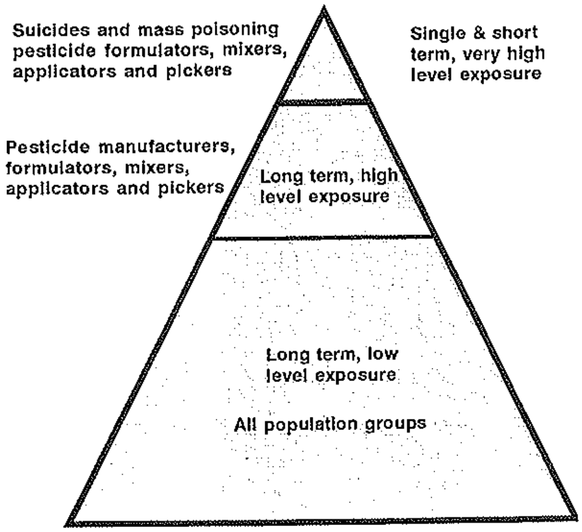

Fig. 3. Population groups at risk of exposure to pesticides. (Adapted from Davies et al 1980, and Davies 1984).

ing refers to the situation where the toxic reactions appear gradually after prolonged exposure to the agent.

In acute poisoning, the incriminating agent is more readily identifiable, but this is not always the case in chronic poisoning. It is much more difficult to assess the significance of the small doses that contaminate workers daily over long periods, because they do not cause clearly defined clinical symptoms.

Both acute as well as chronic pesticide poisoning are health problems which need preventive intervention. There is, however, a need to set priorities in the national context as to which particular problem needs immediate action. Epidemiological data, which will be presented subsequently, indicates that the priority problem in developing countries is certainly that of acute pesticide poisoning.

5. Acute poisoning

The important routes of entry into the body are through the respiratory, oral or dermal routes. For most pesticides, dermal exposure and absorption are the most important routes of entry under occupational exposure situations. The oral route of absorption is extremely important in situations of accidental, suicidal or homicidal ingestion of pesticides.

The important groups of pesticides which cause acute poisoning are the organochlorines, organophosphates, carbamates, pyrethroids and the nitro and chlorophenols (Table 1). Increasingly, it is the organophosphates that are dominant in producing acute episodes of poisoning because of their extensive use as well as their toxicity.

6. Epidemiology of acute poisoning in developing countries

The extent of pesticide poisoning in the world can only be estimated. In making such estimates, there are a variety of pitfalls, with incomplete compilation of data, misdiagnosis, exclusion of the less serious cases, or the study only of hospitalized cases, and data confined to limited regions and not the whole country. In 1973, it was estimated that 500 000 cases of unintentional acute serious pesticide poisoning annually, requiring hospitalization (WHO 1973). Suicide attempts were excluded.

In 1982 (Jeyaratnam, Senewiratne, Copplestone 1982), a national study of hospital cases of acute pesticide poisoning in Sri Lanka, with a population of 12 million, showed that 10 000 persons were admitted annually, with about 1000 deaths. The public health importance of the figures were highlighted by the fact that the deaths due to acute pesticide poisoning for that year were almost twice the total number of deaths due to malaria, poliomyelitis, whooping cough, diphtheria and tetanus, the traditional public health problems of developing countries. It should be pointed out that the figures included suicide attempts and suicides, which comprised about two thirds of the hospitalized poisonings.

Suicides comprise a large proportion of about two thirds of all deaths due to pesticide poisoning in developing countries (Jeyaratnam, Senewiratne, Copplestone 1982; Jeyaratnam, Lun, Phoon 1987). For example, the herbicide paraquat is extensively used as a means to commit suicide. Paraquat poisoning is a major problem in Malaysia particularly, with 74% of such poisonings due to

Table 1
Some types of pesticides and their acute toxic effects

Organochlorines
Early and dominant symptoms are apprehension and excitement, dizziness, hyperecxcitability, disorientation, headache, muscular weakness and convulsions
Organophosphates
Important and early symptoms are usually nausea, headache, tiredness and weakness, abdominal pain and blurring of vision. Measurement of blood cholinesterase levels are useful for diagnosis
Carbamates
Symptoms or poisoning are basically identical to that of organophosphate poisoning. The main difference is that signs and symptoms appear earlier and that the effects last a much shorter period compared to organophosphate poisoning
Pyrethroids
Synthetic pyrethrins (pyrethroids) have low mammalian toxicity. No cases of human accidental poisoning from pyrethroids have been reported
Nitro and Chlorophenols
Onset of acute poisoning is rapid. The main effects are a marked rise in body temperature accompanied by nausea, excessive sweating, restlessness, rapid respiration and heart rate, finally leading to dehydration and collapse. Dinitro-orthoeresol (DNOC) stains the skin yellow (this indicates exposure, and not necessarily poisoning)

Adapted from: Jeyaratnam, 1993a.

suicides, 14% due to accidents, and only 1% due to occupational accidents (Wong and Ng 1984). The reason for this is probably the ready availability of extremely toxic pesticides. While suicide in any society is a social problem which requires attention from many disciplines, the ready availability of these toxic pesticides should be controlled to limit the current epidemic of acute pesticide poisoning in the developing world. Recently, a WHO task group reviewed the available estimates and other pesticide poisoning data and summarized the overall public health impact of pesticides (WHO and UNEP 1990). It stated that 'the estimated 3 million cases of aeute severe poisonings may be matched by a greater number of unreported, but mild, intoxications, and acute conditions such as dermatitis' (these numbers includes suicide attempts). The numbers are depicted in Fig. 4, which is the inverse of the pyramid shown in Fig. 3 (Jeyaratnam, 1990). This is because the associated morbidity is small although a large number of persons are potentially at risk from long term low level exposure to pesticides. On the other hand, although the numbers exposed to high levels of pesticides for short periods are small, their morbidity and mortality are high.

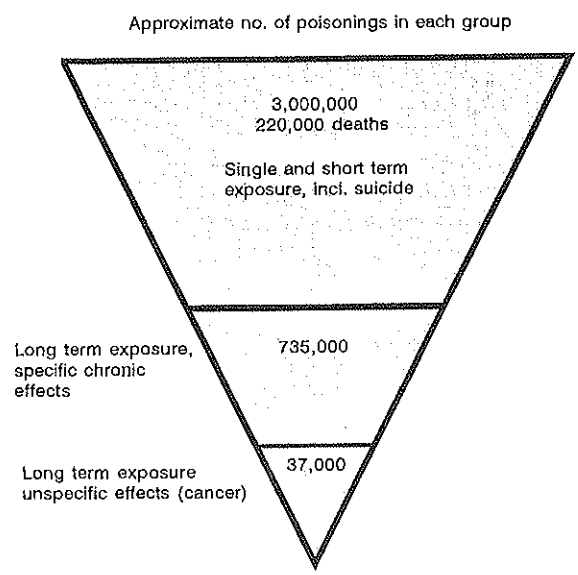

Fig. 4. Estimated overall annual public health impact of pesticide poisonings. Source: WHO and UNEP 1990.

On the basis of the data, WHO states that 'there is no segment of the general population that is sheltered from exposure to pesticides and potentially serious health effects, although a disproportionate burden is shouldered by the developing world and high risk groups in each country'.

7. Pesticide poisonings in developing countries

Data on acute pesticide poisoning in Africa has recently become available. It has been estimated (Choudhury 1989) that 11 million cases of pesticide intoxications occur annually in Africa, including minor cases that did not require hospitalizations. Table 2 indicates the extent of the problem in some of the African countries.

Some data is also available from South East Asia. In Indonesia, although the officially collected records do not indicate a problem, local studies estimate that there are 30 000 cases of pesticide poisoning annually, of which approximately 2400 require hospitalization (Jeyaratnam 1990).

In Thailand, the epidemiological surveillance report records 2094 cases of pesticide poisoning with no deaths for the year 1985, while the data collected by the National Environmental Board record a total of 4046 cases resulting in 289 deaths, indicating great variation even in official records (Kritalugsana 1988). The epidemiological surveillance data in Thailand are routinely obtained on the basis that pesticide poisoning is one of the 54 notifiable diseases in that country, whereas the National Environmental Board collects data from a variety of sources.

A survey of agricultural workers in Asian countries (Jeyaratnam, Lun and Phoon 1987) indicated that 13% of such workers in Malaysia and 5% of Sri Lankan workers reported ever being poisoned by pesticides, and that 7% of the Malaysian workers and 3% of the Sri Lankan workers had a poisoning in one year. On this basis, if it is taken that maybe on average, 3% of agricultural workers in developing countries suffer an episode of poisoning a year, of the 830 million agricultural workers in the developing world, there are about 25 million cases of occupational pesticide poisoning. The bulk of these episodes of poisoning are not recorded, as they are considered minor and self-limiting, and most of the cases do not seek medical attention.

8. Identification of factors influencing poisoning

The workers knowledge of hazards is an important factor for the prevention of acute poisoning. However, this knowledge must be factual and correct. Erroneous beliefs can seriously impair worker's capacity to protect themselves from risks. For example, the most important route of absorption of many pesticides is through the skin, whereas absorption through inhalation is relatively less important. However, many farm workers believe that the inhalation route is the most

Table 2
Number of poisonings in some African countries in the 1980s

Country	Population (millions)	% agricultural labour force	Cases of pesticide poisoning per year
Sudan	24	80%	384 000
Tanzania	23	85%	368 000
Kenya	22	80%	350 000
Uganda	17	80%	272 000
Mozambique	15	70%	240 000
Cameroon	11	80%	175 000
Zimbabwe	10	80%	160 000
Ivory Coast	10	80%	160 000
Malawi	8	85%	128 000
Senegal	7	80%	112 000
Mauritius	2	75%	3200

important and that their knowledge of health risks associated with pesticide use is adequate. This misconception may have arisen because of the obvious odour of pesticides during spraying.

Occupational poisoning episodes occur largely during spraying, mixing, and diluting of pesticides (Jeyaratnam, Lun, Phoon 1987). The use of malfunctioning or defective equipment is also an important factor contributing to accidental acute pesticide poisoning among agricultural workers (Jeyaratnam, Senewiratne, Copplestone 1982). Preventive efforts should focus on these areas. Copplestone (1982) states 'We are more likely to be effective in preventing accidental poisoning by pesticides if we concentrate our activities on those areas where hazard is really high than by trying to give blanket coverage to all users'.

Some of the specific factors contributing to acute pesticide poisoning (Jeyaratnam 1985) include the lack of protective clothing suitable for tropical climates, poor knowledge and understanding of safe practices in pesticide use, use of pesticides (by farmers) in concentrations in excess of requirements, poor maintenance facilities for spray equipment, giving rise to hazardous contamination, and use of pesticide mixtures.

9. Control of acute pesticide poisoning

The starting point in any control programme is to establish the extent of the problem. It is apparent that acute poisoning is a major health problem that almost exclusively a concern in the developing countries. The developed countries, even though using the bulk of pesticides produced worldwide, have almost totally contained the occurrence of acute pesticide poisoning. Only 1% or less of all deaths due to acute pesticide poisoning occur in the developed world, with the balance of 99% or more occurring in the developing world (Jeyaratnam 1985). This situation demonstrates that acute pesticide poisoning is controllable and that lessons on this can be learnt by the developing countries from the developed world.

Yet little has been done. The situation in Sri Lanka is a case in point. Since 1982, published data had indicated that acute pesticide poisoning was an issue of even greater significance than the traditional public health problems of communicable disease seen in developing countries, yet there has been no significant progress since then (Table 3). There is an urgent need to take action.

The knowledge for solving the problem is available. Strategies for containment include the integration of pesticides into sound pest management practices, including intercropping and biological control (Forget 1990), the continued development of safer compounds (Tordoir 1993), the enactment of national legislation, the provision of labelling, sound storage and transport practices (WHO, 1975), the proper training of users, and for the primary health care system to include occupational health care to pesticide users, including prevention, facilities for monitoring of workers and recognition and acute treatment of poisoning (Jeyaratnam, 1990b).

The problem can be solved if all interested parties collaborate. It is wasteful and unnecessary to embark on activities which purely seek to blame the agrochemical industry. It is recognized that pesticides are primarily used for their beneficial effects, but responsible action must be taken to eliminate or minimize the associated hazards (Forget 1990). Thus, the people, national governments, agrochemical industries, scientists and international agencies all have a role to play in any control programme.

10. The role of responsible agents

10.1. The role of governments

The ultimate responsibility to control the use of pesticides so as to minimize health hazards

Table 3
Hospital admissions for pesticide poisoning in Sri Lanka 1984–88

Year	Total number	Deaths
1984	16085	1459
1985	14423	1439
1986	14413	1452
1987	12841	1435
1988	12997	1524

Source: Ministry of Health, Sri Lanka.

devolves to national governments. They must continue, and wherever necessary, strengthen, health education programmes among pestieide users, particularly to ensure safe practices.

Though many countries have enacted legislation, enforcement remains insufficient. As an immediate corrective measure, it may be appropriate to consider selective enforcement or selective legislation to control those pesticides considered to be the most hazardous. For this purpose, the WHO document 'Recommended classification of pesticides by hazard and guidelines for classification' (WHO 1988) would be useful. Pesticides classified as extremely hazardous and highly hazardous should be identified for stricter controls.

Agricultural activities are undertaken in remote rural areas, which often lack health care facilities. The primary health care approach can be regarded as the most suitable for such situations. Such an approach involves the consumer (in this case, the worker) in the process of health care delivery, thereby making it more effective. The primary health care approach also incorporates the multisectoral approach, which is essential in the control of pesticide poisoning.

10.2. The role of the agrochemical industry

The agrochemical industries are often not included in control programmes. This is a great drawback whieh needs to be rectified, as these organizations can contribute significantly to the control of poisoning, particularly in the following areas of: research into developing appropriate personal protective equipment for tropical countries, prevention of marketing of pesticide mixtures, maintenance and repair of spray equipment, research to develop hazard free spray equipment, and the use of safe pesticide containers which are unlikely to be accident prone.

10.3. The role of international agencies

The international agencies, such as the WHO, the ILO, have contributed a great deal in their attempts to control pesticide poisoning. They should continue their efforts, with particular emphasis on edueation and training on safety in the use of pesticides and applied research activities, and should play the role on intermediary for the involvement of agrochemical industries in safety activities.

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Green revolution agriculture and chemical hazards

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1. Introduction

When serious food shortages developed in many developing countries in the late 1950s, efforts were made to improve the productivity of the major grain crops, such as rice, wheat, and corn to help feed the people in these nations. Plant breeders developed short-stem, hybrid grains that responded in a positive way to high fertilizer applications (Kendall and Pimentel, 1993). The yield gains per hectare and total grain production of these hybrids were remarkable, particularly in Asia. The high yields were achieved primarily through the increased use of agricultural chemicals which are produced from fossil energy, a finite resource (FAO, 1984). For the past 40 years fertilizer and pesticide applications have increased, with a corresponding increase in crop yields (Richardson, 1991; WRI, 1992). Recently, however, in the highly productive areas of Asia including agricultural experiment stations, yields in the rice/wheat systems have started to decline (Duxbury, 1993). This situation is alarming to agriculturalists worldwide.

Even before this current situation developed in Asis, it was recognized that ultimately, because of diminishing returns it would be impossible to continue increasing the amounts of fertilizers and pesticides applied to these grain crops (ICIATI, 1977; Goyal and Huffaker, 1984; Huffman, 1989). For example, when nitrogen fertilizer applications are increased from 200 to 270 kg/ha or higher, crop yields are significantly reduced (Munson and Doll, 1959; OECD, 1986). Furthermore, growing energy shortages and increasing costs of agricultural chemicals are expected to constrain the worldwide use of fertilizers and pesticides.

Although the reliance on chemicals in Green Revolution agriculture has contributed to the remarkable gains in the production of grains in the world, especially in developing countries, the extensive use of fertilizers and pesticides has caused serious public health and environmental problems (Bull, 1982; WHO/UNEP, 1989; Pimentel, 1989; El Sebae, 1989; Dinham, 1993; WRI, 1992). In this paper, the effects of pesticides and fertilizers on public health and the environment, especially in developing countries is assessed.

2. Pesticides

2.1. Extent of use

Worldwide the use of pesticides has grown steadily since the late 1940s and at present about 2.5 million tons of pesticides are used at a cost of about \$20 billion each year. Despite the application of this amount of pesticide plus the use of various biological and other non-chemical controls, about 35% of all agricultural crop production is lost to pests (Pimentel, 1991). Insect pests

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cause an estimated 13% crop loss, plant pathogens 12%, and weeds 10% (Cramer, 1967). In the United States, crop losses to pests are estimated to reach 37%, with insects causing an estimated 13% loss, plant pathogens 12%, and weeds another 12% (Pimentel el al., 1991). Thus, pests destroy an enormous amount of food and fiber despite all our efforts to control them with pesticides and non-chemical controls.

Worldwide an estimated 67 000 different pest species attack agricultural crops. Included are approximately 9000 species of insects and mites, 50 000 species of plant pathogens (USDA, 1960), and 8000 weeds (Ross and Lembi, 1985). In general, less than 5% of these are considered serious pests.

2.2. Crops treated

The developed nations use about 80% of the pesticide applied yearly, while the developing nations use about 20% (Table 1). Most of this pesticide is applied to high value crops like cotton, fruit, and vegetables. Although the dosages of pesticides per hectare usually are relatively low, major quantities of pesticides are applied to grain crops like rice and corn because enormous acreages of arable land are planted to these staple crops (Kendall and Pimentel, 1993).

In some developing countries, pesticide use is encouraged because governmental subsidies reduce its cost to farmers. The median level for subsidy of pesticides in developing countries is 44% of the total retail price (Repetto, 1985). In contrast, the Indonesian government found that when farmers had to pay the full price of pesticides they were careful to determine whether they needed to treat or not, and significantly reduced their use of pesticides (Oka, 1993).

Table 1
Estimated annual pesticide use

Country/ region	Pesticide use (10^6 metric tons)
United States	0.5
Canada	0.1
Europe	0.8
Other developed	0.5
Asia developing	0.3
Latin America	0.2
Africa	0.1
World	*2.5*

Data from Pimentel (1993a).

In some developing nations, pesticide use is growing rapidly. For example, in India pesticide use is increasing at about 12% per year (Singh, 1993). At this rate, pesticide use will double in less than 6 years. Chlorinated insecticides, like BHC and DDT, are still in heavy use. Currently, these two insecticides account for nearly 70% of the total pesticides used in India (Singh, 1993).

3. Public health effects

Human pesticide poisonings and illnesses clearly are the highest price being paid for heavy pesticide use. A recent World Health Organization and United Nations Environmental Programme report (WHO/UNEP, 1989) estimated there are 1 million human pesticide poisonings each year in the world, and about 20 000 deaths. In the United States, nonfatal pesticide poisonings reported by the American Association of Poison Control Centers total about 67 000 each year (Litovitz et al., 1990), Blondell (1991) has indicated that because of demographic gaps, this figure represents only 73% of the actual total number of incidents.

Although developing countries use only approximately 20% of all the pesticides applied in the world (Pimentel, 1993), most of the pesticide-induced deaths occur there (Committee, House of Commons Agriculture, 1987). Frequently in developing countries there are inadequate occupational and other safety standards, insufficient enforcement of standards, poor labeling of pesticides, illiteracy, inadequate protective clothing and washing facilities for workers, and in general insufficient knowledge of pesticide hazards (Bull, 1982; WHO/UNEP, 1989; Dinham, 1993).

Food also is highly contaminated in some developing countries. For example, in India more than 80% of the staple grain foods were found to be contaminated with pesticides (Singh, 1993). During chapati preparation, DDT and BHC residues remain in the cooked food and adults receive a daily dosage of 208 and 519 μg, respectively. Therefore, the daily intake of DDT through grains alone is about 69% of the prescribed safe level by the World Health Organization (Singh, 1993).

Because of the heavy contamination of staple foods with DDT and BHC, the safety of mother's milk in India is a major concern. For example, DDT was found to be present at a level of 0.35 ppm in milk samples from Ludhiana and 0.62 ppm in samples from Mukteshwar (a cotton region). Singh (1993) reported that infants in these regions were receiving pesticide dosages that were 13 and 24 times the levels recommended by the World Health Organization.

Both the acute and chronic health effects of pesticides warrant concern. While the acute toxicity of most pesticides is well documented (WHO/UNEP, 1989; Ecobichon et al., 1990), information on chronic human illnesses, including cancer, resulting from pesticide exposure is limited. The International Agency for Research on Cancer found 'sufficient' evidence of carcinogenicity for 18 pesticides, and limited evidence of carcinogenicity for an additional 16 pesticides, based on animal studies (WHO/UNEP, 1989). With humans the evidence concerning cancer is also mixed. Estimates are that the yearly number of U.S. cases of cancer in humans associated with pesticides ranges from 6000 to 10 000 (Pimentel et al., 1992).

Many other acute and chronic maladies are beginning to be associated with pesticide use. For example, the recently banned pesticide, dibromochloropropane (DBCP), used for plant pathogens control, has been found to cause testicular dysfunction in animal studies (Foote et al., 1986) and has been linked to infertility among human workers exposed to DBCP (Potashnik and Yanai-Inbar, 1987). Also, a large body of evidence accumulated over recent years from animal studies suggests that pesticides can produce immune dysfunction (Thomas and House, 1989). In a study of women who had chronically ingested groundwater contaminated with low levels of aldicarb, used for insect control, (mean = 16.6 ppb), Fiore et al. (1986) reported evidence of significantly reduced immune response, although these women did not exhibit any overt health problems.

Of particular concern are the chronic health problems associated with organophosphorus pesticides which have largely replaced the banned organochlorines (Ecobichon et al., 1990). The malady OPIDP (Organo Phosphate Induced Delayed Polyneuropathy) is well documented and includes irreversible neurological damage (Lotti, 1984). Other problems with memory and mood have been documented. There is evidence to confirm that persistent neurotoxic effects may be present even after the termination of an acute poisoning incident (Ecobichon et al., 1990).

Such chronic health problems constitute a grave public health issue, because every person, everywhere is exposed to some pesticide residues in food, water, and the atmosphere. Of the food crops, fruits and vegetables receive the highest dosages of pesticides. For example, about 35% of the foods purchased by U.S. consumers have detectable levels of pesticide residues (FDA, 1990). From 1 to 3% of these foods have pesticide residue levels above the legal tolerance level set by FDA and EPA (FDA, 1990; Hundley et al., 1988). Conceivably, these residue levels could well be higher because the U.S. analytical methods now employed detect only about one-third of the more than 600 pesticides now in use (OTA, 1988). Therefore, there are many reasons why 97% of the U.S. public is genuinely concerned about pesticide residues in their food (FDA, 1989).

The lack of public health data about the effect of pesticide use in developing countries is of particular concern to medical specialists in these regions because these specialists have evidence that Green Revolution agriculture and the intense use of chemicals is having negative impacts on public health (Pimentel et al., 1992).

4. Environmental effects

4.1. Domestic animals

In addition to pesticide problems that affect humans, several million domestic animals are poisoned by pesticides each year, and meat, milk, and egg products are contaminated by these chemicals. Colvin (1987) reported that in the U.S., 0.5% of animal illnesses and 0.04% of all animal deaths reported to a veterinary diagnostic laboratory were due to pesticide toxicosis. These percentages are thought to be higher in developing countries because the regulation and use of pesticides are not well monitored.

Furthermore, these percentages are based only on poisonings reported to veterinarians. Many animal pesticide poisonings that occur in the home or on farms go undiagnosed and are attributed to other factors. In addition, when a farm animal poisoning occurs and little can be done for an animal, the farmer seldom calls a veterinarian, but either waits for the animal to recover or destroys it.

Shiploads of beef from developing nations have had to be destroyed because of excessive pesticide contamination (ICIATI, 1977). As a result, several Central American governments have been forced to establish laboratories to test meat for export for pesticide residues. Frequently, if the meats are found to contain pesticide residues above the acceptable level set by the importing nation, the contaminated meat is sold in local markets (ICIATI, 1977).

Similarly, other nations lose significant numbers of livestock and large amounts of animal products each year due to pesticide-induced illness or death. Reliable data concerning these livestock losses do not exist and frequently information becomes only available when an incident of mass destruction of livestock occurs. For example, when the pesticide, leptophos, was used by Egyptian farmers on rice and other crops, 1300 draft animals were poisoned and lost (El Sebae, 1991).

