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GLOBAL OVERVIEW OF THE PESTICIDE INDUSTRY SUB-SECTOR

Sectoral Working Paper

Prepared by

Industrial Statistics and Sectoral Surveys Branch
Policy and Perspectives Division

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SECTORAL WORKING PAPERS

The Industrial Statistics and Sectoral Surveys Branch of the Industrial Policy and Perspectives Division of the United Nations Industrial Development Organization (UNIDO) publishes major surveys on selected industrial sectors. In the course of the research work, several sub-sectoral reports are produced by staff members and outside experts. Some of the reports believed to be of interest to government officials, industrial managers and market researchers, are published in the Sectoral Working Papers series. These papers are more exploratory and tentative than the formal publications of UNIDO, and are circulated with the least possible delay to encourage comments and criticism. Citation and use should take into account this provisional character. No responsibility is accepted for errors.

Abstract

The purpose of this working paper is to shed light on historical trends and future developments in the world market for pesticides as well as to propose techno-economic criteria for the establishment of local formulation and pesticide chemical industries in developing countries. The document is divided into four main parts dealing with the identified global trends and current situation in the pesticide sub-sector of the agrochemical industry; a forecast of the demand to the years 1990 and 2000; an overview of the technical feasibility of application form and active ingredient manufacture; and a brief analysis of alternative strategies to exploit current industrial opportunities in developing countries.

Favourable prospects for subsector growth in developing regions result mainly from growing domestic demand. Special importance of non-tariff barriers to entry, such as regulatory requirements for sales and environment protection, good manufacturing practices, safety in distribution and use, and so on, favour co-operation strategies with experienced partners.

International organizations may assist enterprises in developing countries to turn industrial opportunities into reality in the following areas: participation in the preparation of strategic and techno-economic feasibility studies; technical co-operation in the operation, expansion and rehabilitation of manufacturing facilities; and contribution to the elaboration of industrial sectoral policies which also support the achievement of health and environment protection objectives.

Preface and acknowledgement

This working paper was prepared by Dr. J. Pogány in the Industrial Statistics and Sectoral Surveys Branch of UNIDO as an input to the study entitled "Global survey of the fine chemicals industry", in order to assess the relative importance of pesticides in the fine chemical sector.

The preparation of this document was co-financed by VEGYTERV, the Hungarian Chemical Industries Engineering Center, H-1994 Budapest, Hungary, Erzsébet Királyné útja 1/c. The Industrial Statistics and Sectoral Surveys Branch wishes to acknowledge the contribution of VEGYTERV staff members Mr. I. Rombányi and Mr. L. Rosta, both to the organization of the trade database and the development of the pesticide demand estimation model. The contribution of Mr. G. Honti, consultant to UNIDO, to the chapter on "Technical feasibility of pesticide production" is also appreciated.

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References to dollars ($) are to United States dollars, unless otherwise stated.

A comma (,) is used to distinguish thousands and millions.

A full stop (.) is used to indicate decimals.

A slash between dates (e.g., 1980/81) indicates a crop year, financial year or academic year.

Use of a hyphen between dates (e.g., 1980-1985) indicates the fulll period involved, including the beginning and end years.

Totals in tables may not add up precisely because of rounding.

Besides the common abbreviations, symbols and terms and those accepted by the International System of Units (SI), the following abbreviations and contractions have been used in this report:

R&D	Research and development
WHO	World Health Organization of the United Nations
FAO	Food and Agriculture Organization of the United Nations
UNSO	United Nations Statistical Office

Key terms

For the purpose of this paper, certain repeatedly used terms are defined as follows:

PESTICIDES are agrochemicals consisting of fungicides, herbicides and insecticides.

PESTICIDE PREPARATION (formulated product, pesticide application form) is the safe and effective finished, or partially finished (e.g., concentrate for dilution) product for use in agriculture to protect plants and crops from the harmful effects of fungi, insects and weeds.

PESTICIDE CHEMICAL (active ingredient) is the major input for the manufacture of pesticide prepartions.

CARRIER (diluent, additive) is an inert material used in the manufacture of pesticide preparations to facilitate field application.

INTERMEDIATES are chemical starting materials or reactants used in the organic syntheses of pesticide chemicals.

UNIT OPERATION is a physical change, e.g., filtration, heat transfer, or particle-size reduction in the pesticide chemical and processing (formulation) industries.

CHEMICAL CONVERSION (unit process, chemical change) is a chemical reaction applied to industrial production.

REGISTRATION is the process whereby the responsible national government authority approves the sale and use of a pesticide following the evaluation of comprehensive scientific data which demonstrate that the pesticide preparation is effective for the intended purposes and does not endanger human or animal health or the environment.

I. INTRODUCTION

The study assesses statistical and technical trends as well as opportunities for and constraints to the development of the industrial production of pesticide fine chemicals and dosage forms in developing countries. It also outlines alternative industrialization strategies and suggests international co-operation for the implementation of these strategies.

A brief summary of the historical evolution of this industrial sector is followed by setting the objectives and outlining the methodology used. Production and trade data collected from FAO, UNSO and other sources were harmonized and completed with estimates of an econometric model developed by UNIDO both to describe the global and regional markets and to generate scenarios for alternative futures.

The sectoral analysis evaluates the demand, international trade and production of pesticides between 1975 and 1985. Global markets were analyzed for fungicides, insecticides and herbicides. The effect of crop structure on pesticide use and general characteristics of the markets were also evaluated. Some simple scenarios were developed for the years 1990 and 2000.