Of the more than 600 pesticides now in use in the U.S., residue tests are made for only 41, which have been determined by the Food and Drug Administration (FDA) and U.S. Environmental Protection Agency (EPA) to be of public health concern. While the monitoring program records the number and type of violations, there is no significant cost to the animal industry because the meat, including poultry is generally *sold and consumed* before the test results are available. About 3% of the chickens with too high or thus illegal levels of pesticide residues are sold in the market (NAS, 1987).

4.2. Destruction of beneficial natural predators and parasites

In both natural and agroecosystems, many species, especially predators and parasites, control or help control herbivorous pest populations (DeBach, 1964; DeBach and Rosen, 1991). Beneficial parasites and predators keep herbivore populations at low levels, and therefore only a relatively small amount of plant biomass is removed each growing season (Hairston et al. 1960). Indeed, these natural beneficial species make it possible for ecosystems to function normally.

Like pest populations, also beneficial natural enemies of pests are adversely affected by pesticides (Croft, 1990). For example, in U.S. cotton and apple crops, destruction of natural enemies by pesticides has resulted in outbreaks of numerous pests, including the bollworm, tobacco budworm, cotton aphid, spider mites, and cotton loopers in cotton (OTA, 1979), and the European red mite, red-banded leafroller, San Jose Scale, oysterscale scale, rosy apple aphid, wooly apple aphid, white apple leafhopper, two-spotted mite, and apple rust mite in apple crops (Croft, 1990). Significant pest outbreaks also have occurred in other crops, like potatoes and cabbage (Croft, 1990; OTA, 1979). Also, because parasitic and predaceous insects often have complex searching and attack behaviors, sublethal insecticide dosages may alter this behavior and thereby disrupt the effectiveness of these biological controls.

When outbreaks of secondary pests occur because their natural enemies are destroyed by pesticides, additional and frequently more expensive pesticide treatments are made to sustain crop yields. For example, from 1980 to 1985 insecticide use in rice production in Indonesia drastically increased (Oka, 1991). This caused the destruction of beneficial natural enemies of the brown planthopper and the pest population exploded. Rice yields dropped so much that rice had to be imported into Indonesia for the first time in many years. The estimated loss in rice in just a two-year period was about $1.5 billion (FAO, 1988).

Following the incident, entomologist I.N. Oka and his cooperators, who previously had developed a successful, low insecticide program for rice in Indonesia, were consulted by Indonesian President Soeharto's staff (Oka, 1993). Their advice was to substantially reduce insecticide use and return to a sound 'treat-when-necessary' program that protected the natural enemies. Following Oka's advice, President Soeharto mandated in 1986 that 57 of 64 pesticides be withdrawn from use on rice, and pest management practices be improved. Pesticide subsidies to farmers also were eliminated. After a 65% reduction in pesticide applications, rice yields in Indonesia increased 12% (Oka, 1993).

4.3. Pesticide resistance in pests

In addition to destroying natural enemy populations, the extensive use of pesticides often has resulted in the development of pesticide resistance in insect pests, plant pathogens, and weeds. A report of the United Nations Environment Programme ranked pesticide resistance as one of the top four environmental problems in the world. About 504 insect and mite species (Georghiou, 1990), a total of nearly 150 plant pathogen species, and about 273 weed species now are resistant to pesticides (Pimentel et al., 1992).

Increased pesticide resistance in pest populations frequently results in several additional applications of the commonly used and different pesticides to maintain expected crop yields. Additional pesticide applications compound the problem, by further increasing environmental selection for resistance traits. Despite all attempts to deal with it, pesticide resistance continues to develop in all crop pests (Dennehy et al., 1987).

The impact of pesticide resistance, which develops gradually over time, is felt in the economics of agricultural production. A striking example of this occurred in northeastern Mexico and the Lower Rio Grande of Texas (Adkisson, 1972). By the late 1960s, extremely high pesticide resistance had developed in the tobacco budworm, a major pest of cotton. Finally in the early 1970s approximately 285 000 ha of cotton had to be abandoned, because pesticides were ineffective and there was no way to protect the cotton crop from the budworm. The economic and social impacts on the Texan and Mexican farming communities dependent upon cotton were devastating.

Although the costs of pesticide resistance are high in the United States, its costs in tropical developing countries are significantly greater, because there pesticides not only are used to control agricultural pests but are also vital in the control of human disease vectors. Indeed, one of the major costs of pest resistance in tropical countries is associated with malaria control. By 1961, for example, following the early pesticide use, the incidence of malaria in India declined to only 41 000 cases/year. Over time, however, mosquitoes developed resistance to pesticides and the malarial parasites became resistant to drugs used for malaria treatment, and as a result the incidence of malaria in India has exploded to reach about 59 000 000 cases per year (NAS, 1991). Similar problems are occurring in the rest of Asia, Africa, and South America, and the worldwide incidence of malaria is now estimated at 270 million cases per year (NAS, 1991).

4.4. Honeybee and wild bee poisonings and reduced pollination

Honey and wild bees are absolutely vital for pollination of fruits, vegetables, and other crops worldwide. Their direct and indirect benefits to world agricultural production amount to several billion dollars each year. For most crops both crop yield and quality are enhanced by effective pollination. For example, McGregor et al. (1955) demonstrated that for several cotton varieties, effective pollination by bees resulted in yield increases from 20 to 30%.

Because most insecticides used in agriculture are toxic to bees, their heavy use has a negative impact on both honeybee and wild bee populations. In some cotton growing regions of Tanzania and Kenya, bee-keeping by small farmers and others is impossible because of the heavy use of insecticides on this crop (Bull, 1982). Without the pollination some needed food crops can not be grown there. Estimates of annual agricultural losses attributed to reduced insect pollination of crops due to pesticide impacts, may range as high as $4 billion/yr in the U.S. (Pimentel et al., 1992).

Mussen (1990) emphasizes that poor pollination not only reduces crop yields, but, more importantly, it reduces the quality of crops such as melons and other fruits. In experiments with melons, E.L. Atkins (P.C., University of California, Riverside, 1991) reported that with adequate pollination melon yields were increased 10% and quality was raised 25% as measured by the dollar value of the crop.

4.5. Crop and crop product losses

Basically pesticides are applied to protect crops from pests to lessen damage and thereby preserve yields. However, sometimes crops are damaged by the very pesticides used to protect them. This occurs when: (1) the recommended dosages suppress crop growth, development, and yield; (2) pesticides drift from the targeted crop to damage adjacent nearby crops (e.g., citrus adjacent to cotton); (3) residual herbicides either prevent chemical-sensitive crops from being planted in rotation or inhibit the growth of crops that are planted; and/or (4) excessive pesticide residues accumulate on crops, necessitating the destruction of the harvest. Crop losses translate into financial losses for farmers, distributors, wholesalers, transporters, retailers, food processors, and others in the food chain. The costs of crop losses increase when the related costs of investigations, regulation, insurance, and litigation are added to the equation. Ultimately the public pays for these losses in higher marketplace prices.

In the U.S. reliable data on crop losses due to pesticide use are difficult, if not impossible, to obtain. Many losses are never reported to the state and federal agencies because the injured parties settle privately (Pimentel et al., 1992). The same difficulties exist worldwide.

Damage to crops may occur even when recommended dosages of herbicides and insecticides are applied to crops under normal environmental conditions. For example, heavy dosages of insecticides used on crops suppressed growth and yield in both cotton and stawberry crops (ICAITI, 1977). Furthermore, when weather and/or soil conditions are inappropriate for pesticide application, herbicide treatments may cause yield reductions ranging from 2% to 50% (Akins et al., 1976). The increased susceptibility of some crops to insects and diseases following normal use of 2,4-D and other herbicides was demonstrated by Oka and Pimentel (1976).

In addition, crop damage occurs when pesticides drift from the target crops to nontarget crops located as far as several miles downwind (Barnes et al., 1987). Drift occurs with almost all methods of pesticide application including both ground and aerial equipment, but the potential problem is greatest when pesticides are applied by aircraft. With aircraft, 50% to 75% of applied pesticide misses the target area (ICAITI, 1977; Mazariegos, 1985; Ware, 1983). In contrast, from 10% to 35% of the pesticide applied with ground application equipment misses the target area (Hall, 1991).

Crop injury and subsequent loss due to drift is particularly common in areas planted with diverse crops. For example, in 1983 and 1984, nearly $20 million of cotton was destroyed in southwest Texas by drifting 2,4-D herbicide when adjacent wheat fields were aerially sprayed with the herbicide (Hanner, 1984).

Another hazard occurs when residues of some herbicides persist in the soil and crops planted in rotation are injured (Keeling et al., 1989). For example, in 1988/1989, an estimated $25–$30 million of Iowa's soybean crop was lost due to the persistence of the herbicide Sceptor in the soil (Pimentel et al., 1992).

Once harvested most crops are vulnerable to the destruction by other groups of insect and other pests. When proper storage facilities are not available, losses may range from 25% up to 75%. This is especially a problem for grains and other crops stored on small farms in developing nations. When the harvested grains and other crops are treated with pesticides to prevent post-harvest losses, there is a danger that applied dosages may be too high and that the pesticide persists to create major public health problems (Dinham, 1993).

4.6. Ground and surface water contamination

Many pesticides applied to crops eventually end up in ground and surface waters. In the United States the three most common pesticides found in groundwater are aldicarb (an insecticide), alachlor, and atrazine (two herbicides) (Osteen and Szmedra, 1989). Estimates are that nearly one-half of the groundwater and well water in the United States is or has the potential to be contaminated (Holmes et al., 1988). EPA (1990a) reported that 10.4% of community wells and 4.2% of rural domestic wells have detectable levels of at least one pesticide of the 127 pesticides tested in a national survey. According to Nielsen and Lee (1987), it would cost an estimated $1.3 billion annually if U.S. well and groundwater were monitored for pesticide residues. Undoubtedly, similar and even more serious groundwater contamination problems exist in developing countries.

Groundwater contamination with pesticides is a serious problem because about one-half of the world population obtains its water from wells, and once groundwater is contaminated, the pesticide residues remain for many years. Not only are just a few microorganisms able to degrade pesticides but the groundwater recharge rate averages less than 1% per year. Pesticide contamination of drinking water constitutes an important health problem in both developed and developing countries (Bull, 1982; Dinham, 1993).

4.7. Fishery losses

Millions of tons of soil are washed and blown from pesticide treated cropland into adjacent locations including streams and lakes where they contaminate aquatic ecosystems (USDA, 1989). Pesticides also drift during application into streams and lakes and contaminate these aquatic systems. Also, some soluble pesticides are easily leached into streams and lakes (Nielsen and Lee, 1987).

Once in aquatic systems, pesticides cause fishery losses in several ways. These include: high pesticide concentrations in water that directly kill fish; low level doses that may kill highly susceptible fish fry; or the elimination of essential fish foods like insects and other invertebrates. In addition, because most government safety regulations ban the sale of fish contaminated with pesticide residues, these unmarketable fish constitute an economic loss.

Each year large numbers of fish and other aquatic foods are killed by pesticides worldwide. For example, based on EPA (1990b) data we calculate that from 1977 to 1987 the cost of fish kills due to all factors has been $141 million/year; from $6 to $14 million in fish/year are killed by pesticides. These estimates of fish kills are considered to be low for the following reasons. In many instances, no estimate is made of the number of fish killed and also, fish kills frequently cannot be investigated quickly enough to determine accurately the primary cause. In addition, fast moving waters in rivers dilute pollutants so that precise causes of kills frequently cannot be identified. Moving waters also wash away some of the poisoned fish, while other poisoned fish sink to the bottom and cannot be counted. Perhaps most significant is the fact that, unlike direct kills, few, if any, of the widespread and more frequent low-level pesticide poisonings are dramatic enough to be observed and therefore go unrecognized and unreported.

4.8. Wild birds and mammals

Worldwide wild birds and mammals are also damaged by pesticides. These animals serve as 'indicator species' for assessing the general health of a given ecosystem. Deleterious effects on wildlife include: death from direct exposure to pesticides; secondary poisonings from consuming contaminated prey; reduced survival, growth, and reproductive rates from exposure to sublethal dosages; and habitat reduction through elimination of food sources and refuges (McEwen and Stephenson, 1979). Although in developing nations many crops receive relatively little or no pesticide, some crops, such as cotton, receive pesticide applications ranging as high as 30 to 50 kg/ha/year (ICIATI, 1977). Also in the U.S., some crops receive this much pesticide, however, on average 3 kg of pesticide per hectare is applied. In some countries, such as the Netherlands, the *average* amount of pesticide applied per hectare per year may be as high as 21 kg (NIPHEP, 1992).

The full extent of bird and mammal destruction is difficult to determine because these animals are often secretive, camouflaged, highly mobile, and live in dense grass, shrubs, and trees. Typical field studies of the effects of pesticides often obtain extremely low estimates of bird and mammal mortality (Mineau and Collins, 1988). This is because bird and mammal carcasses disappear quickly due to vertebrate and invertebrate scavengers, and field studies can not account for birds that die a distance from the treated areas.

Nevertheless, many bird casualties caused by pesticides have been documented. For instance, White et al. (1982) reported that 1200 Canada geese were killed in one wheat field that was sprayed with a 2:1 mixture of parathion and methyl parathion at a rate of 0.8 kg/ha. Carbofuran applied to alfalfa killed more than 5000 ducks and geese in 5 incidents, while the same chemical applied to vegetable crops killed 1400 ducks in a single incident (Flickinger et al., 1991). The application of carbofuran is estimated to kill 1–2 million birds each year in the United States (EPA, 1989; Mineau, 1993). Another pesticide, diazinon, applied on just three golf courses killed 700 Atlantic Brant geese or 1/4th of the wintering population (Stone and Gradoni, 1985).

Several studies have reported that the use of herbicides in crop production results in the total elimination of weeds that harbour some insects which serve as food for several species of birds (Potts, 1986). For example, the use of herbicides led to significant reductions in populations of the grey partridge in the United Kingdom and common pheasant in the United States.

Pesticides also adversely affect the reproductive potential of many birds and mammals. Exposure of birds, especially predatory birds, to chlorinated insecticides has caused reproductive failure, sometimes attributed to eggshell thinning (Stickel et al., 1984). Most of the affected species populations have recovered since DDT was banned in the United States. However, DDT is still being widely applied in many developing countries (Singh, 1993).

4.9. Microorganisms and invertebrates

Pesticides easily move into soils, where they may be toxic to the arthropods, earthworms, fungi, bacteria, and protozoa. These small organisms are vital to world ecosystems worldwide because they dominate both the structure and function of all natural systems.

For example, an estimated 4.5 tons/ha of fungi and bacteria exist in the upper 15 cm of soil. They, along with the arthropods, make up 95% of all species and 98% of the biomass (excluding vascular plants). Microorganisms are essential to proper functioning in the ecosystem, because they break down organic matter, thus enabling vital chemical elements to be recycled. Equally important is the ability of some microorganisms to 'fix' nitrogen, making it available for plants. The role of microorganisms can not be overemphasized, because in nature, agriculture, and forestry they are essential agents in biogeochemical recycling of the vital elements in all ecosystems (Brock and Madigan, 1988). To date no relevant quantitative data on the extent of microorganisms destruction by pesticides have been collected in any nation, making it impossible to place a dollar value on the damage inflicted on this large group of organisms by pesticides.

5. Fertilizers

5.1. Extent of use

Yearly, about 200 million tons of commercial fertilizer nutrients are added to the land areas of the world (WRI, 1992) (Table 2). From the start of the Green Revolution, which began in the late 1950s, there has been nearly a 20-fold increase in the use of commercial fertilizers. As mentioned, the breeding of crops to tolerate large amounts of fertilizers, particularly nitrogen (N), and the application of large amounts of fertilizers to increase crop yields provide the basis of the Green Revolution (Kendall and Pimentel, 1993).

Because of the importance of N inputs to the success of the Green Revolution and because the N content of fertilizer is the major environment pollutant, N is the focus of this analysis. At pre-

Table 2
Estimated amounts and sources of fertilizer nutrients worldwide

Sources	Amounts in million tons		
	Nitrogen	Phosphorus	Potassium
Commercial fertilizer	80	30	90
Animal wastes	250	60	180
Human wastes	120	30	100
Biological N-fixation	100	—	—
Total	*550*	*120*	*370*

sent about 80 million tons of commercial N are used in world agriculture each year (Tables 2 and 3). Approximately 55% of this is applied to land in developing nations and 45% in developed nations (FAO, 1990). In addition, to the large amount of commercial N applied, other major sources of N include biological N-fixation by microorganisms, livestock manure, and human wastes (Table 2).

5.2. Distribution of fertilizers

Most of the N is applied to grain crops because these crops dominate world agricultural production and are staples of human diets (Kendall and Pimentel, 1993). The regions of the world receiving the heaviest applications of N are China and Europe (FAO, 1990). At present, China is using large quantities of N to help produce needed food for its extremely dense population of about 1.2 billion (PRB, 1993) (Table 3).

Table 3
World use of commercial nitrogen fertilizer, 1990

	10^3 tons	kg/ha
North America	11 245	48
Europe	15 365	110
Oceania	468	17
Former USSR	10 045	43
Africa	2 145	11
Latin America	3 880	22
Asia[a]	9 679	51
India	7 396	44
China	18 855	126
World	*79 078*	*53*

[a]Excluding India and China
Data from FAO (1990).

In Europe the shortage of agricultural land and its high population density, account for the heavy use of N and other fertilizers. For example, the amount of N applied per hectare in the Netherlands is 528 kg, from both commercial sources and livestock wastes (NIPHEP, 1992). In regions of the world where there are heavy applications of commercial N and/or where there are large numbers of livestock per hectare, N-pollution of ground and surface water can increase to hazardous levels. Little, if any, monitoring is currently being carried out in either developed or developing nations to ascertain the causes and seriousness of N pollution. According to Nielsen and Lee (1987) it would cost the U.S. $800 million per year to carry out a satisfactory job of monitoring N in well and groundwater resources.

5.3. Erosion and loss of fertilizers

Surface waters receive N primarily from erosion and leaching. Of the total N applied for crop production, only 25–50% is harvested in the crop. Of the N remaining, 20–50% is lost by erosion, 10–50% by leaching, and 10–50% by volatilization (Pimentel, 1989). Soil erosion in the U.S., for example, averages about 16 tonne/ha per year (USDA, 1991). Note the soil formation rate under agricultural conditions is only about 1 tonne/ha per year, emphasizing the magnitude of losses incurred by erosion (Pimentel, 1993b). One ton of rich agricultural soil washed into surface waters may contain as much as 4 kg of N, 1 kg of phosphorus (P), and 20 kg of potassium (K) (Alexander, 1977; Greenland and Hayes, 1981). Therefore, the loss of 16 tonne/ha per year of soil, containing about 64 kg of N, is more than the 48 kg/ha per year of N applied per hectare per year in the U.S. (FAO, 1990). Troeh et al. (1991) report that the U.S. loses an estimated $18 billion annually because fertilizer nutrients are eroded from the land.

Through leaching and soil erosion, N is also reaching surface waters. In the U.S. the amounts of nitrate-nitrogen in most lakes and reservoirs are usually quite low or below 0.1 ppm (Pimentel, 1989). This is because aquatic plants take up and utilize the N almost as fast as it is available. Streams usually have higher concentrations of nitrate-nitrogen than lakes, and the concentrations may range from 0.1 to 0.5 ppm (Pimentel, 1989).

As N use increases in Green Revolution agriculture, the pollution problems grow as well.

5.4. Public health problems

The impact of fertilizer nutrients, especially N, on human health is relatively minor compared with that of pesticides. The primary health concern is the level of N in drinking water. For instance, when infants ingest drinking water with nitrate-nitrogen levels above 10 ppm (10 mg/liter), they may develop methemoglobinemia or cyanosis (NAS, 1972; EPA, 1986).

The recommended acceptable limit of nitrate-nitrogen in drinking water in the U.S. is 10 ppm, this is about the same as the 50 ppm of nitrate recommended as the acceptable limit by the World Health Organization (WHO) (OECD, 1986; NIPHEP, 1992). WHO's maximum acceptable limit is 100 ppm of nitrate (Conway and Pretty, 1988).

In addition to contaminating water supplies, the heavy application of nitogen fertilizer (160 kg/ha or higher) to some crops, especially leafy vegetables results in a high N content (Shuphan, 1972). When such vegetables, as spinach, are consumed by infants, aged 2–10 months, they may develop methemoglobinemia (Shuphan, 1972).

Livestock can also be adversely affected by nitrate-nitrogen. With concentrations of about 5 ppm in drinking water, methemoglobinemia may occur in young animals (Pimentel, 1989). The afflicted animals show cyanosis, rapid breathing, and extreme respiratory problems (Shuval and Gruener, 1972). With prolonged periods of exposure, livestock may experience reduced milk production, vitamin A deficiency, thyroid disturbances, and reproductive difficulties and abortions.

5.5. Environmental effects

5.5.1. Eutrophication

When lakes and rivers are polluted with N, P, K, and other nutrients from eroded or leached fertilizers, livestock and human wastes, algae and other micro- and macro-plants frequently explode in growth. The enrichment and eutrophication of waterways comes from the various sources listed in Table 2.

Perhaps the most serious effects of heavy eutrophication are fish kills and overall degradation of aquatic ecosystems. The dense growth of plant materials and subsequently their rapid decomposition, depletes oxygen in the water, causing severe fish kills (Halasi-Kun, 1981).

In addition to fish kills, heavy weed and algal growth restrict the recreational use of the aquatic ecosystems. It is unpleasant to swim in ill-smelling algal growth or heavy growths of macro-weeds. Also, boats are nearly impossible to operate in heavy weed growths. Control of aquatic weeds without first controlling the enrichment caused by fertilizer nutrients is impossible.

When lake and river enrichment becomes severe, many fish and larger invertebrates die and population outbreaks of small plants and animals take place (Pimentel, 1989). The outbreak of smaller organisms drastically reduces the biological diversity of the polluted aquatic ecosystems. Most of the organisms high in the trophic system, such as fish and the large invertebrates, are greatly reduced in number or lost from the system, and the aquatic ecosystem becomes unstable (Lo Pinto, 1981).

6. Conclusion

The success of the Green Revolution was made possible by the development of grains that tolerate high levels of fertilizers. Basically then, higher crop yields realized have been dependent on the 20–30-fold increase in the use of agricultural chemicals, primarily fertilizers and pesticides supplied from fossil fuels. Now 30 years after the initiation of the Green Revolution technologies, crop yields have leveled and in some regions are beginning to decline.

Throughout the world, the heavy use of pesticides and commercial fertilizers is causing millions of human poisonings and several thousand deaths each year, especially in developing countries. Overall pesticides appear to have a greater impact than fertilizers on human health and the environment. Chemical pollution in agriculture costs about $100 billion in diverse public health and environmental damage each year worldwide. The higher proportion of human pesticide and fertilizer poisonings and deaths occurring in developing countries reflects existing conditions of inadequate occupational and other safety standards, insufficient enforcement, poor labeling, illiteracy, and insufficient knowledge about the hazards of pesticides and fertilizers.

Continuing shortages of arable land combined with the rapid growth in the world population, that is expected to double in the next 40 years, will require increased agricultural population, especially in developing nations. To achieve this, more chemicals will probably be used, while the public health and environmental problems associated with their use will intensify. Governments and the public policy makers must therefore find ways to protect human health and the stability of the environment from the pollution created by the heavy use of agricultural chemicals.

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Part IV

Impact of Transfer of Chemical Technology of Developing Countries

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Experience from activities in the Third World to improve the knowledge and ability to determine chemical hazards

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1. Introduction

Thirty-two years ago I went on my first mission to a developing country in order to set up an operating residue analysis laboratory. In the following I will try to summarize experiences from practical work in more than a dozen countries mostly situated in tropical zones with a rather bad infrastructure. The knowledge has in most cases been very frustrating due to the increasing insight of the threats from the expanding use of toxic chemicals in relation to the difficulties to create a working chemical laboratory to control the situation.

2. Case stndies

At my first mission thousands of people suddenly developed severe nervous symptoms ending up with tremor and in many cases death. The intoxication was suspected to be caused by the intake of methylmercury from a seed dressing agent. The source could be from imported wheat aimed as planting seed. Bad harvest and starvation made the farmers eat the imported seed. The aim of my mission was to set up a laboratory at the medical school and the agricultural college in order to be able to measure levels of mercury in human blood and foodstuff. This happened in the early days of environmental science where even the so-called developed countries were suffering from unknown effects of pesticides, thus being developed.

Ten years later, in another tropical country I was engaged in setting up an analytical laboratory at the university. The aim was to be able to analyze wildlife and their accumulation of chlorinated pesticides such as DDT, Lindane and Dieldrin. Afterwards my colleagues and I went out on a sampling trip. One day we bought dried fish sold at the roadside by some local people. These fish were also analyzed and found to contain Lindane up to a level of 90 mg/kg, which was about 100 times above the maximum level accepted for food consumption. We went back to the fishermen to interview them, trying to identify the lake where the fish were caught. The men told us that they had found out that Lindane besides its effect against insects also was very toxic to fish so they bought it in the local store and sprayed the lake. The fish were killed and floated up to the surface, easy to collect of course. These people, from their point of view, acted quite logical and focused on an important point of the draw-back of introducing toxic chemicals in developing countries. The same basic intelligence was shown in the mercury case I mentioned before. The farmers were of course told that the mercury treated seeds were toxic. They had however, a natural suspiciousness against authorities so they made their own experiments and gave the

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seed to hens and they did not die. Of course the farmers, quite logical, draw the conclusion that if the treated seed was safe for a small bird it could not be toxic to a big human being. In a third tropical country they intended to farm shrimps and milkfish living in brackish water, by mixing run off from rice paddies and sea water in dams along the shore. The shrimps died often before harvest. Through chemical analysis it could be proved that the death was caused by pesticides used in the ricefields. It was not known that shrimps are closely related to insects and thus suffering from the pesticides.

My last example is also related to uncontrolled release of mercury. In gold washing, metallic mercury is used in very big quantities to amalgamate the gold at the riverside. Big quantities of mercury is lost to the river and another part is lost to the atmosphere in a primitive system to recover the mercury via destillation. In a well documented process mercury is converted biologically to methylmercury, the same chemical that caused the death from the dressed wheat above.

I hope that these few examples will convince everybody that the ability of carrying out highly sophisticated chemical analysis is a must, when introducing toxic chemicals into the environment. Chemical industries developed new pesticides only from the point of view that they should be effective against the pest and have a long time of duration. They hardly knew anything about their adverse effect on the environment. After World War II the chlorinated pesticides were introduced all over the world. Not until the end of the fifties heavy draw-back from the use were indicated by Rachel Carsson. Not until the beginning of the sixties the development of new analytic instruments and detectors made it possible to analyze residue levels in biota. It was a big shock to find that DDT and its metabolites were accumulated in the food webs, often with a magnitude of ten for each step in the chains. It was also estimated that the half life in soil in the temperated zone could be 30 years.

In order to illustrate the demand to be able to analyze a fish for DDT at the ppb level, that is 1 g per ton of fish, it is the same as to find one white man among all chinese in China. Furthermore, it should also be possible to determine whether he is 1.6 or 1.8 m tall. The difficulties in setting up laboratories in developing countries shall be seen in this perspective. During the sixties and up to the present the growing environmental science were able to point out a long list of adverse effects from the use of persistent chemicals against pests and other mostly chlorinated substances such as PCB that had escaped from the closed systems they were aimed at.

3. From the frying pan into the fire

In the early seventies the use of DDT and similar substances were black listed globally. From may point of view this ban was not justified with respect to tropical countries. This point is not if it was right or wrong, but only that all research and knowledge was based on the behaviour of the chemicals in temperated zones of the world. Here the ban was well motivated partly because of halflife of 30 years, because of accumulation in food webs, because of adverse effects and last but not least here the insects did not transfer lethal diseases to human beings. Introduction of a chemical has, without saying, to be tested in the environment where it is going to be used and therefore, resource must exist there.

In a first phase following the western ban of pesticides surplus stocks were sold cheap to the Third World. Thus even Sweden was trying to sell organic mercurials abroad. Such a substance should never ever be used anywhere in the world. In the next phase when the surplus stocks were sold out, for example, Toxaphene was introduced. Partly because this substance had a very low toxicity to mammalian but mainly because it already existed in the market but was not covered by the DDT-ban. It was invented during the forties but was never able to compete with DDT. Toxaphene was also chlorinated and within a few years the production figures were higher than the highest DDT ever had, but it was more expensive than DDT and thus hard to afford for poor countries. Furthermore the introduction of Toxaphene was an almost criminal mess. It was not so accumulating as DDT but apart from this it suffered from all the same disadvantages as DDT and a number of its own. Thus Toxaphene was extremely toxic to fish (cf. the use of Lindane by fishermen) and it was proved also to cause liver cancer and was genetically active. From the frying pan into the fire. Some thousand tons later it had to be banned too.

4. Temperated versus tropical climates

As mentioned before the most discriminating property with DDT is its long halflife in the environment as proved in temperated climates. From an insect protection point of view this was a big advantage. The crops were protected for a long time. Therefore, the modern phosphorous pesticides and pyretrines are not really able to substitute DDT as they have a short duration period. Eggs of many pests are not attracted by the pesticides and it is therefore necessary, especially in tropical climates, to spray within very short intervals. Furthermore, the phosphorous compounds are rather toxic so the farmers have to be well protected. The pyretrines that are harmless to man, fish etc. are on the other hand so expensive that they are not alternatives to farmers in poor countries. To conclude: in the past almost all development of pesticides have been carried out to fit to the conditions in a rich western country situated in a temperate climate. In the future it must be a matter of course that a substance should be tested in the very environment where it is aimed to be used. One important term that should be tested besides obvious tests about effects against pest and non-toxicity to non-target organisms is its halflife in soil where it should meet the criteria to disappear before the next growing season. On the basis of common knowledge it is not excluded that DDT used in a proper way in a tropical country could meet this criteria. The reason is as follows. In hot climates the biological halflife is short. Furthermore, during a dry season following the rainy season, the common water co-destillation law for water unsoluble substances may pass the DDT to the atmosphere. This is of course not enough, the substance should also be degraded. DDT is, however, a so-called aromatic chlorinated compound, which is known to lose chlorine when exposed to the shortwaved, high energetic ultraviolet that can be expected at low latitudes. Own experiments carried out in Nigeria, proved that DDE, the most biologically stable metabolite of DDT, in ampoulles hanging outside the lab disappeared totally from one day to the next. Even DDT was effected. Lindane or Toxaphene which are alicyclic to there property was totally stable. The accumulation of DDT in tropical countries is still under discussion. However, DDT is so discriminated that it should never come back, but well some of its better properties when creating new substances especially for the use in tropical countries. Thus the high DDT levels found in human blood and in mothers milk may not have its background in, for instance, fish consumption but originate from partly indoor spraying against mosquitos or a post harvest spray to protect fruit and vegetables. It is still a good idea, when visiting such countries only to eat fruit with living pests on. To conclude, all introduction of a new pesticide should be tested in the country where it is aimed to be used. In a cost benefit analysis it is important to insure that no accumulation in soil and biota will take place. Consequently it is of great importance that qualified chemical laboratories are available, which today is very seldom the case and in the following I will try to put forward some of the reasons. Finally, I will try to summarize what could be done in the future to overcome the problem.

5. Infrastructure in developing countries

One of my first missions was on behalf of UNESCO to visit several African universities in ten countries in order to evaluate their interest and ability in environmental chemistry. Generally speaking, their interest was big and the theoretical knowledge was good. On the other hand, their ability from a practical point of view was bad. Even at institutes that had appropriate instruments, these most often were labelled: occasionally out of order. Also the new literature was hard to find, and common laboratory practice among the students was not at a level that was acceptable as a base for setting up a residue laboratory.

A common problem in most countries in the

Third World is that electric- or water-supply is cut off almost everyday and that high humidity will corrode the sensitive electrical parts in the analytical instruments. In this connection it is fair to blame the instrument companies for selling instruments to these areas that are not suitable and where one service organization often have to serve half a continent causing very expensive service costs and long waiting time.

6. Manpower

In many developing countries the practical work is done by low educated technicians. A PhD is not expected to work at the laboratory bench. To try to overcome this cultural calamity young scientists are often offered scholarships at specialist laboratories in the West in order to adapt a working discipline necessary to run a pesticide analytical laboratory. Unfortunately, one of two alternatives often occur. These, often very intelligent young people, adapt themselves to the western lifestyle and do not want to go home again. As they often have no problem to compete with young western scientists the consequence is a severe brain drainage. The other alternative is, that if they go back home, they often do not have the mental strength to fight against the cultural fenches at the same time as they become frustrated about all lack of chemicals or non-working instruments.

7. Training courses

In the field of pollution analysis many international organizations have run training courses for groups of scientists from the Third World and held at university institutions in the West. However, sometimes the participants were not those that were aimed to work practically. It was up to the participating countries to select the members in the workshop. Due to nepotism we could have the cousin to a primeminister that liked to have a holiday in the West. As a consequence of these costly mistakes FAO arranged a successful six weeks training course in Manilla with participants from most countries in the Far East. It was pointed out sharply that the trainee should be those technicians that were aimed to carry out the practical work. The training course resulted in a group of young people that seemed to be very motivated and were able to analyze even low levels of DDT in their own blood. Unfortunately, even this construction had a trap built in. The participants passing the course got a fine diploma which rendered them a promotion when they came back home causing a new vacancy at the laboratory bench. Trying not to paint in too dark colours I would like to tell a sunshine story also. One of the participants in Manilla were able via her promotion to climb up the ladder and is today director general of the Environmental Chemical Laboratory in her country.

8. Demand on Western instructors

Many instructors engaged in development in the Third World comes from specialized university institutions. They are doing it for idealistic reasons in combination with maybe a 'viking' spirit. This engagement has often a rather low academic meritation value. He has often no knowledge about the lifestyle he has to be confronted with. Cultural confrontation therefore often occurs. There is a great wisdom in the old sentence: 'When in Rome, be as the romans'. One problem is obvious. If you are young and your mission is to train the personnel in practical laboratory bench work you may suffer from the low status this discipline has in the country. If progress has to be accomplished it is absolutely necessary to bring about changes in this attitude. Therefore, in a first phase the best is if an older person with a professor title is the instructor. He will at the same time, in general, be better able to pass the different levels in the bureaucratic pyramid and reach the top in order to get things done.

9. How to create a working chemical laboratory in the Third World

In my opinion the first step in setting up a laboratory in a developing country is that the chemical instructor is sent out for at least 1 week to the selected institute to study the infrastructure and get to know the local staff and to inspect any instruments already present with respect to fitness and condition. It is recommendable, if possible, to try to select one person to go through a training program. When the instructor returns to his institute he should order appropriate instruments for the beginning of a 6-week training course so that the trainee could work with his own instrument and all services necessary could be done immediately. When the course is over the instrument is shipped back to the institute. It is my experience that it is beneficial if three or four trainees are running the training program at the same time. Such a team will be able to support each other and not feel so isolated in a strange and new environment. This arrangement is also very beneficial from an economical point of view.

When returning back home the trainee should be giving a period of time to apply his knowledge, but after a couple of months the instructor should arrive at the institute for a trouble shooting period of at least 14 days, but he should also be able to return for more time if needed. He must also try to keep running contact and not think that no news is good news. It is also necessary to emphasize that even in the best case it will take between 1 and 2 years to get the laboratory working. The analytical part in a joint biological/chemical program, the chemistry part should start 1–2 years before the biological part. In many cases in the past it has been the other way around. The above model has now been applied in three developing countries and I think it is a good frame. The most serious problems have been on the infrastructure level that do not seem to work well in many countries. Thus, it has been almost impossible to get pure gases without which the instruments lose all their sensitivities. Another problem is the accessibility of clean solvent at the local chemical companies.

Last but not least are the problems with water — and electrical supply and aircondition. The project is like warfare, if a single supply line is missing the war can be lost.

As these problems so far, are common for most countries it might be a good idea to try to overcome the difficulties in a separate research project placed in a western country where the condition in a laboratory in the Third World is simulated. If support for such a project could be financed by an international board millions of dollars could be saved in the future, and also, a lot of human disappointments and ending up with a safer and cleaner environment.

Another problem that could be overcome if some activities are centralized is the problem with shifting personel. A person that has gone through the steps in the training program is today almost indispensable. But if money were available it should be possible to utilize modern videotechnique where a professional photographer could follow the project from beginning to end. The actors should thus be the trainee themselves and any international organization should be allowed to use the video to send where necessary, and the speakertext could be translated to any language. Any technician can then run the video over and over again until he masters all details.

Somebody may put forward the question if it is really worth the effort to set up residue laboratories in the Third World. If the samples instead were sent to a commercial laboratory in the West they could be analyzed much cheaper. I hope it is evident from my presentation that the answer should be NO.

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Biotechnology and the production of resistant crops

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1. Introduction

In the past, breeding new crop varieties has been restricted to sexual crosses between different lines of the crop species and with its wild relatives. The advent to genetic engineering now puts the whole of the living world potentially at the disposal of breeders because traits can be handled as molecules. It is now routine, for example, to introduce genes from bacteria and viruses into plants as well as genes from completely unrelated plant species.

The term "resistant" in the context of crop plants can be used in at least three different ways:

(1) resistant to pests and diseases
(2) resistant to herbicides.
(3) resistant to abiotic stress, e.g. drought, Salinity.

The case for resistance to pests and diseases is self-evident because plant productivity diverted by pests and diseases cannot be turned into yield. Many pests and diseases can be controlled by pesticides, but these, and their costs of application, are extra inputs for the grower. The plant itself is the first line of defence against pests and pathogens, and use of resistant varieties by growers can both reduce inputs and the environmental impacts of pesticides (see Pimentel, this volume).

The case for herbicide resistance is that there are many parts of the world where some crops could be grown, but, at present, are not because of weed problems. The weeds can be controlled by appropriate herbicides, but, unfortunately, the crops themselves are sensitive to the same herbicides and post-emergence weed control is not possible. If such crops can be made resistant to herbicides, then the range of crops available to growers in a particular area may be increased.

Resistance to drought is most desirable where rainfall or irrigation water is limited or unreliable, and resistance to salinity would allow crops to be continued to be grown in areas where ineffective management to irrigation has raised the salt-content of the soil. In both cases, crops with these properties could also allow marginal lands, which, at present cannot support crops, to be exploited.

Most of the activity in plant genetic engineering has been concentrated on the first two of these categories. In most of the developed world the field-testing of genetically engineered crops is regulated by government, although the form of the regulation varies from country to country. The existence of government records has made it possible for the OECD to collate approvals for the release of genetically engineered plants in a database, BIOTRACK, and hence monitor progress of this new science (OECD, 1991). From these data it is possible to gain an overview of the direction that the industry is taking. However, it must be said that because of differences in the way that different countries regulate and report field releases, the data can only indicate general trends. Moreover, information from the international plant breeding institutes (e.g. IRRI, CIMMYT, ICRISAT) is not included.

A recent report (OECD, 1994) indicated that

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between 1986 and the end of 1992, there had been approximately 1000 field releases to genetically engineered plants in the developed world. About one-third of these involved oilseed rape and a further 15%, potato. In other words, roughly half of the approvals were for just two crops, the remaining half being spread across twenty-five different crops, none of which individually exceeded 10%. The major small gain crops are hardly represented at all. To some extent this can be explained because the technology for engineering these crops has only recently been developed.

Of traits that have an agricultural application, by far the largest number of approvals, about one-half, have involved herbicide resistance, a further one-third disease, virus, or insect resistance and less than 1% abiotic stress resistance. Taking combinations of traits and crop, about one quarter of approvals were for herbicide resistance in oil-seed rape. The next most common combination was virus resistance in potato, at about 5%.

From these data, it can be seen that despite the promise of the new technology, the effort, so far, has been with crops and traits that are amenable to manipulation, rather than determined by the economic necessity of the product.

For the purposes of this paper. I shall assume that the technical difficulties that have so far dogged the applications of genetic engineering will be overcome.

The concerns about engineered forms of resistance can be divided into two discrete, but overlapping groups. The first is to do with the trait, its host plant and the environment into which it is to be introduced — it is these concerns that most recent legislation in developed countries has addressed. The second group of concerns arises from the use and exploitation of the engineered crop and includes social and economic factors.

2. Trait, host and environment

Nearly all guidelines, whether statutory or voluntary, implemented in the developed countries take as the foundation of any risk or safety assessment for the release of genetically manipulated plants, an appraisal of the trait itself (e.g. its source and its function), the host crop plant, the environment into which it is to be released, and their possible interactions. In general, the developed countries have followed the guidelines for sound development of a biotechnological product outlined in the OECD booklet "Recombinant DNA Safety Considerations" (1986). Although there are considerable differences in the form of these regulations, the data requirements are comprehensive — the list of questions in EEC Directive 90/220/EEC runs to three closely printed pages — other countries' regulations have similar lists, either explicitly in the regulations or in the background documents. Despite the different legistlative environments in the developed countries there is a strong will to harmonise requirements and this carries with it a commitment to mutual recognition of data.

The major concerns are:

- gene transfer to wild or seedy relatives by cross-fertilisation
- the ability of the manipulated crop to become established within or beyond the field where grown
- the effects of the trait on local flora and fauna
- genetic and phenotypic variability
- properties of the plant line conferred by the vector system used to transform the plant
- properties of the line which may affect worker safety.

These generic concerns are just as applicable in a developing nation as they are in the most economically developed countries. But it is worth pointing out that the level of concern, i.e. the severity of a hazard is very dependent on context. For example, in most of the developed world, the major crop species have been introduced from elsewhere, but many developing countries are the centres of origin, or centres of diversity, of these same crops. The risks of introducing alien genes into wild relatives may be, therefore, somewhat higher in developing countries. This, of course, ignores the fact that many indigenous crop species in the developing world have been selected from the native flora, and are only slightly changed from their wild progenitors, with which intercrossing is not merely possible but a regular occurrence (Simmonds, 1976).

In the context of 'resistant' crops, this raises some special concerns, for example:

1. A crop engineered for, say, insect resistance, could breed with a wild relative, populations of which had previously been kept under control by the target insect. The introgression of insect resistance into the wild species could then convert it from an annoying weed into a more serious problem (Gliddon, 1994).

2. Carry-over of a crop, from seed dropped during harvest, or inefficient harvesting, is a constant agricultural problem. If the crop has been manipulated for herbicide resistance to allow a herbicide to be used on the crop for weed control, this immediately removes that herbicide as an option for control of carry-over. For some crops which have a propensity for weediness outside cultivation, the options for control will be similarly limited.

3. Social and economic concerns

During the 1960s, agriculture in the developing world was transformed by the Green Revolution. Not a small part of this success was due to the development of crop varieties which were more resistant to pests and diseases than the lines which they replaced. The very rapid success of the Green Revolution exposed problems in agriculture which had not been previously manifest to the same extent. Fifty years ago plant breeding might have been considered a benign technology, but the Green Revolution showed that even conventional breeding and agricultural practices carried risks with them.

Plant biotechnology could take agriculture to the verge of a second revolution in plant breeding, and, at this juncture, it might be worthwhile to take some time to examine what lessons can be learned from the Green Revolution, so that avoidable mistakes can be eliminated as the new revolution progresses; it is rare indeed that an opportunity arises to avoid, or even correct, the mistakes of a previous generation.

Three linked major biological problems arose from the Green Revolution (for discussion see Barrett, 1981):

- Genetic vulnerability
- Narrowness of the genetic base of many crops
- Genetic erosion

Prior to the Green Revolution, growers tended to use traditional locally adapted crop varieties. These varieties were often very variable in themselves and there was diversity between different regions. Moreover, traditional cropping practices might include the planting of several different crop species in the same field (intercropping). The Green Revolution displaced this diversity with genetically uniform monocultures. If a disease, or pest, was able to overcome the resistance of these crops, then this uniformity made the crop very vulnerable to rapid spread of the disease, or pest. The very success of the Green Revolution varieties also meant that these same varieties might be used as parents in breeding programmes across large areas of the world. Therefore, the range of genetic material used in breeding programmes was reduced in comparison to what it had been prior to the Green Revolution. Selective breeding can only be carried out if there is genetic variation and the highly variable indigenous varieties of the Third World have, in the past, provided a valuable breeding resource, both for local breeders and the developed world. The rapid displacement of indigenous crops by the uniform Green revolution varieties rapidly eroded this resource. To these problems might be added the reduced ability of agriculture to respond to sudden changes in the environment (both biotic and abiotic); when problems arise there may not be any immediately available varieties to fill the breach — the "reserve strategy" (Duvick, 1977). Genetic manipulation of crops has the potential to generate very similar problems, but these are not problems inherent in the technology but in economics and how the technology is exploited.

Development costs in plant breeding and biotechnology are hard to obtain because of commercial confidentiality, and much of what is public is largely anecdotal. However, at the present time, it would appear that the costs of producing a variety by genetic engineering may be between one and two orders of magnitude greater than by conventional means. Even allowing that the start-up costs of a new technology are higher than for a more mature technology, the present techniques in plant biotechnology would not appear to offer a cost advantage over conventional methods. If higher costs continue to be characteristic of the genetic engineering of crops, then the ways in which those costs can be recouped are rather limited. The options appear to be:

1. Specialisation in crops with a high market value and perhaps combined with vertical integration — the breeding company moving into cultivation and marketing.

2. Maximising market share and spreading the product across as many markets as possible, either by licensing arrangements for the gene (or construct) or as finished varieties.

Both have implications for the developing world. Many developing countries now grow small quantities of high value produce, e.g. vegetables and cut flowers, for the developed countries. It would therefore seem likely that this trend would continue when transgenic varieties are available. Whilst the same safety issues arise with these types of crops as with staple crops, the areas planted are always likely to be small. A recent report also pointed out that a move towards high value products with niche markets, combined with some degree of vertical integration, is almost an economic necessity and that traits that could reduce inputs, especially in the developing world, are not likely to provide a substantial growth area in the near future (OECD, 1993).

One of the major lessons from modern monocultural farming practices is that any control measure for a pest or disease, whether genetic or chemical, will select for resistant forms of the target species, and very rapidly if used on a large enough scale (Barrett, 1981). The larger an area planted with a resistant crop, the more likely it is that the very qualities that make it successful will be cancelled out by the evolution of resistance in target organisms. The world-wide marketing of a small range of constructs is likely to decrease the already fragile security of food production, through increased genetic vulnerability.

Most of the genes used to produce herbicide resistance in crop plants are for resistance to compounds to which weeds have, in the past, evolved resistance. It would therefore seem reasonable to expect that widespread use of herbicide-resistant crop plants would lead eventually to the evolution of resistance to the herbicide treatment in the weeds of the crop, thus negating the advance. It is also worth noting that the herbicide Atrazine which has been engineered into crop plants is also a ‘priority hazardous substance’ and a candidate for reduced useage (see Finkelman, this volume) under risk reduction programmes.

Although the early claims for genetic engineering suggested that the technology might be used every time that a new trait was desired in a variety, current practice is to insert the trait into an agronomically acceptable line and, once this has been done, to use it in exactly the same way as a conventionally produced line with a desirable trait. With this in mind, it can be seen that the use of new traits in a limited range of genetic backgrounds in breeding programmes world-wide, could be just as likely as the Green Revolution to produce a narrowing of the genetic base of many crops.

It would therefore seem possible that, with the economics of plant genetic engineering as they are, there is the potential for history to repeat itself with the new technology. However, this is not to deny that the economics of the technology may change and the present high costs are simply a consequence of pioneering attempts in a new technology.

If it is assumed that development costs of the new technology decline dramatically, so that they are of the same order as conventional breeding, what prospects are there for plant biotechnology in the developing world? The first and most obvious one is that it would make it far easier for developing countries to develop their own indigenous biotechnology industries and not be dependent on the multinational companies who at present dominate the market. The second and, perhaps, most significant one with respect to security of food resources is that of biodiversity.

It is now generally accepted that increasing genetic diversity in cropping systems is the simplest and cheapest solution to genetic vulnerability. In the aftermath of the Southern Corn Leaf Blight Epidemic of 1970, a great deal of concern was expressed about widening the genetic base of many crops and this disaster provided the impetus for the establishment of gene-banks world-wide, under the auspices of FAO, IBPGR and other international organisations (Barrett, 1981, Holden and Williams, 1984). However, these great collections of diversity of crops species and their near relatives are under-used by plant breeders. This is not to say that there is little of any use in the gene-banks, but that the traits which are certainly there are more often than not in an unsuitable genetic background and the costs of backcrossing them into an agronomically desirable background are too high. If the transformation technologies can be made to work cheaply and effectively, then this bottleneck in exploiting biodiversity can be by-passed. In turn, the diversity of crops in the field would be increased and the security of crop production improved. Moreover, should problems arise, as they inevitably will, a range of available genetic diversity could be rapidly utilised to ameliorate the situation. The ready availability of genetic diversity through genetic engineering (the 'boutique' approach) should also allow developing countries to 'mix and match' agricultural strategies to suit their own needs, to a greater extent than was possible in the Green Revolution.

The regulatory frameworks set up in the developed countries have been set up to oversee research-and-development and, in some cases marketing. Although the triggers for the regulations and the form of regulation vary from country to country, the data and information requirements are very similar and several models exist on which a developing country could base its own regulations. No matter how well regulated the testing of products is during the research-and-development phase, some problems simply cannot be tested for in small-scale, or large-scale, tests; they may only become apparent when a new crop has been grown on a large area for several years, e.g. resistance problems with target pests, pathogens and weeds, cumulative pesticide problems.

The second group of problems lies in the economics of biotechnology and the need to recoup the development costs. Problems could arise from products developed for the agriculture of the developed world being marketed in Third World countries in which the particular form of the technology may not be appropriate. However, at the present time, most plant biotechnology is undertaken by private companies for marketing in the developed world where there are proprietary rights over plant varieties and the seed producer is able to receive royalties on his products. In most Third World countries, patent rights and statutory plant breeders rights do not exist and most companies would be reluctant to market products because of the difficulties of obtaining a return on their investment, particularly in those countries where there is a tradition of farmers saving seed from season to season. For the same reason, most biotechnology companies would not invest in products aimed exclusively at developing nations (OECD 1993).

Despite the high costs, several developing countries have invested heavily in the transfer of the new technologies. The dangers here are of two types. First, traits will be used because of their tractability, with the possibility that the same trait will be used in a range of crops. Second, economic and political necessity may lead to products being put on the market without full risk assessment and without consideration of potential social and economic effects. This latter problem is likely to become greater if the costs of the technology are reduced substantially.

4. Conclusion

The production of resistant crops via plant biotechnology has the potential to revolutionise agriculture. One major effect will be to reduce, and in some cases eliminate, dependence on pesticides. Some other applications, engineered herbicide resistance, for example, are likely to increase pesticide use. Methods and regulatory frameworks do exist to assess hazards during the research-and-development phase but some hazards cannot be assessed at this stage because they are scale-dependent. Other hazards exist which can be predicted, but which are dependent on the economics of the technology and how the products of the technology are exploited. It is in these latter categories that the greatest risk lie because, in general, they lie beyond the reach of most regulatory processes. The question, now, is whether it is possible, or desirable, to regulate at this level.

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Chemical Safety Information for developing countries

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Abstract

Background: chemicals are used all around the world. Approximately 70 000 chemical compounds are produced industrially and in every day use. The International Labour Office has recently published a compilation of exposure limit values for chemicals considered hazardous by 15 countries, which lists 2 129 chemical substances. The trade of chemicals does not recognize boundaries, and most of these compounds and substances are extensively used also in developing countries, where the capability is limited and the level of knowledge about hazards and proper use is not always adequate.

Chemical Hazards in Developing Countries: Studies in Asia and Africa show that the most prevalent chemical hazards in priority order are: 1. skin exposure to chemicals; 2. labelling of chemicals; 3. chemical splashes; 4. chemical gases (other than solvents), smokes and fumes; 5. organic solvents; 6. chemical explosions; 7. cotton, asbestos, silica and other dusts. These hazards are more serious in small and medium sized industries than in large ones. Many of them are interlinked and depending on other significant factors such as poor housekeeping, lack of knowledge about hazards, and poor personal protection.

Information for Improvements: Several proven methods exist to provide essential information on chemical hazards and their prevention for developing countries. These include: 1. harmonised labelling systems; 2. provision of chemical safety data sheets in locally understandable format and language; 3. transfer of knowledge and information in large quantities by networking institutions of developing countries to each other, and equally by linking them into international networks of industrialised countries; 4. the use of new and efficient methods to collect, process and disseminate information on chemicals and hazards associated, such as microcomputer technology, laser readable compact discs (CD-ROMs), and local desk-top-publishing systems. Some developing countries have already considerable experience in the use of these methods.

1. Chemical safety in developing countries

The need to have indicators that relatively reliably explain the level of safety and health in industries and, in particular, in industries in developing countries is widely recognised. Statistics on occupational accidents and diseases answer only a few questions and, even more importantly, these are often inadequate or non-existing especially in developing countries. The increasing exchange of international expertise and information in the form of development projects has created

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an immediate need for an easily applicable though still reliable method to evaluate the magnitude of occupational hazards. The results in quantitative and qualitative forms are necessary so that preventive programmes can be efficiently carried out.

This type of information on working conditions and environment was not available in Thailand and a proper method to collect data was lacking. A similar situation is common in many if not most countries in the world reducing the outputs of development programmes in order to improve working conditions and environment including chemical safety.

1.1. Studies in Africa

Ulfvarson [1] observed a number of industrial hygiene and chemical safety related problems and hazards in a study in Kenya. A similar study was also carried out by Saarinen and Monyo [2] in Tanzania. Both studies identified closely similar main problems such as: chemical factors: organic solvents, harmful organic dusts (cotton, sisal) and nuisance dusts.

These results were obtained using a Walk-Through Study method, in which one may collect factual and comparable information on health and safety in industries quickly and reliably. It has been used earlier both in developing countries for industrial hygiene surveys (Ulfvarson, 1982; Saarinen, 1985) and in industrialised countries.

Ulfvarson further reported the following miscellaneous factors as the main problems: unsatisfactory personal protection, lack of proper washing facilities, lack of knowledge about hazards. Equally Hasle et al. (1986) [3] used a closely related method in the Survey on Small Scale Enterprises in Thailand. Small and medium sized enterprises seem to have much higher hazard prevalences than do large factories.

1.2. A study in Thailand

Another study was carried out in Thailand (Takala, 1992) [4] in order to recognise the most important and urgent problems in this developing economy. The study was undertaken by the 'National Institute for the Improvement of Working Conditions and Environment' (NICE), a United Nations Development Programme funded and International Labour Organisation (ILO) executed project. The information collection was carried out by seven international experts and additional data was collected by local inspectors.

The results of this study indicate that chemical hazards are generally having a high prevalence as compared to a number of other hazards.

The most usual chemical hazards in priority (prevalence) order were:

1. skin exposure to harmful substances,
2. lack of proper labelling of chemical containers and packages,
3. risk of splashes of chemicals, for example into the eyes,
4. inhalation of gases, vapours, smokes and fumes (such as pesticides but excluding solvents).
5. inhalation of organic solvents,
6. risk of chemical explosions,
7. inhalation of cotton, asbestos, and other harmful dusts.

All of these hazards are, without exception, much more prevalent in small and medium sized enterprises than in large (more than 100 employees) factories.

The Fig. 1. illustrates the levels of chemical hazards as compared to other problems at places of work in Thailand.

1.3. Hazards are interlinked

The following links between chemical safety and important factors, 'contributors' have been detected in Thailand. It seems to be reasonable to expect that similar conditions exist in most other developing countries.

Poor housekeeping, which itself is very often found to be a problem in particularly small and medium sized enterprises, is positively correlated with the high prevalence of the risk of inhaling organic solvents.

The level of mechanisation and automation is linked to skin exposure to hazardous substances, harmful gases, smokes and fumes, harmful dusts, risk of chemical explosion and to poor labelling of chemicals.

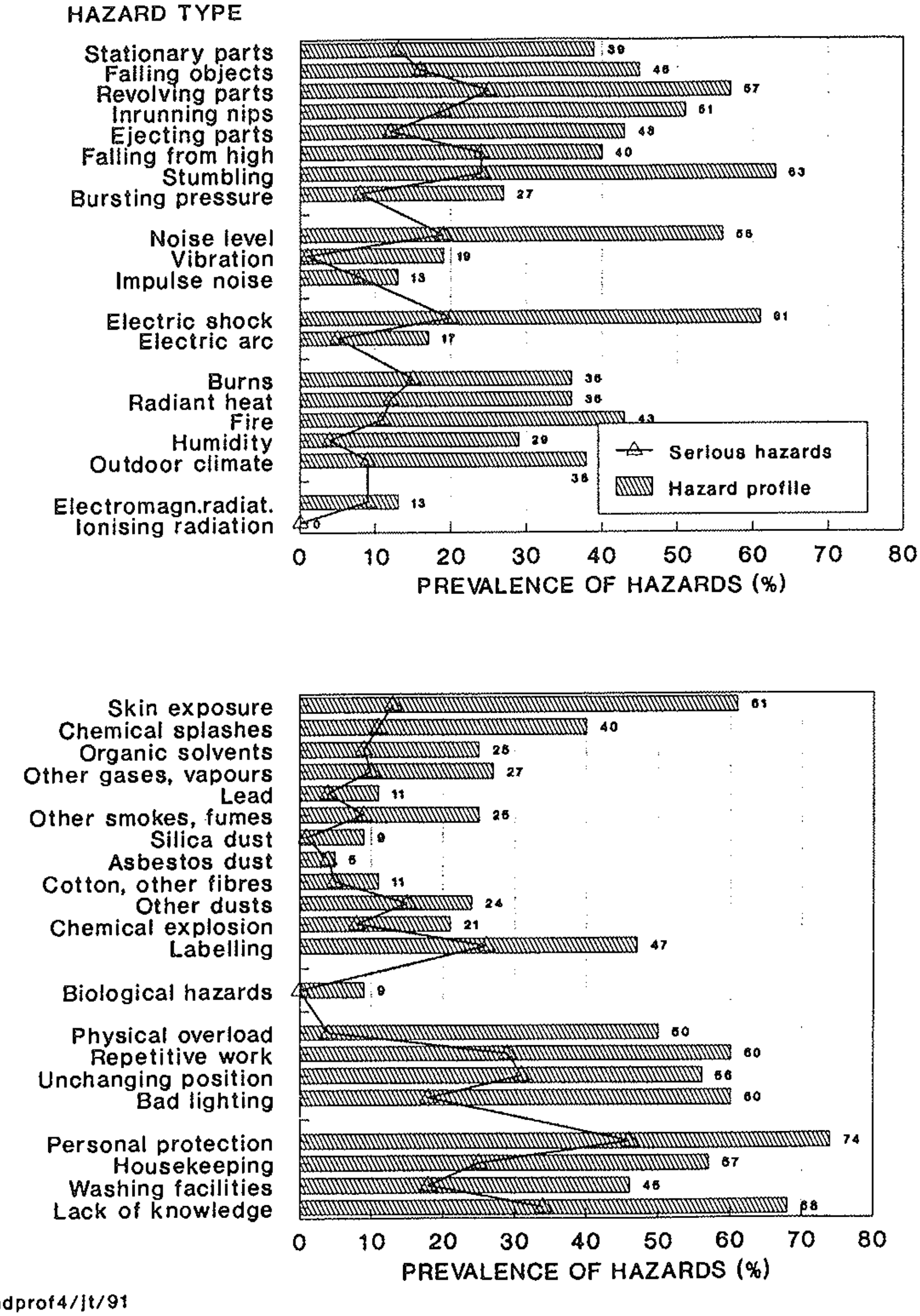


Fig. 1. Prevalence of hazards and serious hazards in Thailand (percentage of factories of those surveyed, where the hazard has been detected).

Lack of knowledge about hazards is associated with skin exposure to chemicals, chemical splashes, inhalation of organic solvents, risk of chemical explosion, and to poor labelling of chemicals.

Poor personal protection is present at the same time as the risk of chemical splashes.

Predominantly female manpower in industries have significantly higher risks of inhalation of cotton dust.

Fig. 2. shows the associations between some of these hazards and factors.

Furthermore some chemical hazards and factors were found to be linked to each other. This was demonstrated by a statistical method called the log-linear analysis. These associations are shown in the figure.

2. Information for the improvement of chemical safety

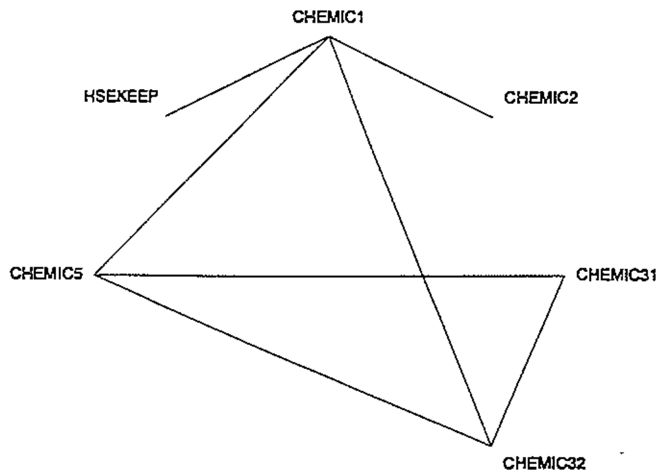
Utilizing information on chemical safety permits the application of earlier findings and experience into new and improved practices. Information is available on processes, on machinery and equipment, on the organization and management of work with respect to industrial health, and on human behavior. Safety information is available in many forms and technical levels. It may be conveyed by symbols and gestures, pictures, illustrations and drawings, by verbal communication, in printed form, in microphotographic form, through magnetic media, and most recently, on laser readable compact discs, CD-ROMs.

The increasing complexity and diversity of technological processes and the growing number of chemical compounds that find their way into industry, agriculture and other branches of economic activity compel the occupational safety professional to systematically gather a substantial amount of information. Ironically, the safety professional is often faced not only with a lack of information or with difficulty in finding it, but rather with a mass of information that is often overwhelming. Quickly finding *relevant* information is generally more important than finding quantities of materials that are not on target.

Many modern professionals rely on modern information technology to manage their acquisition of new information. Large on-line hosts offer thousands of data bases, a few of them dealing directly and some others indirectly, with safety information [5]. Most of the data bases contain numerical, statistical or bibliographic data and at most contain abstracts, but some full-text data bases are also now available. Through modern telecommunications, access to data bases is internationally available. However, at the international level, most use of the on-line information is by a limited number of large-scale users such as safety and health institutes, multinational corporations and medical professionals.

One example of an international information data base on safety information is the network run by of the International Labor Office's (ILO) International Occupational Safety and Health Information Centre, CIS. The ILO is a specialized agency of the United Nations and deals with international labour standards, international cooperation and provides information. The CIS network included 75 National Centres in 1993. These are usually national institutes, such as the National Institute of Occupational Health (NIOSH) in the United States, and the Institute National de Recherche et de Sécurité (INRS) in France, or occupational safety and health administrations such as the Health and Safety Executive in the United Kingdom. After a development period a new system of information dissemination was begun in practice in 1987. A number of data bases and other technical and legal information have been made available on CD-ROMS. The information is both information about information, i.e. bibliographic data, and full-text information completely contained on the CD-ROM.

The CIS system currently services some 5000 user stations. In contrast to systems which require telecommunications (telephone) access, the CD-ROM system is advantageous to those who have limited access to telecommunication lines. In addition to industrially developed countries more than ten National Centres and hundreds of individuals in developing countries use this system currently. The most important problems related to CD-ROM use in developing countries deal



Legend for figure 6:

CHEMIC1	= Skin exposure to chemicals	CHEMIC32	= Other harmful gases, vapours
CHEMIC2	= Risk of splashes	CHEMIC5	= Labelling of chemicals
CHEMIC31	= Organic solvents	HSEKEEP	= Poor housekeeping

DATA Information

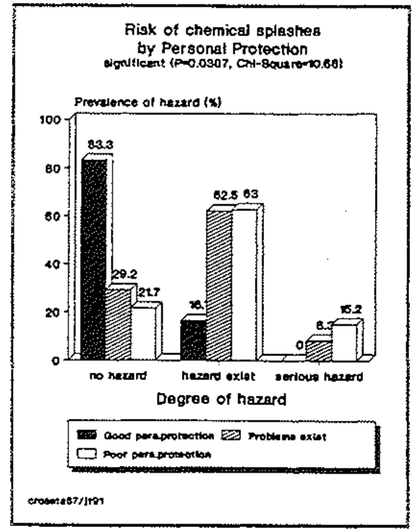
26 unweighted cases accepted.
0 cases rejected because of out-of-range factor values.
74 cases rejected because of missing data.
26 weighted cases will be used in the analysis.

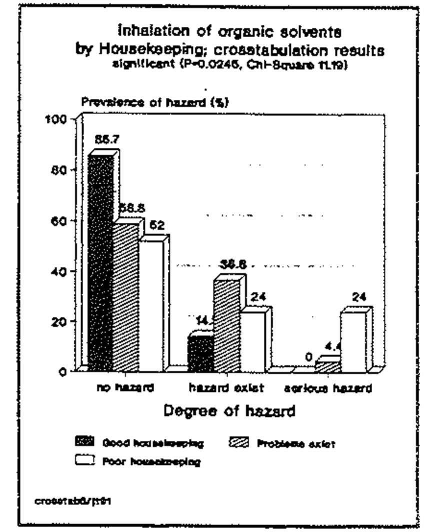
FACTOR Information

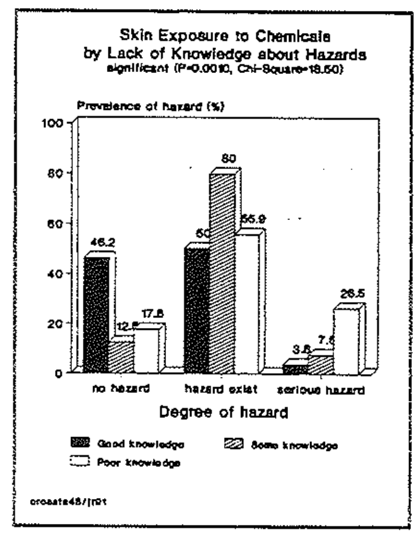
Factor	Level	Label
CHEMIC1	2	
CHEMIC2	2	
CHEMIC31	2	
CHEMIC32	2	
CHEMIC5	2	
HSEKEEP	2	

If Deleted Simple Effect is	Direction	DF	L.R. Chisq Change	Prob	Iter
CHEMIC1*CHEMIC2	+	1	11.880	.0006	9
CHEMIC1*CHEMIC32	+	1	9.027	.0027	5
CHEMIC31*CHEMIC32	+	1	9.026	.0027	5
CHEMIC1*CHEMIC5	+	1	7.568	.0059	5
CHEMIC31*CHEMIC5	+	1	7.567	.0059	5
CHEMIC32*CHEMIC5	?	1	7.794	.0052	3
CHEMIC1*HSEKEEP	+	1	4.155	.0415	9

Likelihood ratio chi square = 23.43625 DF = 50 P = 1.000







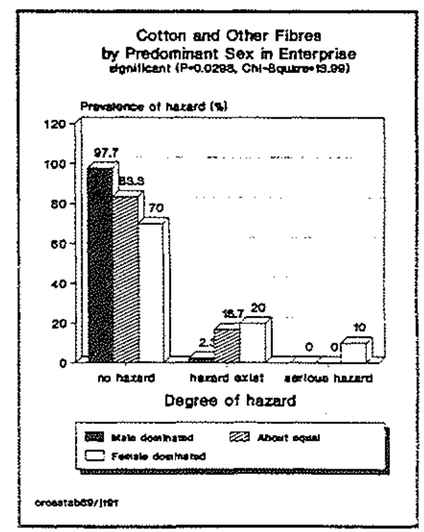


Fig. 2. Associations between chemical hazards and housekeeping, related results

with the equipment and the cost to acquire it. A microcomputer and a CD-ROM reader is still a major investment, which cannot often be afforded in these countries.

2.1. The information cycle

In order to assess the relative merits of various information systems, it is useful to discuss the dissemination of information in terms of the 'information cycle'. The flow of safety information is represented schematically in Fig. 3 which is based on Robert's model [6]. In the first step of the cycle, the safety information is identified or described by the author of a document, where the word 'document' is used in its broadest sense (a.o. scientific article, textbook, statistical report, piece of legislation, audiovisual training material, chemical safety data sheet or even floppy disc or data base). Such documents may result from origiual research, or may be a synthesis or summary of other documents or research reports. It is (1) sent to a publisher or editor, who will evaluate its validity for publication. The publication of a document is an important criteria for evaluating its usefulness and general accessibility simply because unpublished reports are difficult or impossible to find. Some documents are published di-

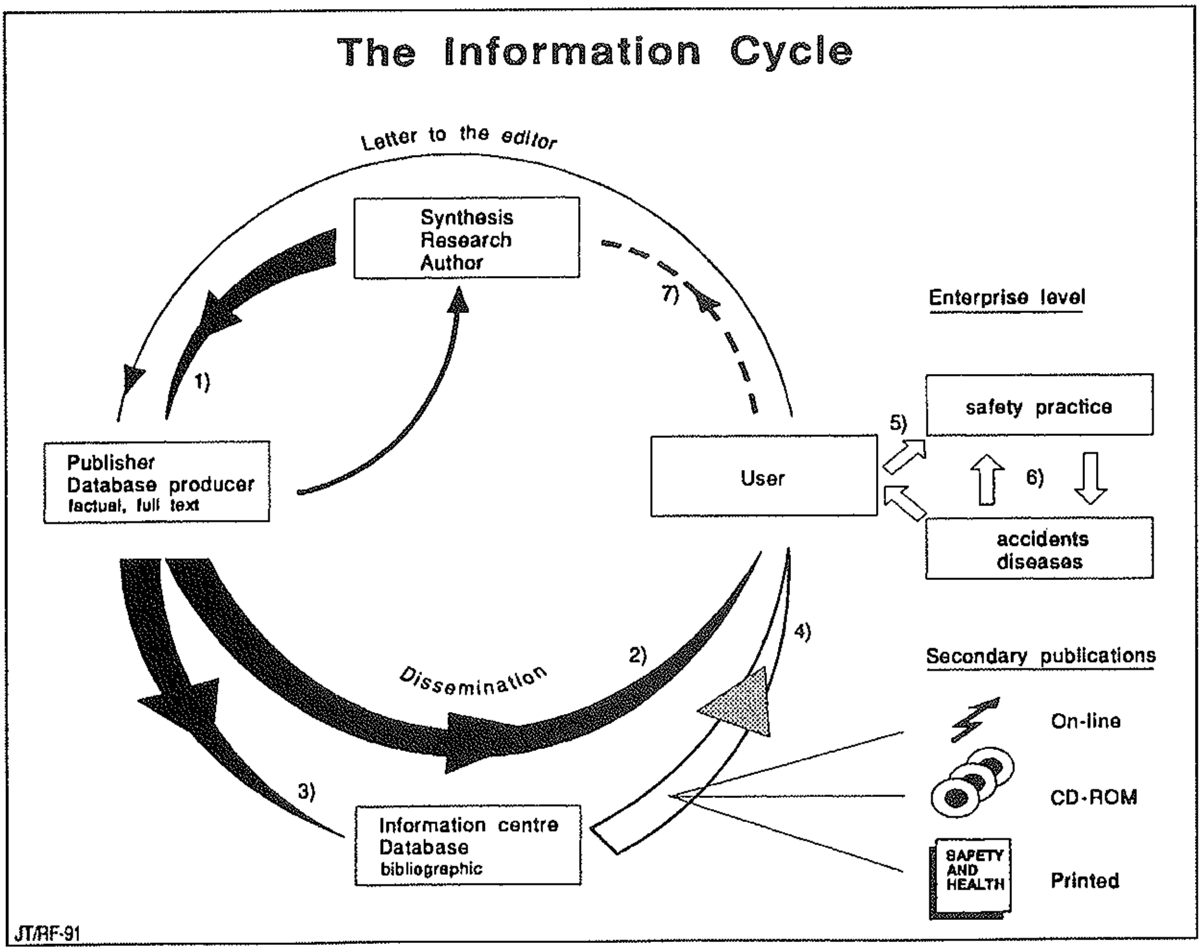


Fig. 3.

rectly on CD-ROM. Published documents can be used directly by a safety professional (2) or may target a different, non-professional end-user such as the worker at the workplace. A chemical safety data sheet on a chemical [7] produced by a manufacturer and subsequently machine translated into another language is an example of this type of document.

The document, the primary information, may then be (3) sent to an information centre, which systematically collects, screens and selects information, thus carrying out the first rough reading of large amounts of documents. A secondary publication such as a periodical containing abstracts and/or a data base may be published by the information centre, drawing attention periodically to significant matters of safety and health work. This secondary publication or data base is (4) targeted to the user or safety professional. Examples of such secondary data bases and publications include the CISDOC and NIOSHTIC data bases and the Safety and Health at Work Bulletin.

The user of the published material may communicate feed-back directly to the author or to the publisher. This process is common for scientific publications.

At this point in the information cycle, the published document may be modified as a result of 'reality testing', when the safety professional uses (5) the information in order to reduce the number of accidents, work-related diseases or solve other problems at work. Experience (6) contributes to better anticipation of health hazards and accidents [8], and may result in new research findings (7), reports and documents which are sent to the publisher thus completing the cycle. Information can enter the information cycle in either electronic or in conventionally printed form.

2.2 Electronic / conventional information

While libraries are indispensable collections of conventional printed information, locating periodical data from printed copy is difficult. Most larger safety and health collections have therefore been computerized and searching is carried out using the bibliographic data base, or cataloguing system to locate relevant documents. Full-text collections, which contain entire documents, rather than just abstracts on bibliographic data, also exist on microfiche or microfilm and can be linked to the data base search system automatically or manually. On-line systems — thanks to their large capacity — are better suited for full text storage and retrieval. Currently, however, only limited amount of full text safety information have been made available on-line.

New archiving methods and image processing systems are now available which use larger laser-readable archiving discs, and may partially replace microfiche-based systems currently used. These archiving systems are, however, currently neither designed nor suitable for copying and disseminating data in larger quantities. It is probably not likely that the printed word will lose its attraction, because once located, browsing and getting an overview of the subject is still superior on paper on computer screen. The higher quality of illustrations and drawings, the light weight and its convenience, (no devices needed to read it) also contribute to the success of printed information, particularly during the learning process. Furthermore, hard paper copies are reliable for storage purposes and are cheap. There may also be psychological reasons that people prefer paper.

On the other hand, electronic or magnetic form for storing and processing safety information has become a viable alternative and is widely accepted as the data storage prices have decreased. Microcomputers can easily handle tens or even hundreds of megabytes, that is hundreds of millions of characters of safety information or tens of thousands of typed pages. For copying thousands of pages, magnetic media is superior in speed. The compact discs, CD-ROMS provide a high level of storage space connected to a reliable and safe archiving method. Although printed paper copies are still needed, printing can be done selectively and may be decentralised. Only those pages currently necessary in locations not far from the final end-user of the information may be printed. The shipping of tons of paper is no longer necessary. A notebook sized computer with a portable CD-ROM reader [9] and 15 different CD-ROM discs literally gives the safety professional a library of 10 Gigabytes (10 billion characters or 3.25 million pages) in his/her lap.

Compact discs can hold approximately 660 megabytes (million characters) of data — the equivalent of 250 000–330 000 typewritten pages or 1841 single-sided floppy diskettes [10]. One CD-ROM weighs only as much as a letter while the same information when priuted may weigh as much as 1200 kg.

Disadvantages of the CD-ROM system include relatively high prices of equipment especially for developing countries, contents of the information usually reflect the level of industrialised countries and it is more complicated to modify the contents than with paper products. A production of a local CD-ROM would almost certainly require assistance or technical co-operation. Smaller data bases, however, are easier in this respect as these can be stored on floppy and hard disks.

3. Data bases: tool or target?

Once one has assembled millions of words of information into a data base, one must develop a sufficient and effective method for gaining access to it. In the most general sense, a data base is defined as a collection of information organized in a particular way for one or more purposes [11]. One simple data base, or more precisely, file we are accustomed to is a telephone book. Dictionaries, catalogues, and library card files are other examples of familiar data base files. A table where rows are called records and columns are called fields can also be called a data base.

The information in a computerised data base is managed by a computerized data base management system which accepts, organizes and stores information, manipulates it in various user-specified ways, and reports the results. The data base programs to be used in the field of occupational safety and health should be selected in such a way that they follow as closely as possible the requirements set by the safety professional and needed for the solution in question. Applications which require a relatively large number of records of similar forms and patterns, or the location of information according to several criteria simultaneously, or frequent calculations, counts or statistical analysis, or utilized continuously changing or accumulating data, are those most suitable for consideration for computerized data base management [12].

3.1. Why a data base?

The advantages to collecting and using data on a data base depend to some extent on whether the system is a single-user or multi-user one. The advantages of a data base system over traditional, paper-based methods of record-keeping are:

- Compactness: No need for possibly voluminous paper files.
- Speed: The machine can retrieve and change data far faster than a human can. In particular, ad-hoc queries can be answered quickly without any need for time-consuming manual or visual searches.
- Less drudgery: Much of the sheer tedium of maintaining files by hand is eliminated. Mechanical tasks are always better done by machines.
- Currency: Accurate, up-to-data information is available on demand at any time [13].

3.2. Existing occupational safety and health data bases

The different types of data bases include:

- Bibliographic data bases: These are data bases of already published documents, where one record may include fields such as author name, title of document, name of publisher or source and location of document, and its abstract. The records generally include classification indicators which are primary or secondary descriptors or keywords describing the record. Keywords are often taken from a set of controlled vocabulary or thesaurus. The document itself is not stored in the data base [14].

— Full-text data base: Unlike the bibliographic data base, which contains only bibliographic information and an abstract, all relevant text ('full text') of the document is included in the data base. There are usually some classifiers and descriptors as well, to help in retrieval. Data bases on chemical safety data sheets, each containing one to ten pages and also full encyclopaedias and other publications, may be in such format.
— Factual data bases: These contain measures or numerical values, such as threshold limit values of chemical substances.
— Multi-media data bases: These hold pictures, drawings, illustrations, sound and video (or references and links to it) as well as the text.
— Mixed data bases: elements of each of the data bases described above are included.

Table 1 provides a summary of bibliographic and full text chemical safety data bases that are easily available around the world. The table is not exhaustive and needs to be updated regularly. A number of other data bases have been referred to in literature [15,16].

3.3 Access to data bases

Large safety data bases that can be accessed through large computers and are always accessible whenever the computers are running are called 'on-line' data bases. The organisations that run on-line systems are referred to as their hosts [17]. Until recently, on-line data bases have been the only feasible solution for the storage and dissemination of information via magnetic media, using computers and specially made search software for the retrieval and downloading of data [18]. Practically anybody who has access to a video display (or microcomputer) terminal and telecommunication (data or telephone) line may use this media.

Large hosts keep hundreds of different data bases available 24 hours a day. With on-line searching, various strategies combining a number of technical requirements can be carried out. Using special searching techniques such as descriptor or keyword searching out can accumulate a large amount of available materials and can concentrate on the most relevant information. In addition to search by keyword, 'free' text searching which searches for specified words located in almost any field of the data base text can provide additional information. Practically no limitations exist as to the size of a data base and several large data bases may be put together to form a cluster. Such a cluster can be used as a single data base so that one search strategy can be applied to all or to selected data bases simultaneously. This type of 'ALL SAFETY' data base is currently being set up with one of the large hosts, the European Space Agency's Information Retrieval System, ESA-IRS. This cluster is intended to include many large data bases and its size is in the range of Gigabytes, or billions of characters. Such clusters are, of course, completely computer dependent.

Telecommunication problems and the limited number of terminals available in developing countries restrict services such as these mostly to the industrialised world. The level of existing infrastructure, political such as security, secrecy and centralisation, and cultural reasons may severely restrict the use of on-line services [19]. In addition, the access and search systems often tend to be quite complicated which further limits the number of users. Those only occasionally interested in the information are insufficiently skilled or perhaps forget the correct procedures. Consequently trained information specialists tend most often to use these computerized systems. Safety professionals, particularly at the factory level, rarely use them. On-line data bases are not much used for safety training purposes due to expensive, by the minute, user charges. On-line data bases are, however, irreplaceable when the data base size so large that a CD-ROM or even several of them cannot accommodate all data.

In order to improve access, particularly to areas with limited numbers of computers, some data bases are also made available in printed form. The ILO's Safety and Health at Work - ILO/CIS bulletin [20] is a printed version of CISDOC which is issued eight times a year and includes annual and 5-year indexes. Similarly, EXCERPTA MEDICA is available as a journal. Some data bases have been also made available on microfiche such as RTECS although it is more common that the paper based bibliographic infor-

Table 1
Databases on chemical safety

Database name	Database type	Language	PC FLOPPY DISKS	CD-ROM name	AVAILABLE-THROUGH	CONTENTS
CANADIANA	Bibliographic	English	CD downloads	CCINFOdisc B 1	ILO/CIS	OSH information
CANCERLIT, CANCER-CD	Bibliographic	English	CD downloads	CANCER-CD	ILO/CIS	Cancer info
CCOHS PUBLICATIONS	Full text	Engl/Fre	CD downloads	CCOHS PUBLICAT.	ILO/CIS	OSH information
CESARS	Factual	English	CD downloads	CCINFOdisc A 2	ILO/CIS	Chemical info
CESARS Help Information	Full text	English	CD downloads	CCINFOdisc A 2	ILO/CIS	Chemical info
CHEM (EC chem.labelling)	Factual	English	IBM, dBaseIII +		ILO/CIS	Risk/safety info
CHEMICAL ABSTRACTS, CAS	Factual	English	CD downloads	CABCD	SilverPlatt/ESA	Chemical info
CHEMINFO	Full text	English	CD downloads	CCINFOdisc A 2	ILO/CIS	Chemical info
CHEMINFO	Full text	English	CD downloads	CCINFOdisc A 1	ILO/CIS	MSDS data sheets
CHEMTOX	Full text	English			V.Nost.Reinhold	
CHRIS	Full text	English	CD downloads	CHEM-BANK	ILO/CIS,S	Chemical info
CIS THESAURUS	Descriptors	Engl/Fre	ASCII,Microisis		ILO/CIS	Terminology
CISDOC (CISILO)	Bibliographic	English	CD downloads	OSH-ROM	ILO/CIS	OSH information
CISILO (CISDOC)	Bibliographic	English	CD downloads	CCINFOdisc B 2	ILO/CIS	OSH information
CISILO français (CISBIT)	Bibliographic	French	CD downloads	CCINFOdisc B 2	ILO/CIS	OSH information
CISINFO	Full text	English	Floppy software		ILO/CIS	Chemical info
ClinMED, MEDLINE Prof.	Bibliographic	English	CD downloads	ClinMED-CD	ILO/CIS	Clinical medicine
DAISY (Gloves)	Full text	Swedish			AI Sweden	
DATABASES	Factual	English	ASCII,WP,dBase4		ILO/CIS	OSH Databases
DOMESTIC/NON-DOM SUBST	Factual	Engl/Fre	CD downloads	CCINFOdisc A 2	ILO/CIS	Chemical info
ECDIN	Factual	English	CD downloads	ECDIN	EC	Chemical info
EINECS plus-CD	Factual	English	CD downloads	EINECS Plus-CD	ILO/CIS	Chemic inventory
ENCYCLOPEDIA, ILO	Factual	several	ASCII	CD in prepar.	ILO/CIS	OSH information
ENCYCLP.Chem.Engieering	Full text	English	CD downloads	Kirk-Othmer CD	bookshps	Chemical info
EPACHEM	Full text	English	dBaseIII +		EPA,ILO/CIS	Chemical data
EXPOSURE LIMIT VALUES	Factual	English	IBM, dBaseIV		ILO/CIS	Exposure limits
Excerpta Medica	Bibliographic	English	CD downloads	Excerpta Medica	ILO/CIS	Medical info
FACTS chem. accidents	Bibliographic	English	ASCII		TNO Netherl.	Chemical info
GLOSSARY of OSH terms	Text	En/Fr/Sp/Ge/Ru/It	IBM,ASCII Microisis		ILO/CIS	Terms in 6 lang.
HAZARDTEXT	Full text	English	CD downloads	TOMES PLUS	Micromedex Inc.	Hazard management
HOMMEL:H.buch gefähr.Güt	Full text	German	CD downloads	Gefahrgut-CD	Springer Verlag	Chemical info
HSELINE	Bibliographic	English	CD downloads	OSH-ROM	ILO/CIS	OSH information
INDEX MEDICUS		English				Medical info
INFOCHIM	Full text	French	CD downloads	CCINFOdisc A 2	ILO/CIS	Chemical info
INFOCHIM	Full text	French	CD downloads	CCINFOdisc A 1	ILO/CIS	MSDS data sheets
INRS-B-BIBLIOGRAPHIE	Bibliographic	English	CD downloads	CCINFOdisc B 2	ILO/CIS	OSH information
IPCS CHEM SAFETY CARDS	Full text	Engl/Eur.	CD downl/floppy	OSH PUBLICATIONS	ILO/CIS	Chemical info

Table 1 (*continued*)

Database name	Database type	Language	PC FLOPPY DISK	CD-ROM name	AVAILABLE-THROUGH	CONTENTS
IRPTC/UNEP	Factual	English			IRPTC/UNEP	Chemical info
ISST	Bibliographic	Fre/Eng			ESA-IRS, CSST	OSH information
KETURI	Full text	Finn/ENgl	in Engl, dBaseIV		FBLP, ILO/CIS	Data sheets
LEO	Bibliographic	Fi/En/Sw			IOH, Finland, ESA	OSH information
MAJHAZ Chemical info	Bibliographic	English -	IBM, dBaseIII +		ILO/CIS	Major haz chemic
MBLINE	Bibliographic	Swe/Eng			AI/Sweden	OSH information
MEDITEXT	Full text	English	CD downloads	TOMES PLUS	Micromedex Inc.	Chem/med. info
MEDLINE 1966-to present	Bibliographic	English	CD downloads	MEDLINE 4 Vol. ILO/CIS	Medical info	
MSDS (see TRADE NAMES)						
NEW JERSEY HAZ.SUBST	Full text	English	CD downloads	CCINFOdisc A 2	ILO/CIS	Chemical info
NICEDIC	Full text	English	IBM, dBaseIII +		ILO/CIS	OSH information
NIOSHTIC	Bibliographic	English	CD downloads	OSH-ROM	ILO/CIS	OSH information
NIOSHTIC	Bibliographic	English	CD downloads	CCINFOdisc C 1	ILO/CIs	OSH information
NiPERA CAB	Bibliographic	English	CD downloads	CCINFOdisc A 2	ILO/CIS	
NIVEAUX DE BRUIT	Factual	French	CD downloads	CCINFOdisc B 2	ILO/CIS	OSH information
NOISE LEVELS	Factual	English	CD downloads	CCINFOdisc B 2	ILO/CIS	OSH information
NOMS DE MARQUE, FTS	Full text	French	CD downloads	CCINFOdisc A 1	ILO/CIS	MSDS data sheets
OHMTADS	Full text	English	CD downloads	CHEM-BANK	ILO/CIS	Chemical info
OSHA databases	Full text/bibl.	English	CD downloads	OSHA disc	OSHA/USA	OSH information
OSH-UK	Full text/bibl.	English	CD downloads	OSH-UK	HSE/U.K.	OSH information

Table 1 (*continued*)

Database name	Database type	Language	PC FLOPPY DISK	CD-ROM name	AVAILABLE-THROUGH	CONTENTS
PEST-BANK Product Data	Factual	English	CD downloads	PEST-BANK	ILO/CIS	Pesticides
PEST-BANK Tolerances	Full text	English	CD downloads	PEST-BANK	ILO/CIS	Pesticides
PRIS - EXPERIMENTAL PEST	Factual	English	CD downloads	CCINFOdisc A 1	ILO/CIS	Pesticides
PRIS - INSECT RELEASES	Factual	English	CD downloads	CCINFOdisc A 1	ILO/CIS	Pesticides
PRIS - MAX RESIDUES	Factual	English	CD downloads	CCINFOdisc A 1	ILO/CIS	Pesticides
PRIS - MINOR USE	Factual	English	CD downloads	CCINFOdisc A 1	ILO/CIS	Pesticides
PRIS - PEST MGT RESEARCH	Full text	English	CD downloads	CCINFOdisc A 1	ILO/CIS	Pesticides
PRIS - THESAURUS	Synonyms	English	CD downloads	CCINFOdisc A 1	ILO/CIS	Pesticides
PUBLICATIONS	Full text	Eng/Fren	CD downloads	OSH PUBLICATIONS	ILO/CIS	Criteria, data sheets
REPERTOIRE TOXICOLOGIQUE	Full text	Fre/Eng			CSST,ESA	Chem data sheets
RIPA	Full text	French	CD downloads	CCINFOdisc A 1	ILO/CIS	MSDS data sheets
RIPP	Full text	English	CD downloads	CCINFOdisc A 1	ILO/CIS	MSDS data sheets
RTECS	Coded text/bib	English	CD downloads	CHEM-BANK	ILO/CIS	Chemical info
RTECS - English	Full text/bibl	English	CD downloads	CCINFOdisc C 2	ILO/CIS	Chemical info
RTECS - français	Full text/bibl	French	CD downloads	CCINFOdisc C 2	ILO/CIS	Chemical info
SILD - EMPLOI LIMITE	Factual	French	CD downloads	CCINFOdisc A 1	ILO/CIS	MSDS data sheets
SILD - LACHERS	Factual	French	CD downloads	CCINFOdisc A 1	ILO/CIS	MSDS data sheets
SILD - PRODUITS EXPER.	Factual	French	CD downloads	CCINFOdisc A 1	ILO/CIS	MSDS data sheets
SILD - RESERCHE	Full text	French	CD downloads	CCINFOdisc A 1	ILO/CIS	MSDS data sheets
SILD - RESIDUS	Factual	French	CD downloads	CCINFOdisc A 1	ILO/CIS	MSDS data sheets
SILD - THESAURUS	Synonyms	French	CD downloads	CCINFOdisc A 1	ILO/CIS	MSDS data sheets
TDG/49CFR	Factual	English	CD downloads	CCINFOdisc A 2	ILO/CIS	CHEMICAL INFO
TOXLINE 1981–87	Bibliographic	English	CD downloads	TOXLINE	ILO/CIS	Toxicology
TOXLINE 1988–	Bibliographic	English	CD downloads	TOXLINE	ILO/CIS	Toxicology
TRADE NAMES, MSDS	Full text	Eng/Fre	CD downloads	CCINFOdisc A 1	ILO/CIS	MSDS data sheets

mation is supported by full-text microfiche. In these cases the data base is in two parts: on paper (or in electronic format) and on microfiche.

3.4. Access through compact discs

Most of the data bases described here are already available in another electronic format: CD-ROM. There are currently eight different CD-ROMS directly related to safety and health issued by the Canadian Centre for Occupational Health and Safety, CCOHS [21]. Two discs contain Chemical Information like MSDS, CHEMINFO, etc., and two others hold Occupational Safety and Health Information like CISDOC, FATALITY REPORTS and French data bases. The last two discs include information from the United States, such as the NIOSHTIC and RTECS data bases. Two other full text CD-ROMS are also available: the PUBLICATIONS disc and another on Canadian Safety and Health legislation.

The commercial CD-ROM publisher Silver-Platter Co. Ltd. has a series of 'Health CD-ROMS', many of them directly related to occupational safety and health such as the OSH-ROM [22] containing CISDOC, NIOSHTIC, HSELINE and MHIDAS data bases, as well as other CD-ROMS such as CHEMBANK, TOXLINE, EINECS, PESTBANK, MEDLINE a.o. [23]. Altogether, a dozen safety and health CD-ROMs have been published, most of which are regularly updated (often four times a year) and they include more than 100 different data bases (see Table 1). These figures grow continuously and the list will have to be regularly updated. A large number of data bases exist for specific scientific and technical fields such as INSPEC (physics) and COMPENDEX (engineering) but these are not included in the list of safety and health data bases. Detailed guidelines for accessing and selecting correct data bases on safety and health in general, ergonomics, potentially dangerous products a.o., exist in the literature [24–26]. Names and addresses of vendors are available from the CIS-ILO or from the CIS National Centres in industrialised and in developing countries [27]. Pricing details and a free information package may be obtained directly from CIS. Specific information for developing countries are given e.g. in the African Newsletter on Occupational Health and Safety [28].

In addition to on-line and CD-ROM systems, much safety and health information is also available on standard microcomputer floppy diskettes and hard disk formats. These must obviously be smaller data bases than those described above and are not necessarily publicly available. All CD-ROMS and many on-line data bases, or more properly subsets of them, may be downloaded onto the users' floppy or hard disk, after which the information can be used as any other data in a microcomputer. This method complements the 'read-only' system of the laser readable CD-ROMs and the user may add, modify or delete information of may build up a tailor-made data base, keeping in mind, however, any copyright conditions which may apply.

3.5. Relational data bases on safety and health: a model system

A system that covers many individual areas of safety information aimed at managing data necessary for correct decision making can be designated a Decision Support System (DSS) or sometimes Management Information System (MIS). The need for a DSS can arise from a safety officer problem-solving needs or an industrial hygienist's need to keep track of sampling and analytic results or of labelling and data sheet registries[29, 30]. Safety training courses, lectures, handout and leaflet preparation, where immediate, simple, ready-to-use information is essential, lend themselves to a DSS, particularly when such training is required by law. Inquiry services on safety issues are amenable to DSS, particularly since individual inquiries would be quickly and accurately replied if using data bases compared to searching from books or other printed materials. Inspectors, industrial hygienists or consultants who visit many worksites where they are expected to know and recommend immediate solutions for particular safety questions may benefit from instant access to the literature as may be the occupational medicine specialist who deals with patients that may have been affected by any of a multitude of adverse conditions of work. Finally DSS is amenable to disease or accident notification systems. Serious accidents must be investigated in order to prevent their reoccurrence and/or to be in compliance with standards.

The field of occupational safety and health is such a wide one, covering disciplines from engineering and chemistry to psychology, legal systems, physical phenomena and medicine, that no individual can be expected to achieve mastery of all problem areas. A system providing information on a wide range of subjects and from different points of view would therefore be extremely useful to many practitioners. A number of individual solutions — computerised or manual — have been created, but the challenge of linking these together to design a relational system for gathering, processing and disseminating information often remains for the user to develop. Developing an appropriate data base management system requires understanding the types and subjects of the most frequent queries encountered. A few models and samples for using microcomputer hard- and software for setting up a Decision Support System in safety aud health and linking individual tasks have already been designed [31–33].

The end user of the information, for example a safety professional, may wish to take a single work item and use one retrieval word (keyword, descriptor) to located as much data as possible [34,35] from different, individual files which are linked (related, joined) to one another. If these files are computerised, that is, the data are contained in data base files, this could be done almost simultaneously in the following manner, using the chemical methyl isocyanate as an example (Table 2).

Unfortunately in order to access the information on Methyl isocyanate a number of different programs are needed. In the model presented

Table 2
Example of Related Data Bases in a Decision Support System

Query word	Data base	Description
METHYL ISOCYANATE	CHEMICALS	from a chemical labelling file, information on the toxic substance includes risk and safety phrases and symbols, or similar information from the EINECS data base on CD-ROM
METHYL ISOCYANATE	DIC	from a dictionary file describing in common terms the effects, hazards and uses of methyl isocyanate and how to prevent the danger
METHYL ISOCYANATE	SCAN	System for Computerised Accident Analysis, where investigated accidents occurring with this substance may be studied
METHYL ISOCYANATE	MSDS	from a chemical safety data sheet collection, this may be a download from a CD-ROM (e.g. MSDS data base, CHEMINFO data base or TOXLINE data base) or a machine-translated data sheet
METHYL ISOCYANATE	EXPOSURE LIMITS	data base, where more than 2100 permissible exposure limits of 15 countries and the ACGIH (US) have been given
METHYL ISOCYANATE	RTECS	toxicological studies on chemicals, particularly useful for substance identification with its 300 000 synonyms
METHYL ISOCYANATE	MAJHAZ	data base for information on chemicals potential to cause major disaster, figure 4.
METHYL ISOCYANATE	CISDOC, NIOSHTIC, HSELINE	data bases for literature on the chemical and disasters linked to it, figure 5.

MAIN MENU

1. Exposure Limits
2. Major Hazards
3. Chemical Labels
4. Data Sheets
5. Dictionary
6. Maintenance
0. Exit

1. EXPOSURE LIMITS & 3. CHEMICAL LABELS

15 countries and 2129 chemicals
Also listed: synonyms, carcinogens, sensitizers and other effects.

- - -
Name: METHYL ISOCYANATE
CAS number: 624-83-9 RTECS number: NQ 9450000
- - -
Synonyms:
ISO-CYANATOMETHANE
- - -
Exposure limits:

Country / Effects	H Time	TWAppm	TWAmg	STELppm	STELmg
GERMANY / SEN		0.01	0.025	I	I
SWITZERLAND / SEN	8*5	0.01	0.025	0.02	0.05
BELGIUM / SK		0.02	0.047	-	-
HUNGARY / SK,IR,SEN		-	0.05	-	0.06
FRANCE / SK		0.02	0.05	-	-
USSR / SK,All		-	-	-	0.05
USA: NIOSH/OSHA / SK		0.02	0.05	-	-
USA: ACGIH / SK		0.02	0.047	-	-
DENMARK / SK		-	-	0.01	0.03

- - -
Major Hazard Chemical Name: METHYL ISOCYANATE
EEC number: 615-001-00-7
Formula: CH3NCO
Symbols: F, T
Risk Phrases:
12-23/24/25-36/37/38
Safety Phrases:
9-30-43-44
Comments:
This substance caused a major disaster in Bhopal, India
- - -

2. MAJOR HAZARDS

Sources of information on major hazard chemicals.

- - -
CIS number:
Reference info:
Sax: Dangerous Properties.... ISBN 0-442-28020-3
87-109
EPA Chemical Profiles
88-276
Toxicologisch-Arbeitsmedizinische Begründung von MAK-Werten (Diisocyanate)
CCINFOdisc CHEMINFO
87-1010
Sax: Hazardous Chemicals Information Annual No.1
82-1002
NIOSH Publication No.81-123
Metyyli-isosyaniitti, Finland
81-1933
INRS Fiche Toxicologique NO.162
80-1616
Hommel: Handbook of Dangerous Substances, sheet 582

5. DICTIONARY:

Easy to read full descriptive text on chemicals and other safety and health questions.

Dictionary of Working Conditions and Environment 234.00

Methyl isocyanate (MIC) : One of a group of *isocyanates* used in the production of pesticides like the product Temik of the Union Carbide Co. MIC reacts quickly with water and can be easily absorbed through the skin or inhaled. It causes moist human tissues like lung interiors to swell and the eyes to develop cataracts. Victims can suffocate because MIC causes the lungs to fill with fluid, and they can suffer liver damage and burning of the nasal passages, throat and trachea. The Union Carbide, Bhopal, India factory leakage in December 1984 caused by accidental adding of water into the MIC tank and inadequate safety precautions resulted in deaths of more than 2,000 people in the surroundings in the worst industrial accident ever.

Methyl mercaptan : (methyl sulfide or methyl sulphide). Hydrogen sulfide ester of methanol. Since it is readily hydrolyzed to the parent compounds, it has practically the same toxicity, both qualitatively and quantitatively, as *hydrogen sulfide*.

Methyl mercury (1) (monomethyl mercury) : The most toxic of the organic mercury compounds. It is usually found as a salt. Methyl mercury is easily absorbed by the organism through the lungs, skin, and gastrointestinal tract. Methyl mercury may cause injuries to the nervous system, brain, skin, and unborn babies.
-*Injuries to the nervous system and brain.* Methyl mercury passes from the blood to the brain. It may cause both acute and chronic poisoning with symptoms from the brain and the nervous system. Mild poisoning appears as shaky hands, insensitivity and pricking in the

4. DATA SHEETS:

Safety information on over 700 chemicals

FS-636

NATIONAL BOARD OF LABOUR PROTECTION IN FINLAND
(machine translated data sheet, CIS-ILO, CH-1211 Geneva 22)
*** no liability accepted by CIS-ILO *** 1990 ***

NO: 16026-7 DATE: 02.01.1981

1.1 TRADE NAME: METHYL ISOCYANATE

1.2 USE: LABORATORY CHEMICAL

1.3 MANUF/IMPORTER: SAI-LAB SUOMEN TUKKUKAUPPIAITTEN LIITTO
ADDRESS: FABIANINKATU 23
00130 HELSINKI 13 TEL:90-171606
2.1 TOXICITYCLASS: 1 2.2 FLAMMCLASS: 1 2.3 TRANSPORTCLASS: 3.1
2.4 UN-NUMBER: 02480 2.5 CARCINOGENS: -

2.6 WARNING LABELS:
F HIGHLY FLAMMABLE
T TOXIC
R12 EXTREMELY FLAMMABLE.
R23 TOXIC BY INHALATION.
R24 TOXIC IN CONTACT WITH SKIN.
R25 TOXIC IF SWALLOWED.
R36 IRRITATING TO EYES.
R37 IRRITATING TO RESPIRATORY SYSTEM.
R38 IRRITATING TO SKIN.
R42/43 MAY CAUSE SENSITIZATION BY INHALATION AND SKIN CONTACT.
S9 KEEP CONTAINER IN WELL-VENTILATED PLACE.
S30 NEVER ADD WATER TO THIS PRODUCT.
S43 IN CASE OF FIRE, USE ...
S44 IF YOU FEEL UNWELL, SEEK MEDICAL ADVICE (SHOW THE LABEL WHERE POSSIBLE).
S101 PREVENT CONTACT WITH SKIN, EYES AND RESPIRATORY ORGANS.

3 SUBSTANCES HAZARDOUS TO HEALTH:

1 METHYL ISOCYANATE CAS:624-83-9*%100.
LD50*00071 MG/KG (ORAL, RAT) MAC = 0,02 CM3/M3 =. 0,05 MG/M3
EASILY FLAMMABLE LIQUID. TOXIC WHEN INHALED AND ON SKIN.

4.1 BOILING POINT: BP:*00039CE

4.2 MELTING POINT: MP:*00019CE - 21,5 CE

4.3 VAPOUR PRESSURE: VP:*NOT KNOWN

4.4 SOLUBILITY IN WATER: INSOLUBLE

4.6 DENSITY: 960 G/DM3

Fig. 4.

here dBase III plus, dBaseIV, WordPerfect, InfoSelect, SilverPlatter CD-ROMS, CCINFO CD-ROMs, MINISIS, MicroISIS (UNESCO), Harvard Graphics, PageMaker, Ventura were all utilized both for access and presentation purposes. Ideally, one single software would cover all needs, but so far no such software exists.

However, partial relational data base files do exist such as the Chemical Data and Exposure Limits [36,37] and can be tailored to user needs and can incorporate data files most often used. In this way information available from places of work such as inspection reports and accident investigations could be combined with information from outside sources and international data bases [38,39]. Hypertext may sort out some problems in providing access into different files independently of their structure or software used to put the information together. This new method is already being tested for safety and health CD-ROMs.

4. Training packages on CD-ROMs

Images may also be stored on a CD-ROM as well as animated training packages. Whereas the bibliographic and factual data bases are primarily designed for the safety professionals, the full-text data sheets including images and illustrations are targeted to the factory-floor level, to safety representatives, supervisors and workers. Several training packages containing quizzes and animated illustrations are already available on CD-ROM, e.g. 'How Workplace Chemicals Enter the Body', 'Excavation Safety' and 'Hazards of Photocopiers'.

RECORD NUMBER	48699 DATABASE: CISILD
CIS ACCESSION NUMBER	CIS 87-1453
AUTHOR	Shristava , P.
TITLE	Bhopal - Anatomy of a crisis
SOURCE	Ballinger Publishing Co., 54 Church Street, Harvard Square, Cambridge, MA 02138, USA, 1987. 184p. Illus. Bibl. Index. Price: US$19.95.
ISBN	0-88730-084-7
LANGUAGE(S)	English
SUMMARY	Analysis of the Bhopal accident (India), 1984
ABSTRACT	An analysis of the Union Carbide disaster in Bhopal (India), 3 Dec. 1984, in which a large quantity of methyl isocyanate gas (MIC) leaked from a storage tank, killing thousands of people. Contents: causes and characteristics of industrial crises (in general); causes of the Bhopal disaster, including a HOT (Humn, Organisational, Technological) analysis; consequences of the acoident in India, the USA, and elsewhere; three models of the crisis (as seen by the Government of India, by the Union Carbide company, and by the surviving victims); suggestions for the prevention of industrial crises and for coping with them when they occur.
MAJOR DESCRIPTORS	INDIA ; DISASTERS ; DEVELOPING COUNTRIES ; METHYL ISOCYANATE ; CHEMICAL INDUSTRY
MINOR DESCRIPTORS	EMERGENCY ORGANISATION ; CAS 624-83-9 ; ACCIDENT DESCRIPTIONS ; OCCUPATIONAL SAFETY ; ANALYSIS OF ACCIDENT CAUSES ; COMPENSATION OF OCCUPATIONAL ACCIDENTS ; ROLE OF GOVERNMENT ; USA
SUBJECT CATEGORY CODE	230 - Chemical, oil and fuel, plastics and rubber industries
SPECIALIST CATEGORY	Occupational safety, accidents
DOCUMENT TYPE	Books, pamphlets, guides
PUBLICATION YEAR	87

Fig. 5.

More advanced systems including Computer Based Training (CBT) have also been developed but so far, only a few linked to occupational safety and health [40]. Complex training programmes using large laser discs, full video and audio facilities, and touch screens controlled by computer software are indeed efficient computer training packages. However the price to produce these paekages is high, limiting the large scale access to them.

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An International Journal for Scientific Research into the Environment and its Relationship with Man

Opportunities and constraints in monitoring chemical hazards by religious organizations

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Abstract

The paper has been entitled Opportunities and Constraints in Monitoring of Chemical Hazards by Religious Organizations' for several reasons. First, by 'opportunities' I do not refer to the practical or effective commitment of religious groups to the monitoring of chemical hazards, but rather I indicate some of the church documents which encourage the faithful and, therefore, religious groups to be committed to the protection and conservation of the environment or to the improvement of humankind's relations to natural resources. Second, by 'constraint' I wish to describe what is being done and I must immediately state that what is being done is rarely related to the monitoring of chemical hazards.

1. Opportunities

Concern for environmental safety and quality of life is not new to the Church. Many have traced the doctrinal and spiritual aspects of this concern to the Bible and to the earliest centuries especially after the polemics aroused by Lynn White, Jr., in December 1966 and published in March 1967. This polemic is not of interest to us today. What does interest us is the fact that the extent of the environmental crisis so pervades all aspects of contemporary life on the planet that it has led the highest Church authorities to encourage commitment on the part of the faithful to seek solutions to the crisis in the name of their very faith.

John Paul II, during his 1984 visit to Canada, invited representatives of Christian Churches and confessions to study the effects of technology on Gospel values. His very first Encyclical 'Redemptor hominis' (1989) dedicated three long paragraphs to the environmental crisis that human beings must face.

The first steps toward interreligious discussion of this theme, and not least, cooperation of believers with environmental organizations were taken in 1987.

From the Catholic point of view, one can claim some of the statements of the Second Vatican Council's Pastoral Constitution on the church in the Modern World, '*Gasudium et Spes*', promulgated in 1965, as the first declaration of the highest magisterial teaching on the deteriorating relation between humankind and the environment. In 1971, in his Apostolic Letter '*Octogesima adveniens*', Paul VI wrote rather forcefully that

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'by an il-considered exploitation of nature he [man] risks destroying it and becoming in his turn the victim of this degradation.'

Beyond his first encyclical, John Paul II has expressed his views on the environmental crisis in other encyclicals — particulary '*Sollicitudo rei socialis*' and '*Centesimus annus*' — and in numerous discourses. One of his most important statements is that of his 1990 Message for the World Day of Peace 'Peace with God the Creator, Peace with All of Creation'. His discourses to participants in Study Weeks organized by the Pontifical Academy of Sciences are of particular importance. Some of them are reproduced in the Academy's publication of the Acts of those Study Weeks. We add that not only the 1987 Synod of Bishops on the laity but also several epsicopal conferences, among them the Conference of the Dominican Republic, have addressed the problems of the environment.

The Concern of the World Council of Churches for the environment has become clear since its Sixth Assembly, held in Vancouver in 1983. Although J.N.K. Mugambi, in his report to the 1986 Potsdam Working Group of Church and Society, finds in the 1937 Oxford conference on Life and Work the first reference to human beings' relation to the environment, he admits that only the 1966 World Conference on Church and Society highlighted the struggles of peoples in the 'Technical and Social Revolutions of Our Time'. In 1979, the MIT World Conference on Church and Society 'widened the scope of ecumenical thought by bringing together theologians, scientists, philosophers, politicians and technocrats to discuss 'Faith, Science and the Future'. The convening of this conference was rooted in the conviction that life on earth was threatened by technological invention and innovation.' The Sixth Assembly, held in Vancouver, formulated the concern of the World Council of Churches for humankind's relation to the environment under the heading of 'Justice, Peace and the Integrity of Creation'. The Vancouver Assembly of the World Council of Church therefore mandated that a World Convocation on 'Justice, Peace and the Integrity of Creation' (JPIC) be held in Seoul, South Korean, March 6–12, 1990. This Convocation became an ecumenical event in which all Christian Churches or Confessions participated, among them the Catholic Church.

Of particular importance must be attributed to the European Ecumenical Assembly, known also as Peace with Justice, which was held in Basel, Switzerland, 15–21st May, 1989. This Assembly was planned, prepared and organized together by the Conference of European Churches and by the Roman Catholic Bishops' Conferences of Europe.

Slightly more than a week ago, 9–15 October 1993, the World Council of Churches held a meeting on global warming in Driebergen, Netherlands.

Without attempting to give a list of the many interreligious meetings — among Christians, Jews, Hindus, Buddhist, etc. — that are being held today, I simply draw your attention to the fact that one of the first of these meetings was organized with the help of Franciscans who later established the Center I direct. That meeting was the celebration of the twenty-fifth anniversary of the founding of the World Wildlife Fund, today known as the World Wide Fund for Nature. The celebrations were held in Assisi, September 24–29th, 1986. The interreligious meeting was attended by Jews, Catholics, Anglicans, Muslims, Hindus and Buddhists.

In concluding this section on the opportunities or on the encouragement that religious groups have received to commit themselves to improving humankind's relation with the environment, and among these the monitoring of chemical hazards, allow me to cite the conclusions of two Study Weeks organized by the pontifical Academy of Science. The 1987 Study Week on 'A Modern Approach to the Protection of the Environment' states: 'Religious concern for the protection of the environment, as evidenced in Papal documents and addresses and in study programs organized by the World Council of Churches, makes us bold to dialogue be encouraged and undertaken concerning the following: environmental problems, human life and the conservation of species, humankind's ethical and religious position in biosphere, progress, and the purpose of scientific research and of its technological applications. Such dialogue could render an incalcula-

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Human health and environmental hazards arising from the use of chemicals in developing countries

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1. Introduction

The recognized or suspected harmful effects of chemicals on human health and the environment are derived from their inherent properties which cannot be influenced. However, the potential harmful effects may be reduced or even eliminated by the proper handling and judicious use of chemicals. There should be no argument over whether chemicals are essential on every segment of human activity, but also, nobody can deny that certain uses (misuses) outweight the benefits that chemicals offer. This permanent conflict of benefit against risk needs to be fully understood through an unbiased scientifically based risk-benefit evaluation.

The massive expansion in the availability and use of chemicals throughout the world during the last few decades has led to increasing awareness of the potential risks that exposure to chemicals pose, both to human health and the environment. The growing generation of hazardous wastes and intentions for their uncontrolled transboundary movement is dealt with by the widely accepted Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, adopted in 1989 (UNEP, 1994).

It became obvious that fast industrial development can introduce various health and environmental risks that the community is unable to cope with. Many catastrophes caused by chemicals have occurred in recent years such as massive poisoning with methylmercury in Iraq (WHO, 1976) or with TOCP in Morocco (Smith and Spalding, 1959). It should be mentioned, however, that naturally occurring toxins are also known to be the cause of massive outbreaks of acute poisoning as well as causing irreversible effects, including cancer, in exposed populations (Keeler and Tu, 1983; Hall and Strichartz, 1990).

Although cancer is only one of the many serious effects that can result from exposure to chemicals, both man-made and naturally occurring, it has become a matter of considerable concern to the general public and much effort has been made to identify and classify chemicals according to the carcinogenic hazard they pose to humans.

Intense international concern about the dangers of chemicals for human health and the environment, expressed at the United Nations Conference on the Human Environment, held in Stockholm in 1972 led to the establishment in 1980 of the International Programme on Chemical Safety which is a joint venture of the World Health Organization (WHO), the United Nations Environment Programme (UNEP) and the International Labour Office (ILO). The programme was initially set up specifically to provide assessments of the risks to human health and the environment from exposure to chemicals whatever

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their origin, man-made or natural, or wherever they are found, thus providing the internationally evaluated scientific basis on which countries may develop their own chemical safety measures. Twenty years after the Stockholm Conference, the UN Conference on Environment and Development (UNCED) held in Rio de Janeiro requested the creation of an international strategy for the environmentally sound management of toxic chemicals. The conference considered that IPCS should be the nucleus for this strategy, and that cooperation with other organizations having an involvement in chemical safety should be strengthened. In addition, UNCED stressed the need to extend partnership with governments, industries, trade unions, consumers and professional bodies. It has been proposed that the strengthening of IPCS should be accompanied by the setting up of an intergovernmental forum for chemical risk assessment and management which is now underway. UNCED identified six programme areas that would form the objectives of the new IPCS:

- The evaluation of the risks to human health and the environment from exposure to chemicals should be accelerated, and international agreement concerning methods of risk assessment needs to be expanded.
- Harmonization on a worldwide scale is also essential for the classification and labelling of chemicals.
- Mechanisms are required to make the exchange of information on chemicals and their risks easier, and to deal with major accidents and poisonings that involve them.
- Activities to reduce the risks of chemicals and to develop the use of safer alternatives need to be promoted.
- To provide assistance to countries, especially the developing ones, to evaluate health and environmental hazards, and to bring in and enforce legislation when necessary.
- More information and stronger measures are needed in the fight to halt illegal international traffic in dangerous chemicals.

Today the programme provides guidance to countries on how to use available risk assessments to achieve risk reduction, and also helps to strengthen national capabilities to prevent and treat harmful effects of chemicals and to manage emergencies involving chemicals.

Two basic aspects in promoting chemical safety that will be briefly discussed are risk evaluation and risk management, the former being of global and the latter of more regional or national significance and applicability.

2. Risk evaluation

Most of the new chemicals, drugs and pesticides in particular, before being allowed on the market, are extensively and meticulously tested to ascertain their biological potential to produce adverse effects. These studies are normally performed by the manufacturers, using widely accepted procedures. The results together with those published in open literature are critically reviewed by national or international groups of experts with the aim to assess human health and environmental risks arising from the use of chemicals which are likely to be inadvertently absorbed by users or the general population, or spread in the environment.

The risk evaluation is a complex scientific process requiring the meticulous work of a multidisciplinary team of experts. It is not therefore surprising that with the exception of a limited number of certain types of chemicals (pesticides, food additives, some of the major air and drinking-water contaminants, and some hazardous industrial chemicals), few products have been tested appropriately for potential risks. The information available is, in most cases, inadequate to estimate the levels that can be tolerated safely by humans.

The process of risk evaluation is particularly difficult for developing countries lacking infrastructure and having limited expertise. These countries frequently rely upon the results of risk evaluations performed by international organizations, and/or national evaluation bodies.

It should be pointed out, however, that for most chemicals in the environment, epidemiological data essential for assessment of risk to human health confirm neither the absence nor the presence of a specific risk to humans, such as cancer or impairment of reproduction, as the final outcome is normally remote, contrary to acute poisoning.

3. IPCS activities in risk assessment of chemicals

Since the inception of the WHO Programme for the Promotion of Environmental Health in 1948, WHO activities in the field of assessment of chemical safety have been evolving, and are constantly being promoted further following several important WHO Resolutions.

At present, the only truly international evaluations of the risk of toxic chemicals to humans and the environment are made by the International Programme on Chemical Safety (IPCS). Within the framework of the chemical risk evaluation process there are several specific IPCS activities, which are briefly described below.

The international Register for Potentially Toxic Chemicals (United Nations Environment Programme (IRPTC/UNEP) puts together information collected from various international and national scientific institutions and also from independent reputable scientists who publish data in the open literature. This information is made available to Member States on request (IRPTC/UNEP, 1993).

The Joint Meeting on Pesticide Residues (JMPR), sponsored by the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO), provides Member States with estimates of the levels at which various pesticides can be safely tolerated by the human body, called the Acceptable Daily Intake (ADI). The recommended ADIs are then used by national regulatory agencies and by the Codex Alimentarius Commission to propose safe levels of pesticides in foodstuffs. The meetings have been held annually since 1963 and the evaluations are published by FAO and WHO (FAO, 1994; WHO, 1994b). The WHO group of experts has described the procedures in the toxicological evaluation processes (WHO, 1990).

The Environmental Health Criteria (EHC) documents are designed for scientific experts who are responsible for the evaluation of risk to human health and the environment incurred by chemicals. They enable relevant authorities to establish policies for the safe use of these chemicals. The information is detailed enough to allow the scientific reader to make his or her own validation. Over 150 documents dealing with various chemicals or methodologies have been published. The majority of these documents deal with individual chemicals and some of them are devoted to the methodological aspects (e.g. WHO, 1991, 1992, 1993).

Health and Safety Guides are designed for a wide range of administrators, managers, and decision-makers in various ministries and governmental agencies, as well as in commerce, industry, and trade unions, who are involved in various aspects of safe use of chemicals. They summarize toxicity information in simple, non-technical language and provide practical advice on safe storage, handling and disposal of the chemical, accident prevention and health protection measures, first aid and medical treatment in cases of overexposure, and clean-up procedures. So far, over 85 guides have been published.

The International Chemical Safety Cards summarize essential product-identity data and health and safety information on chemicals for use by workers and employers in factories, agriculture, and other workplaces. The cards are prepared using standard phrases, complemented, when appropriate, with information specific to the chemical being used.

The WHO Recommended Classification of Pesticides by Hazard and Guidelines to Classification is a document which was approved by the Twenty-eighth World Health Assembly in 1975 and has since gained wide recognition in a number of Member States and by pesticide registration authorities. Although the Classification takes into account acute oral or dermal toxicity, whichever higher, it also considers any irreversible effect that might be recognized. For practical reasons, a number of pesticides classified as Class III (slightly hazardous) are listed in a separate table as 'unlikely to present acute hazard in normal use'. The guidelines to classification is prone to permanent revision, based on documented scientific evidence; the latest version was published in January 1994 (WHO, 1994a).

4. Risk management

It is easy to demonstrate that a certain chemical is toxic and hazardous in specific circumstances, but is virtually impossible to prove that it is harmless and safe. Therefore it is impractical for scientists to be requested to prove the absolute safety for any given chemical, and they should rather be requested to provide sound judgement of the degree of hazard under given conditions. This definitely varies among communities because the hazard acceptable for one group may not be acceptable and/or applicable for another. For this reason risk assessment is valid globally but risk management should be elaborated upon for any specific situation, country or even area.

As the amount of information on risk assessment has grown, the level of concern has increased rather than decreased. This poses a particular burden to decision makers who are supposed to weigh risk evaluation data against cost, benefit and even political considerations, before endorsing the use of a particular chemical. To facilitate this process in developing countries, chemical control boards should be established with representation of all interested parties having authority to implement and supervise the policy and regulations established by national regulatory authorities. The latter should follow as closely as possible the rules and recommendations described in the London Guidelines for the Exchange of Information on Chemicals in International Trade (UNEP, 1989) and the International Code of Conduct on the Distribution and Use of Pesticides (FAP, 1990). To facilitate the information exchange among the countries over 120 UN Member States have designated a national authority for the implementation of the information exchange and Prior Informed Consent procedure of the London Guidelines and the International Code of Conduct.

Following assessment and identification of the risk arising from toxic chemicals, considerable attention should be paid to activities leading to a reduction of known hazards to an acceptable level. This is done through three different areas of activity: (i) prevention of human poisoning; (ii) promotion of the safe use of chemicals at all levels; and (iii) education and training. The above-mentioned activities are implemented through a variety of joint programmes of various international and national organizations.

5. Prevention of poisoning

This is a specific WHO objective which is now a major activity within IPCS. It includes the production of guidelines for poison control, the validation and availability of antidotes used in the treatment of poisoning and, in particular, the evaluation of existing antidotes used in the treatment of poisonings. The key role in these activities is the development of information systems for poison control, including harmonization and exchange of data. Particular attention is given to medical response to chemical emergencies in cases of accident.

It is not known how many people are poisoned each year or how many die as a result of being poisoned by chemicals. A number of estimates have been made, but these may be unreliable since they are usually extrapolations based on statistics for a few countries or a few chemical substances. Furthermore, there is no international agreement yet on severity grading for different types of poisoning, and these estimates cannot indicate whether cases are mild, moderate or severe. Even death certificates are often quite unreliable in many countries. The few statistics available appear to indicate that the number of poisoning cases in developed countries is stabilizing but those in developing countries may be rising, or at least for those countries where figures are available, there is an improved identification of cases.

Poisoning may occur accidentally or deliberately. A vast range of chemical substances is involved in poisoning cases worldwide, including those used in agriculture, industry, commerce, and the home. In developed countries pharmaceuticals are one of the important use groups of substances giving rise to poisoning; in developing countries pesticides form an important group, as do common industrial chemicals. Carbon monoxide poisoning, from poor fuel combustion in enclosed areas, is still common in both developed and developing countries. Toxic substances of natural origin, e.g. poisonous plants and venomous animals, also give rise to significant numbers of poisoning cases.

In view of this situation, urgent intervention is required in many countries to restrict the availability of highly hazardous chemicals. Although many developing countries have passed legislation to control chemicals, enforcement is often inadequate or non-existent. Experience in developed countries has shown that restricting the availability of highly hazardous chemicals, together with proper packaging and labelling, significantly reduces the incidence of poisoning.

Many of the poisonings are preventable if appropriate measures are elaborated and implemented. This applies particularly to the educational and training programmes. Wider use of the WHO Recommended Classification of Pesticides by Hazard, within the framework of the FAO Code of Conduct on the Distribution and Use of Pesticides, should be helpful in this regard.

6. Promotion of the safe and judicious use of chemicals

Among various activities of IPCS in the area of the safe use of chemicals, special attention is paid to identify sources related to increases in health hazards.

Recommendation for the restriction in availability is one of the essential elements which if endorsed, may considerably increase safety for the user and the general population. A number of guidelines concerning safety aspects during formulation, transport, distribution, storage application and disposal of unwanted chemicals and containers, when respected, would also significantly reduce the hazard from chemicals. Appropriate labelling is a conditional requirement for safety but it is essential that the label is read before use and instruction followed. Appropriate protecting clothing needs to be used, but without other measures, such as good working practice, its effect will be greatly reduced.

Proper timing and assessment of overexposure to hazardous chemicals contribute significantly to the safety of, for example, pesticides used in agriculture or in public health or industrial chemicals. IPCS is assisting developing countries in recognizing the extent of the problem of risk from chemicals to which workers are exposed. Thus, WHO has produced a standard protocol for the assessment of exposure to certain types of pesticides in which determination of erythrocyte cholinesterase activity is crucial and the most appropriate tool for field assessment of exposure to organophosphorus pesticides. When used as part of the surveillance of workers, an individual can be withdrawn from further exposure if his erythrocyte cholinesterase activity decreases significantly from a well-established pre-exposure value. In the past few years, WHO has developed a field method for measuring whole blood cholinesterase activity. The method has been in use in the field for several years, and, along with the progress in technology, the method is being improved and the field kit modernized and subsequently commercialized.

The methodology and recommendations for biological monitoring of exposure to various hazardous chemicals is being produced by WHO.

7. Education and training

In order to support efforts to promote education in the safe use of chemicals, a number of educational and training programmes have been developed within IPCS and by many other national or international organizations. One of the recent programmes has been developed by IPCS for training the trainers in the safe use of pesticides. It is designed to be used at several distinct educational levels, adaptable to local needs. It includes: (i) basic level courses; (ii) intermediate courses; and (iii) advanced level courses. The course is divided into sections, each preceded by specific educational objectives. Each section is divided into one or more subjects, and each subject into a number of modules. Each module is supported by a visual aid in the form of a slide with key words or a photograph. A selection of modules is made from each section appropriate to ble service to a modern approach to the protection.

'Quality of Life: New Global Trends' asserts the following: 'Missionaries are very capable in building and conducting educational, medical, agricultural and cultural facilities in developing countries. Not all, however, are versed even in simple agricultural practices and techniques. Since they exercise in many areas of developing countries a socially significant influence, their professional formation should include basic agricultural principles, practices and techniques, all of which they should communicate to the populations in which they work in total respect for local needs and values.'

2. Constraints

We should note that, in the spirit of what has been said above, several religious environmental groups and centers have come to exist. Their purpose is varied. Some promote environmental education; others are actively committed to the improvement of the environment. Let us list some of the more known among Catholics: a Center of Irish Missionaries in Indonesia that is striving to protect the forests; a Center in Cracow, Poland, established to educate people to assume responsibilities for the environment; a Center in Montevideo, Uruguay, to form people who will work with the poor to protect the environment. Brazil has had several cases of missionaries who have been killed for their work with indigenous peoples to protect the Amazon from goldminers who pollute rivers with mercury. Many Catholic universities have departments of engineering that have assumed environmental responsibilities, departments of forestry, and departments of environmental studies, and so. The same can be said for many other Christian Churches or Confessions. Buddhist and Hindu Centers exist to raise the religious consciousness of their followers to environmental issues.

Having said this, serious constraints exist in the monitoring of chemical hazards by religious groups as religious groups. Beyond the Catholic universities mentioned in the preceding paragraph, few individuals as religious persons are prepared scientifically to monitor chemical hazards. Bophal is a good example where no monitoring existed — religious or non-religious. On the other hand, one should not forget that many religious people work in non-religious groups where they are actively committed to our theme. In general, however, religious groups are more intent on implementing in their communities the values of their respectives faiths. Few know that a United Nations Convention on the Control of Transboundary Movements of Hazardous Wastes (Basel, 20–22nd March, 1989) and a Convention on Atmospheric Pollution (Geneva, 1979) exist.

3. Conclusion

In the light of the religious motivations presented in the first part and since even sustainable development will inevitably create hazardous chemical wastes, then religious faith must be rendered more effective in monitoring such wastes. In the Middle Ages, Europe was already applying laws against the pollution of waters with dangerous substances. In many cases, the formulation and application of those laws was a prerogative of Cathedral Chapters and Monasteries.

Part V

Responsibility of Industrialized Countries and Recommendation for Future Actions

the educational objectives and background of the participants. The course manual is accompanied by an instruction manual designed to enable national authorities to create multilevel courses on the safe use of pesticides in individual countries, in the local language, and with their own resources. The format of the course is such that it can easily be modified in order to be adapted to national needs and for different levels of audience.

IPCS also provides training on basic chemical safety (toxicology, ecotoxicology, risk assessment) for government officials and public health advisers, primarily from developing countries. This training defines the principles of chemical safety and their application to pesticide safety use as well as to other groups of chemicals. A series of linked training modules at an advanced level is in preparation. These modules are directed to government officials with responsibility for pesticides but also other chemicals, including registration and licensing, inspection, safe use and disposal. Courses at this level have also been conducted using existing training materials.

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A few remarks on the dangers of pollution in developing countries

Pier Luigi Zampetti

This congress is devoted to the problem of chemical pollution in developing countries. This subject deals with two ranks of problems from the geueral point of view. The first one concerns relations between industrialized and developing countries, and the meaning of such relations in the contemporary world.

Only afterwards shall we be able to cope with the relation between development and environment, and the feasibility of integrating both. The problem raised by such integration enables us to underline the need to coordinate scientific disciplines, that deal with deterioration of the environment, with socioeconomic disciplines, where development implies also problems of ethical and religious nature.

In this short report of mine I am going to consider the influence of productive systems and, more generally, capitalistic consumers' culture on ecology.

This subject has already been analyzed in detail in my book 'The challenge of the year two thousand' (published by Rusconi), where I have underlined that by saying 'ecology' I do not imply only environmental ecology. Before coping with environmental pollution, ecology must consider human and social deterioration.

The pattern of development that brought about consumers' society fostered a concept of life that deformed the very image of man. The loss of values has affected the way to look at relations between man and nature. I shall say even more: nature has become an instrument of development, for the latter has succeeded in exploiting and taking advantage of man and the whole society, the State included.

For this reason the encyclical 'Centesimus Annus' indicates three types of ecology: human, social and environmental ecology. The three of them cannot be separated even though, actually, they are considered apart one from the other. Environmental problems remain unsolved because of the different approaches taken, whereas the ethical and social aspects of ecology should be combined with the environmental ones.

The United Nations' Conference on Environment and Development held in Rio de Janeiro from the 3rd to the 14th June 1992 approved the 'Rio Declaration' on the integration of development and environment, that was made up of 27 principles. I am going to recall such declaration in order to work out the cultural approach that is necessary to connect the ethical and social ecology with environmental ecology. Clearly I am thinking of ecology in its broadest meaning, without identifying it, as it is commonly done, with environmental ecology that I could define ecology *par excellence*.

Principle 4 of the Rio Declaration contains a major statement that should be the starting point of any proposal to solve the increasingly urgent issue of deterioration of the environment. To achieve a sustainable development, environmental protection is an integral part of the develop-

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ment process that cannot be considered apart from it.

The process of sustainable development refers to a pattern of development where economic growth integrates with the harmony of nature.

But does the above-mentioned concept of development correspond in reality to the development that has been conceived so far? My answer is undoubtedly negative. Development is still thought of solely as economic development. It is the driving force of consumers' society. The decisions concerning the consumption necessary to this society precede the production of goods. The state itself has entered this economic process and become part of its mechanism. For these reasons the economic system manipulates man by influencing his inner choices and controls the state that, with its economic mechanisms, allows the continuous expansion of consumption while neglecting the quality of life. The environment is considered a free space that can hardly be confined since the state has become an instrument of the productive system. For the same reasons, the State cannot take suitable measures in order to change the rhythms and the processes of such system. Against this background, the same firms would be unable to afford the increase of production costs. Their goods would not be competitive as against those of firms located in other countries. Indeed, consumption takes precedence over production not just in the domestic but also in the international market.

The pattern of development that was brought about by the consumers' society has lead to dividing the world into three areas. The relations between industrialized countries, that make up the area of the first world, and developing countries, that make up the area of the third world, must be looked at with great attention. The third world includes two types of countries: those supplying raw materials and those that cooperate with the productive system of industrialized countries and consume the goods that the latter produce. Therefore I believe that the relation between developing countries and countries of the first world is of a *dependent* rather than an *interdependent* nature. International relations between the first and the third world are heavily conditioned by a process of development implying development of economic nature. Therefore countries can be distinguished according to their *geoeconomic* rather than *geophysical* and *geopolitical* features. In other words, the process of economic development that has given rise to the so-called globalization of economy has expolited and taken advantage of man, reduced to a consuming machine, the State in industrialized countries, and the States of the third world in the framework of the international community.

I would like to stress, as I have already mentioned, that the Rio Declaration outlines a concept of development that is totally unlike the one adopted until now. This type of development takes man into consideration, thus differing from a mere economic development that exploits man and the environment. All of which takes place, as was highlighted by principles two and three, as well as by article 2 of the Convention on biological diversity, both within individual countries and in their relations with the others, without considering the needs of environment and development with a view to present and future generations.

'Human beings'—recites principle 1—'are at the centre of sustainable development. They are entitled to a healthy and productive life in concord with nature'. Such principle runs counter the structucs of consumers' society. Its application would require a radical change in the productive system where economic development prevails over ethical and political factors. Only by means of this change could principle 14, that lies at the root of our debate, be applied. 'States will have to cooperate effectively in order to discourage or prevent the transfer in other countries of all activities and substances that produce a serious deterioration of the environment or are considered harmful to human health.'.

As long as capitalism of consumers' society prevails, such principle will not be applied effectively. With a view to the preparatory work of Rio Conference, for the concept of substainable development to be introduced, the right to development should be understood as a fundamental human right. Only then will development no longer be considered as something separate from man or, even worse, an antagonist of man. And the right to environment will then be recognized as a fundamental human right.

Today we are still far from acknowledging man as true and authentical subject of development. Moreover the real western resistance to acknowledge the right to development have involved the exclusion from the Rio Declaration every mention of the right to environment as a fundamental human right[1].

The project of the group of 77, dated 4th March 1992, contained instead a very clear principle that ran as follows: 'Each individual has the right to a clean and ecologically balanced environment, to be informed of the state of the environment and of all activities that have a negative impact on the environment and to participate in the decision affecting their environment'.

The non-recognition is not accidental. It is due to the structures of the western society, that are still heavily dependent on capitalism of consumers' society. Therefore, a precise goal must be set: the community of states must be induced to recognize such fundamental rights. Such purpose requires a strategy: a new pattern of development, whereby the economic system and capitalism are proportionate to man. The principles of this new pattern of development are enshrined in the social creed of the church and are the natural conclusion of the scientific analysis I am making.

I must answer now a very concrete question: what are the measures to be taken for the so-called sustainable development, resulting from the integration between development and environment, to be implemented? Principle 1 of the Rio Declaration will never become operative unless each man and the whole human being become the subjects of sustainable development. Very few results can be expected if we hope for decisive measures taken by the state or the community of states.

The Rio Declaration says nothing about it. It confines itself to a deliberately general statement, while underlining, as it was done before in other international documents, that the best way to deal with the environmental issue is that of ensuring the participation of all the parties concerned at all levels. Then it will be up to us to translate such statements into our historic reality. The Declaration (principle 8) stresses that in order to guarantee a sustainable development and a better quality of life to all peoples, states will have to reduce and eliminate the unsustainable means of production and consumption. An alternative must be found to the consumers' society, thus bringing to an end the pathological distinction between first and third world that was produced by that same society. The prerequisite for the integration between development and environment is the integration between industrialized and developing countries.

'Since only developing countries own the natural resources that are necessary to preserve the earth ecosystem from total deterioration, their needs will have to be properly safeguarded in the future'.

The partaking society fulfills such needs. It envisages a radical change in the structures of society and a new way to look at international relations. In this kind of society, the man, rather than the productive system, will be the subject of development as soon as he becomes the *joint-owner of the means of productions*.

The encyclical Laborem Exercens formulated a principle of fundamental importance, that favours the creation of a man-serving economy. We must ask ourselves: what is the meaning of man being the joint-owner of the means of production? Gradually man must be enabled to own part of them. The participation in the decision-making process will only be possible if the employee shareholding system is further intensified. Joint-ownership (that is to say, owning part of property) is the basis of participation. The connection between the words *part and participation* is extremely significant.

This process is under way in the West. We must try to interpret and govern it in the light of the social doctrine of the Church, whereby man is seen as a person. This principle has never been examined, nor developed until now, and yet it is

[1]See S. Marchisio, Gli Atti di Rio nel diritto internazionale, in ⟨Rivista di diritto internazionale⟩, III, 1992, pp. 594–595.

essential to solve the ecological problem as such. Only by implementing such principle shall we acknowledge the rights to development and environment as fundamental human rights. International relations between the first and the third world would undergo profound changes. By implementing the theory of participation a fundamental principle, that was not included in the Rio Declaration, would be recognized: the universal destination of the wealth of the earth. The demographic problem and the need to release man from poverty, mentioned by the Rio Declaration, can be dealt with and solved only in the perspective. Sharing the means of production lies at the basis of people's capitalism and fosters a democratic economy. It is an economy of a different nature. It is participation that qualifies democracy. Such democracy is not a representative democracy, but rather a deocracy based on participation. The latter implies the democratic process within the economic process itself that produces a new pattern of development based on the man looked at as the subject or as a person.

All men are the subjects of the economy based on participation. In this kind of economy men bring in their being and their human capital that belongs to themselves. It is just the opposite of what happens in the capitalistic economy, where men are considered only for their activities.

Even capitalism in consumers' society had taken human capital into consideration, but only to exploit and repress it, rather than to develop it.

Man lies at the basis of the new pattern of development, with all his mutually integrating dimensions. And here is the power of a pattern of development meant as complete and integral development of the human being. Economic development can no longer be merely economic and become integrated with polictical features. Democracy is the joint between the economic and the political aspects of life. Yet, it must follow the sharing of private property of the means of production or employee shareholding. Such democracy runs counter the economic autocracy produced by the *concentration* of private property of the means of production.

The economic autocracy coexists with political or representative democracy, the latter being conceived only as political democracy and unable to change the autocratic structures of capitalism. When I say 'political democracy' I am thinking of a democracy that is reduced to the mere political aspect. When the economic autocracy falls and democracy appears within the economic system, democracy itself widens. Such extension has a revolutionary consequence. Democracy is no longer dwarfed, as it is true for representative democracy (a merely political democracy), and becomes a full democracy based on participation. It can make development become a full or integral development, as reiterated by the encyclical 'Sollicitudo rei socialis'. This form of democracy becomes the collector of all men's energies and can make the global history turn by 360 degrees.

If the system we build can multiply human energies, material resources will be multiplied as a direct consequence. By so doing, material resources will no longer be squandered, as it is the case when power is held by an autocracy (and indeed it has been so far).

Therefore, the ecological problem can be solved by means of the citizens' participation, barely mentioned by the Rio Declaration. By introducing this new concept of democracy into the economic system, participation becomes the new basis of economy through the coordination of the various development processes in all countries of the world. The Rio Declaration will remain a dead letter unless it is connected with a different concept of man and society that can overcome those economic differences that are the foundations of the present global order.

The idea of a sustainable development capable of eliminating the dangers of pollution on any level in the developing countries, by modifying unsustainable production and consumption methods, can only be applied in this perspective. Unsustainable development is responsible for exporting pollution outside the industrialized countries.

For these reasons, the committment made by developed countries to allot 0.7% of the gross national product to ODA (Official Development Aid) which will become the main source of external funding to sustainable development, though important, is totally insufficient, even if such a sum were to be actually used (which is not at all certain).

This would not allow the real integration between environment and development required for a radical change in the structures not only of the production system, but of the society as a whole. Just like Pope John Paul II has always explicitly maintained in all his social encyclics.

Part VI

Conclusions

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Conclusions

1. State of chemical pollution in developing countries

1.1. Latin America

Before World War II Latin American Countries mainly produced and exported primary products from agriculture and mining. In order to develop and broaden their economy a wave of industrialization took place with a large increase in the production and processing of metal, petroleum and chemical products. Most industries were located in or close to large urban areas on coastlines, within the water catchment areas of major rivers or important underground water resources. Minimal or no attention was payed to environmental consequences. Few attempts have been made in recent years to rectify the situation in this respect largely dependent on economic restraints and a stagnation or a decline in the industrial production in 1980–1990's. The background of this development has been growing external depts in most Latin American countries, decline in international price, unfavourable trends in international commerce and failures of economic policies in many countries. As an example of the difficulties encountered, the export from Brasil generated a positive balance of trade 1988 with 19 billion USD, of which 17 billion were used to pay off part of the debts.

The environmental problems from the industrialization are particularly connected with small scale industries, where occupational exposure to hazardous chemicals is not given appropriate consideration. Also these small industrial plants often discharge hazardous wastes to surface and ground water, to air, soil and sometimes contaminating the food chain.

The environmental impacts of chemicals and chemical pollution are furthermore magnified by the population increase. Since 1930 the population of Latin America has quadrupoled. This population increase has been accompanied by an extensive urbanization and this development can be expected to continue. In Latin America 2/3 of the population now live in urban areas and this number can be compared to 34% in developing countries in general. This urbanization has resulted in a sharp increase in cars and in air pollution. On a yearly basis it has been estimated that the number of excess respiratory illness among children in Latin America by air pollution amounts to 2.3 million cases.

The extensive petrochemical industries in Latin America are responsible for serious environmental problems, both directly and indirectly. There is an oil spill in all oil-producing countries and off shore drilling has caused severe damage to Caribbean mangrove swamps, seagrass meadows and coral reefs. In some of the oil producing countries the pipe lines are old and corroded and they leak constantly. To that picture one has to add terrorist attacks on pipe lines causing extensive leakage of oil.

Large chemical enterprises, based on petroleum products, have been developed in Latin American countries. This production includes olefins (ethylene, propylene and butadiene) and aromatics (benzene, xylene and stryene) comprising about five per cent of world production in both cases.

There are severe environmental problems from domestic waste water — less than 2% of urban sewage is subjected to any treatment. Decades of negligence in this respect has resulted in cholera epidemics in most of the Latin American countries. Industrial effluents often carry heavy metals

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and synthetic organic chemicals. Much of the water pollution is linked to deforestation, which causes soil erosion, and to the abuse of agrochemicals in rural areas.

As in practically all developing countries, pesticides are responsible for particularly severe chemical contamination of the environment in Latin American countries. The money spent by some countries on pesticides has doubled or tripled from 1980 to 1990. The use of highly persistent organochlorine has caused much concern and attempts are made to move away from such chemicals to less persistent carbamates and organophosphates. Previously pesticides were imported from Europe and North America, but now a considerable amount is manufactured in Latin American countries. Thus in Brasil and Mexico 50 pesticides are currently manufactured.

The extensive use of pesticides and the lack of appropriate regulations and/or implementation of existing rules for their handling, has made these chemicals of particular environmental and health concern in developing countries in general — Latin America not being any exception. However, actual data on health effects is limited for several reasons. There is for instance an obvious underregistration of pesticide poisoning. For example in Costa Rica 423 cases of pesticide poisoning were registered at the National Poison Center 1978–1980, but in one single hospital in an area with banana plantation there were 374 cases of such poisoning just in 1980. The number of pesticide intoxication has increased every year since 1980. Seventy per cent of these cases involve agricultural workers. Of manifested effects can be mentioned an increase of abortions in women exposed to mixtures of pesticides during pregnancy in Columbia and reproductive effects in male workers in Costa Rica, exposed to the nematicide dibromochloropropane. There is also a significant exposure of the general population to pesticides. High levels of organochlorine pesticides have been measured in mothers milk, particularly DDT and DDE. Sometime the values have exceeded the values accepted for cow's milk.

Industrial countries have introduced firm regulations concerning contamination of food stuff by pesticides. Therefore contaminated food from developiug countries, when rejected for import by developed countries for that reason, is instead marketed and consumed locally.

It can be concluded that the situation concerning environmental hazards from pesticides in Latin America causes great concern becanse of the increasing quantities used and the low priority given by the Governments to regulate pesticide usage and labour related conditions.

Toxic wastes disposal constitutes another serious threat to the health and environment in Latin America. As an example Mexico produces 450 000 tons of industrial waste daily, of which 14 500 tons are considered hazardous. Of these hazardous chemicals 5 784 tons are generated by 39 000 manufaeturing plants in Mexico City. Only a fraction of this waste is properly handled.

When it comes to chemical hazards in general, the Pan American Health Organization has stated that the improper handling of chemical substances constitutes a major threat to human well being in the Latin American region. While industrialized countries have established extensive legal protection of the people from chemical hazards, such regulations are largely lacking in developing countries. Apart from direct effects on the population, this state of affairs have indirect undesirable consequences. Products which are banned in developed countries, such as certain pesticides, wastes and drugs, are sometimes exported by these countries to Latin American and other Third World countries.

The future possibilities to come to grips with environmental and health hazards by chemicals must, to a great extent, rely on international actions and cooperations. This is true for all countries in the world, but evidently of particularly imminent importance concerning developing countries. These aspect will be dealt with in a later section of this document.

1.2. Africa

The population growth in Africa implies similar, serious problem to the environment as in other developing regions. The fast growing populations, particularly in the Sub-Saharan regions, have created a demand for an increased and sustained food production. The population growth has however outstripped food production, leading to serious food shortage. In the year 2000 it is estimated that Africa can only produce 60% of the food needed for consumption. In contrast to Latin America, the African population is mainly rural, to 80% made up by small-scale farmers. The dominating importance of agriculture in Africa has made their economy highly vulnerable to failures of the crops by climatic and biological conditions, and in particular pests. Among small-scale farmers there is a constant loss of crops around 50%, due to pests. As in other parts of the Third World, the battle against pests is fought by means of wide applications of pesticides. The unrestricted use of pesticides has lead to an extensive, genetically determined resistance to pesticides, which forces a vicious circle with the application of larger quantities and a successively wider diversity of pesticides. Accurate statistics on pesticide trade and usage is scanty, reflecting the lack of control of pesticide handling. Largest use of pesticides is found in large scale cash crop production, such as cotton in Sub-Sahara. The rapid increase of cash crop economy has resulted in an increasing demand for pesticides and other agrochemicals.

The bulk of the pesticides used in Sub-Saharan Africa are imported from Europe, America and Japan. Some donor nations provide outdated or banned pesticides, which in many instances result in excessive supplies of pesticides, which eventually remain unused and pose disposal problems and contamination of the environment.

The chemical hazard situation in Africa differs from the one in Latin America by the fact that industrial contamination is a less dominant problem in Africa than the use and contamination by pesticides and other agrochemicals. Lack of regulations and lack of knowledge how to handle pesticides is probably even more pronounced in Africa than in Latin America.

As in developing countries in general the main issues concerning the impact of pesticides on human health, are misuse and occupational exposure. Serious problems are caused by lack of protective clothing, contamination of water and food, and use of empty pesticide containers — problems to a great extent emanating from a lack of instruction and knowledge. A big threat to the environment is leakage and pollution due to inadequate storage. Old stocks are leaking to a great extent. Moreover, some African countries receive pesticides and other hazardous chemicals from abroad to be dumped at a fee.

The solution of the severe pesticide problems in Africa is the same as for other regions that is information, education, regulation and governmental control.

1.3. Asia

The situation concerning chemical hazards in Asia was not dealt with at the conference in any detail. It is however evident that the infrastructure and other conditions exhibit a greater variation between countries than is the case in Latin America and Africa. Therefore it is hardly possible to discern any trends of general applicability for Asian countries. However, for the developing countries in Asia many of the problems encountered in Latin America and Africa nevertheless are of the same significance. The increasing population and the formation of megacities have created similar problems as in Latin America with chemical pollution from industrial activities, which are particularly difficult to control and deal with among the small and widely scattered industries. To a large extent depending on inefficient infrastructure, corruption and lack of implementation of legal control of trade, inappropriate handling and disposal of chemicals, the pollution problems are very severe in many parts of Asia. This is especially true for the many extremely poor regions in Asia, where the survival of the population evidently is of primary concern rather than a control of chemicals from different sources.

People's Republic of China with its rapid economic development and huge population deserves a particular attention. It is obvious that environmental concern has come in very late and in many respects the situation in China mimics the conditions in the former Soviet Union, where the critical state of the environment in many regions has been revealed in recent years. Although it is difficult to get a comprehensive out-line of the Chinese administration, one problem is the fact that industry and environmental issues are dealt with by different administrative bodies. Among actual environmental pollution problems dust and sulfure released from coal plants and pollution with heavy metals and organic compounds of several rivers should be emphasized.

2. Ecotoxicology in developing countries

The publication of Rachel Carson's "Silent Spring" opened the eyes of the public to the hazards of the pollution of our environment for biological life in general. At least in the industrial countries ecotoxicology has been an area of high importance and revelance since then. The attention has been focused on persistent chemicals, in particular chlorinated organic compounds and heavy metals, which tend to exhibit bioaccumulation in higher trophic levels. It was thus demonstrated at an early stage how DDT accumulated from the lowest levels in water and plankton along the food chain to predatory fish and carnivorous birds by a factor of 1000 or more. Data from tropical countries shows that the bioaccumulation occurs in similar ways also in tropical ecosystems. This could for example be demonstrated for DDT, HCH, HCB and dieldrin in Lake Kariba in Zimbabwe. Similar effects on the organisms as observed in temperate areas could also be detected — egg shell thinning, decline in bird populations, and effects on insects and their larvae. Contamination of the environment with persistent chemicals has become an escalated problem in developing countries. Such persistent chemicals are counted in hundreds today and they emanate from industrial release, i.a. of PAH from petroleum industries, from the use of PCB, chlorinated phenols, organic solvents, household chemicals and—not the least—the large spectrum of agrochemicals. The ecotoxicological concerns focus on food chain transport which is coupled to lipophilicity of the compounds, retention in soil and sediments and mobility between environmental compartments, for instance connected with volatilization, which can be expected to be of greater significance in tropical areas. It should be stressed in this connection that the persistency of chemicals cannot automatically be extrapolated from temperate zones to the tropics. During the conference it was reported that DDE, which is the most stable metabolite of DDT, in ampoulles outdoor in Nigeria disappeared completely overnight. While DDT was decomposed, lindane and toxaphene remained totally stable.

The number of chemicals and the total amounts produced is increasing continuously and there is reason to believe that this increase will predominantly occur in developing countries. A major reason for the requirement of more pesticides is the development of resistant strains of pests. In a report by UNEP (United Nations Environmental Program) pesticide resistance was ranked as one of the top four environmental problems of the world. It is estimated that 504 insect and mite species, 150 plant pathogen species and 273 weed species are resistant to pesticides. In some parts of the world this resistance to pesticide treatment has had disastrous consequences. In Mexico and Texas an extremely high pesticide resistance had been developed in the tobacco bud worm, which is a major pest in cotton. Because of the inefficiency of pesticide application 285 000 har of cotton has had to be abandoned. A disastrous resistance problem has been the malaria parasite, which has caused very severe problems in tropical countries. In India the malaria cases were down to 41 000 in 1961, but reaches now 59 000 000 incidences per year.

Of great concern in the present context is the fact that persistent chemicals, which are banned in industrialized countries are continuously being used in developing countries, often in an indiscriminate way. The errors of the developed world are now flourishing in the economically pressed developing world with 20–30 years delay.

Monitoring of the release of persistent chemicals into the environment from industries and other human activities is most efficiently performed by means of the bioaccumulation in suitable organisms. Mussels function as filters through which large quantities of water pass, retaining plankton and thereby accumulating chemicals, which occur in the water and have been taken up by these organisms. This bioaccumulation property of mussels obviously constitutes a valuable system for biomonitoring of chemicals in the environment. For that reason mussels have been used for a global assessment of environmental levels of chemical contaminants, The International Mussel Watch. This project has been supported by UNESCO, UNEP and governmental grants from USA. The goal of this project has been to quantify sources and rates of waste released in aquatic and especially marine environment. Regional programs are running in Europe, Canada, USA and Taiwan, but the initial implementation of the project has been along the coasts of Latin America. An important part of the project has been a quality control and quality assurance check of the analyses, prior to entering the phase of extensive field analyses. The analyses and the interpretation of the data has encountered some difficulties because of the fact that somewhat different species have been used with different physiological state of the animals. Nevertheless usually there has been a good agreement between laboratories and the results of the quality control of the analyses have been encouraging. Although it is too early to make any overall evaluation of the results, many of the analyses have been below detection limits, but local hot spots have been identified, and these are being followed up to determine the source of the contamination.

Heavy metals constitute a group of chemicals of particular importance from the point of view of ecotoxicology as well as human health hazard. In many parts of the world, and not the least in several developing countries, alarmingly high concentrations of heavy metals are found in the aquatic environment, for example in some Chinese rivers and outside Sao Paulo in Brasil, where high levels of arsenic, lead, mercury, and zinc — beside various persistent pesticides — have been recorded.

The environmental hazards from mercury contamination have been strikingly demonstrated through the Minamata catastrophy in Japan in the 1950's and the even worse mercury catastrophy in Iraque 25 years later. Today mercury still constitutes a major ecotoxicological threat with serious consequences also for humans. The perhaps most important source of present mercury contamination emanates from the use of mercury in gold mining and panning. The technique of amalgamating gold in connection with gold panning is old, but it has received a remarkably wide application, mostly in developing countries, in recent years. The situation is particularly serious in the Amazonas in Brasil. Unofficial estimation of the number of people involved in gold panning in Brasil amounts to 650 000. Two-hundred tons of mercury is legally imported in Brasil, of which about half is used for gold mining. In the gold panning 15–50% of the mercury is released directly into the rivers, 65–83% as vapour. The contribution of mercury contamination from this source both locally and globally evidently is very high. From an ecotoxicological point of view, mercury constitutes an extremely hazardous pollutant. It is well established from research in temperate regions that metallic and inorganic mercury become methylated by microorganisms in the aquatic environment. Methyl mercury, which was the form responsible for the catastrophes in Japan and Iraque, accumulates in the food chain, sometimes reaching very high values in predatory fishes, birds and mammals, affecting humans as well, when exposed, in particular children from early developmental stages, since methyl mercury trespasses the placental barrier. Although less data is available from tropical areas, similar methylation seem to occur also there.

The consequences of the contamination of the environment with toxic chemicals and particularly persistent chemicals such as chlorinated organic compounds and mercury, have been documented on biological life in many parts of the world. As a matter of fact the background of Rachel Carson's book "Silent Spring" was indeed observations on wildlife by persistent pesticides such as DDT. The highly unrestricted use of persistent chemicals in the Third World inevitably must have negative effects on the ecosystems and biological diversity. These effects occur as the result of direct exposure to organisms, indirect effects via contaminated preys and alterations of the habitat by elimination of food and refuges. Several pesticides cause reproductive failures, i.a. egg shell thinning among birds. Contamination of lakes and rivers by pesticides will affect fish populations and therefore will have consequences also for human nutrition and welfare. Insecticides have often had destructive effects on insects, vital for pollination, such as bees. In some cotton growing areas in Kenya and Tanzania bee-keeping is virtually impossible because of the extensive use of insecticides. Contamination of the soil may imply toxicity to earthworms and alteration of the conditions for microorganisms, which are of fundamental importance for ecosystems.

The use of pesticides does not only hit the target pests, but also beneficial parasites and predators. The destruction of natural enemies for instance in cotton crops by pesticides has been shown to result in the outbreak of numerous pests in USA. The elimination of the natural enemies to various pests by pesticides often require more intense and expensive pesticide treatment. A similar situation was observed for rice in Indonesia where the destruction of beneficial natural enemies resulted in such a severe outbreak of pests that the rice yield dropped so much that rice had to be imported from abroad.

The maintenance of the biodiversity implies a balance between economic and environmental considerations and unfortunately this balance most likely will be in favour of economic considerations in developing countries. Putting a "value" on the environment remains however a world wide problem. The attempt for a solution in developed countries concerning the preservation of biological diversity, has been pressure from the general public and this may be the route taken in developing countries. This is likely to be aided by scientific information, but the situation in developing countries suffers from a lack of sufficiently detailed scientific information to make appropriate decisions for instance concerning the choice of the least damaging pesticides.

3. Health hazards from pesticide use

The extensive use of pesticides in developing countries in combination with a lack of regulatory actions to control the handling of pesticides has resulted in a situation, where acute poisoning of people has become a priority health problem. The poisoning is caused by organochlorines, organophosphates, carbamates and nitro- and chlorophenols. The aim of diminishing the use of persistent pesticides has made organophosphates increasingly dominant. The far less toxic pyrethroids are unfortunately too expensive to be used by developing countries to any major extent.

The extent of poisoning by pesticides can only be estimated on the basis of scattered regional and local data. In Sri Lanka with a population of 12 million people, about 10 000 hospitalized pesticide poisoning and 1 000 deaths occurred in one year. This data includes suicide cases, which constitutes 2/3 of hospitalizations. The number of deaths due to pesticide poisoning in Sri Lanka that year was almost twice the number of deaths from malaria, poliomyelitis, wooping cough, diphteria and tetanus. In Sri Lanka 5% of agricultural workers become poisoned by pesticides. The corresponding data from agricultural workers in Malasia is 13%. In the developing countries as a whole it is estimated that 3% of the agricultural workers experience some degree of pesticide poisoning per year. With an estimated number of agricultural workers of 830 million, this would mean 25 million cases per year.

In Indonesia, on the basis of local studies, the number of pesticide poisoning can be estimated to 30 000 cases annually. In Thailand 4046 cases were reported 1985, of which 289 died.

In Africa it has been estimated that 11 million cases of pesticide intoxications occur annually, including minor cases without hospitalization.

In a report by WHO 1990 it is estimated that 3 million cases of severe intoxications, including suicides, may be matched by a greater number of unreported milder intoxications.

It should be emphasized that the developing countries carry a disproportional burden of pesticide poisoning — over 99% of the deaths occur in developing countries. It is obvious that acute poisoning is, to a great extent controllable, but little has been done in the developing countries to rectify the situation. There was for instance no signs of an improvement of the pesticide intoxication situation in Sri Lanka during the years 1984–1988.

Several factors contribute to the present situation in developing countries. Thus there is a lack of knowledge of the hazards involved in handling pesticides. It is generally not realized that the important route of intoxication is not through inhalation, but through skin exposure. There is a lack of protective clothing, suitable for tropical climates. Occupational exposure occurs when spraying, mixing and diluting pesticides. Concentrations in excess of requirements and poor maintenance of the spray equipment are other factors of importance.

The data on hazards to human health by chemical contamination in developing countries almost exclusively concern acute effects. Next to nothing is known about long term effects, for instance the induction of cancer. It may be mentioned however, that according to the International Agency on Research on Cancer, there is snfficient evidence for carcinogenicity of 18 pesticides and limited evidence for 16 pesticides.

The actions taken in order to control the use of pesticides and other chemicals must to a great extent rest on risk assessments, which provide the bridge between research data on the chemicals on the one hand and the practical management of the risk on the other. The traditional approach in risk assessment is the determination of no adverse effect level (NOAEL) form studies in humans or animals, to which value a safety factor is applied. This approach assumes a threshold for the effect. For genetic effects, including genotoxic carcinogens, such a threshold cannot be assumed and a linearized extrapolation has to be used. An essential part of risk management is a proper knowledge of the target dose. In recent years new and improved methods to determine the dose at the level of DNA or proteins have been developed. Risk assessment of chemicals to which humans are exposed and subsequent administrative risk management has been done in developed countries, but it is far from sure that these data are directly relevant to developing countries. The rapidly growing populations and shortage of food under tropical climatic conditions make the requirements for agrochemicals more critical in developing countries and many times it is not possible to apply the same strict regulations as in some developed conntries.

Much of the blame for the present predicament goes to national governments rather than agrochemical industries. It is not only the question of new legislation but also an enforcement of existing legal regulations. There is furthermore a need for a closer cooperation with agrochemical industries in control programs.

4. Impact of chemical and biological technology

Plant breeding technology has brought forward the "Green Revolution", which has led to a dramatic change in the agricultural practice in many developing countries. This implied the introduction of high yielding varieties particularly of wheat, and therefore it was of great importance for the global food supply. However negative side effects also appeared both at a social and agricultural level. In the present context it is of relevance that the new crops have been bred also for high tolerance to certain herbicides and fertilizers, which has caused a drastic increase in the use of such chemicals. The hazards of an increased use of pesticides is obvious, but also the increased application of fertilizers has negative side effects. Of particular importance is high amounts of nitrogen used in some regions, such as China and also Europe. Of the nitrogen in the fertilizers, 25–50% stays in the crop. Of the remaining nitrogen 20–50% is lost by erosion, 10–50% by leaching and 10–50% by volatilization. This nitrogen eventually may contribute to eutrophication and fish killing by the depletion of oxygen. The uptake of nitrogen in leafy vegetables, such as spinach, may imply a health hazard by causing methemoglobinemia and the formation of carcinogenic nitrosamines.

Conventional breeding towards resistance to pesticides, high yields etc. begins to be supplemented by modern biotechnology, in particular at the DNA level, and this trend no doubt will be further emphasized in the future. So far this advanced technology has not reached developing countries to any appreciable extent, but it certainly is only a question of time, when it will be transferred to developing countries. Material for this biotechnology is furnished by tissue and cell cultures, regenerating tissues, somatic clonal variation, anther cultnres, cell fusion, genetic transformation and gene transfer through suitable vectors. It will be possible to more efficiently acquire resistance to pests and diseases, to herbicides and to abiotic stress factors like drought and salinity. During the last few years a large increase in the release of manipulated crops has occurred in developed countries. It is however obvious that this development, beside its great potential for economy, agricultural practices and food production, also comprises drawbacks and hazards, which have been thoroughly discussed and dealt with in most developed countries. Of major concern can be mentioned the risk for transfer of introduced genes in crops to wild weeds through cross-fertilization, the risk for the spread of manipulated crops beyond the cultivated fields and possible effects on the local flora and fauna. Most of these problems can be analyzed and checked at laboratory and controlled field experiments — but not all. A major problem for developing countries, is their lack of scientific expertise and infrastructure, necessary for a safe management and control of this kind of biotechnology. Assistance from developed countries is here of fundamental importance at least at an initial stage.

The need among the developing countries for scientific education and assistance is imminent in many fields, beside biotechnology. Some measures taken in developing countries concerning the choice and management of pesticides have been influenced by the situation in developed countries in temperate regions, without sufficient knowledge of the local conditions and requirements. In temperate regions the banning of DDT was justified, but it can be questioned, whether the replacement of DDT in some developing countries by toxaphen, which is persistent, extremely toxic to fishes and a carcinogen, was a sound step to take. There is an obvious need of education in the developing countries in basic knowledge of the toxicity and biochemical properties of chemical contaminants. The management of chemical pollution and hazards is furthermore dependent on monitoring of the environment, which requires reliable chemical analysis data. This implies access to relevant laboratory facilities and sufficiently trained personnel. Training courses set up by experts from developed countries must be adapted to the conditions in the region dealt with. That means that situations of unusual occurrence in developed countries have to be dealt with, such as occasional cut of water and electric supplies, risk for corrosion of the instruments because of high humidity, insufficient service organizations etc. It is essential that training courses for chemical analyses and other scientific activities involves the personnel, which will actually handle the laboratory work.

5. International guidance and regulations

It was repeatedly emphasized during the conference that an important contributing cause of the problems of chemical pollution and hazards in developing countries, has been a lack of basic knowledge and information of existing knowledge, as well as a lack of application and implementation of guidance and rules, mainly worked out in industrial countries. This neglect has been prevalent not only within developing countries, but also among developed countries in their relationship towards developing countries.

The problems and hazards from pesticides were recognized in the 1950s by FAO, and 1962 the "FAO Committee on Experts on Pesticides in Agriculture" was established to advise on matters relating to pest control. These activities led to the establishment in 1985 of the "International Code of Conduct on Distribution and Use of Pesticides" with particular aim of assisting developing countries. It is voluntary in nature, but defines the responsibility for safe handling and effective use of pesticides.

In order to introduce a better control of the trade with pesticides, based on available scientific knowledge, the UN introduced the "Prior Informed Consent (PIC)", were it is established that international shipment of a pesticide that is banned or severely restricted for use, should not take place without the concent of the importing country. The practical implementation of PIC has been laid down in the "PIC procedure". The PIC regulation and procedure has been extended to cover also other hazardous chemicals than pesticides, and the operational responsibility has been shared between FAO and UNEP in such a way that FAO is responsible for pesticides, while

UNEP is taking care of industrial and consumer chemicals. Within this joint FAO/UNEP programme a database on chemicals included in the PIC procedure is established, and guidance documents are worked out and distributed. To implement PIC, the 118 member countries have nominated Designated National Authorities. Furthermore Guidance for Governments has been published as well as Decision Guidance Documents, giving summaries of ecological and environmental characteristics of the PIC chemicals. FAO's Technical Cooperation Programme (TCP) provides assistance to developing countries for the legal, practical and scientific management of pesticides. Also mainly for the benefit of developing countries a number of Technical Guidelines and workshop and training reports have been prepared.

The strategy of plant protection by FAO, in accordance with the UNCED conference in Rio 1992, is the Integrated Pest Management (IPM), the purpose of which is to optimize various actions for pest control and minimize the hazards. Assistance to developing countries to implement the IPM strategy has resulted in a diminished use of pesticides, for instance in Indonesia.

During the UNCED conference in Rio 1992, the responsibility of the developed countries to assist developing countries in solving their problems concerning chemical hazards, was emphasized and inscribed in chapter 19 of agenda 21, dealing with chemicals in the environment. Apart from discussions of available international regulations to improve the situation concerning chemical hazards, an important suggestion deals with the creation of a special UN body: "Forum for Chemical Safety", which is meant to be of particular help to the developing countries. In accordance with the recommendations in agenda 21 an International Conference on Chemical Safety will be held in Stockholm in April 1994 and one important task of this conference will be the establishment of this "Forum for Chemical Safety". Hopefully the formation of this international forum, as well as other actions recommended in chapter 19 of agenda 21, will pave the way for a closer cooperation between developed and developing countries in handling the critical chemical hazard problems at a global level.

6. Recommendations

International actions and assistance

1. Implementation of the recommended actions in Chapter 19 of Agenda 21, presented at the Rio conference 1992 on:
   * Risk reduction
   * Harmonization of classification and labelling system
   * National capacity building
   * Prevention of illegal traffic
2. Exchange of information between developing and developed countries concerning risk, hazard and effective use and disposal of chemicals.
3. Assistance to developing countries in providing information and advice for the judicious use of chemicals and their disposal.
4. Technical and scientific support for developing countries to minimize human/environmental contamination, improve legislation, develop competence and infrastructure.
5. IPCS should play a major coordination role by facilitating a better articulated work of the international and intergovernmental agencies active in the various fields associated with chemical safety.
6. Information by ILO on occupational health should reach trade unions and the workers, not only governmental institutions.
7. The results of the assessments of health and environmental risks from toxic chemicals by IPCS should be made more easily available to developing countries.
8. International regulations should be brought up to date and respected by all authorities both in developing and developed countries.
9. A consistent implementation of PIC-programme and binding of national aid programmes to exclude economic support for production and marketing of hazardous chemicals.
10. Emphasizing the moral obligation for developed countries to reduce the dumping of chemical wastes in developing countries.
11. International agencies should establish PIC and values for cultivation and use (VCU) for

the transfer of varieties and genetic material, produced by genetic engineering, to developing countries.

12. Existing guide lines by OECD for safe development of plant biotechnology products should form the regulatory basis for developing countries with appropriate adaptation to their needs and the environment.
13. Ways for developing countries to avoid that biotechnology products reduce the diversity in their agro-ecosystem should be examined.
14. Support from developed countries should be provided to developing countries in the risk management of chemicals. Risk assessment methods should be improved for the special conditions in developing countries, also allowing comparisons between chemicals under these conditions.

Actions at national levels

15. Increase in public awareness and a proactive community participation by:
    * Concentrating on a few relevant problems, instead of an across the board type of strategy
    * Improving risk communication
    * Promoting the "right to know" and "responsible care" strategies.
16. Reinforce considerations pertaining to the influence of social and economic problems on environmental/human health.
17. Strengthen collaboration between agencies and ministries within developing countries.
18. Strengthen comprehensive regulatory control of pesticides and industrial chemicals.
19. The "phasing out" of the recognized particularly hazardous chemicals should be carried through.
20. Promote substitution of chemical technologies with other technologies, when feasible.
21. Strengthen the manpower to operate regulatory services through capacity training and provision of adequate resources for their operation.
22. Improving reference national laboratories, as the support unit to an extended network of laboratories.
23. Improving preventive strategies to reduce chemical accidents, including the formulation of contingency plans.
24. Implementing risk reduction as well as clean up actions of contaminated sites, with special consideration on those ecosystems where human health and well-being might be compromised.
25. Internalizing into the local economies the costs of chemical safety and prevention programmes.
26. Training specialists to promote effective use of chemicals in industry, agriculture and forestry.
27. Education and training in safe use of chemicals should be given highest priority within programmes for technical assistance to developing countries.
28. Support monitoring of exposures locally and regionally as a basis for risk assessment and management.
29. Epidemiological studies should be encouraged as a major support for risk assessment and management activities.

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