The technical feasibility of pesticide production in developing countries was assessed both in the pesticide fine chemicals and formulation industries. New product research and development is also discussed briefly.

The developing countries were classified in five groups according to the degree of development of their pesticide industry, in order to propose alternative industrial strategies for each group.

The conclusions underline the insufficiency of available data and information system. The short history of the pesticide industry led to a situation where a few leading companies dominate an annual market (active ingredients) worth $12 billion, from the intermediate production to the marketing of the formulated products. The share of developing countries is relatively small in all fields: about 25 per cent in consumption, over 20 per cent in imports, 3 per cent in exports and about 20 per cent in manufacturing.

The econometric model scenario forecasts a 43 to 69 per cent overall increase in demand by the year 2000 with an increased development (102 to 123 per cent) in the developing countries.

A stepwise industrialization strategy is proposed for enterprises in developing countries. First an independent government quality control and public or private distribution network should be established, followed by packaging and formulation plants. Manufacture of active ingredients is recommended only for countries with a large domestic market and established fine chemicals industries. Development of a new active ingredient takes 10 to 12 years on the average and the costs of product development for global sales might be as high as $50 million. Companies in developing regions capable of discovering new chemical entities should licence them out at an early stage to partners with extensive R&D and international marketing experience. None of the developing countries is expected to build up its own sales organization until the turn of the millenium.

II. BACKGROUND

1. History

The history of plant protection started with the simplest, oldest methods of tillage (ploughing, hoeing), and flooding as well as burning. Man early recognized the pesticide effect of several natural substances such as nicotine and pyrethrum. Man-made products like the copper/lime solution were widely introduced in agriculture in the last century. The first organic chemical pesticide, antinonnin (dinitrocresol) was synthetized already in 1881 but the real beginning of the fine chemicals pesticide industry was the development of the chlorinated hydrocarbons in the 1940s. Their widespread use during the Second World War contributed greatly to the prevention of epidemics and to the control of malaria. The persistency and the accumulation in the food chain relegated these products to the background. More effective, less hazardous products came forward in the agricultural field and the pesticide industry showed steep growth. Due to a common research base and manufacturing process similarities, the pharmaceutical industry has played an important role in the development of the pesticide sub-sector.

The application of synthetic substances in plant protection has created a qualitative change in agriculture. The fact that pests and diseases can be prevented or immediately be killed/eliminated by the use of pesticides and that crops can be treated within hours after the damage or the hazard has been observed, gave preference to pesticides over other control techniques.

The pesticide industry is composed of two different branches: the manufacture of active ingredients is a typical fine chemicals industry while formulation is a processing activity.

The manufacture of active ingredients began in pre-war Germany. During and after the Second World War, not only the other European countries joined in but the USA also played a decisive role in the development of the sector. Later Japan acquired an important share in all fields.

The constant development of new compounds and new families is a typical feature of this industry. Thus in the insecticide field, organo-phosphorous compounds followed the chlorinated hydrocarbons, then came the synthetic pyrethroids followed by hormons, attractants and repellants. In the herbicide field, the super-selective herbicides (triazines) were introduced in the late fifties. Many others followed, like sulphonyl ureas, quaternary ammonium products (gramoxone) and phosphorous products (glyphosate). Similar development took place also in the fungicide field. Here phtalimides, benzimidazoles and dithiocarbamates were joined by triazoles and organo-phosphorous compounds.

The industrial production of pesticide chemicals is limited to a few countries. The formulation industry is widespread. At present, over 4,000 commercial products are available on the market and new products are constantly introduced.

2. Objectives

The immediate objectives of the study are:

(a) To review and assess the available statistical sources on the pesticide industry;

(b) To provide basic information on demand and supply of pesticides at global and regional levels;

(c) To develop methods for studies of alternative futures for the pesticide industry in developing countries and, more specifically, to generate different scenarios for the development of pesticide demand in 14 geographic regions by the years 1990 and 2000.

(d) To describe the main criteria for the establishment of a domestic market oriented pesticide industry;

(e) To identify major issues affecting the growth of the industry at global level;

The long-term objectives are:

(a) To promote the establishment and expansion of the domestic production of pesticides both in the public and private sectors of the economy in developing countries;

(b) To foster international co-operation for the implementation of sectoral industrial strategies.

III. METHODOLOGY

1. Availability of statistical information

Statistical data on the pesticide industry are collected by a number of organizations and institutions. The Statistical Office of the United Nations (UNSO) publishes industrial and trade statistics on pesticide finished products. There is no UNSO database on consumption or sales of pesticides.

FAO maintains a computerized database on consumption of pesticides, expressed in active ingredient tons, at country level and disaggregated into three main users groups: fungicides, herbicides and insecticides. Value statistics are not available.

Machine readable data on exports and imports of pesticide preparations are available from UNSO. The coverage and quality of SITC data (Subgroups 591.1: Insecticides, 591.2: Fungicides, and 591.3: Herbicides)[1/], are relatively good. The most recent trade data on developing countries are probably incomplete. Partner reported data can be included in the database but this does not eliminate the discrepancy caused by belated reporting of South-South trade flows and will therefore bias the data in favour of those countries which trade with timely reporters.

FAO's computerized import-export statistics provide quantities and values for pesticide active ingredients at country level up to 1984 and they served as the main input to our trade database. It should be mentioned, however, that FAO trade statistics are not disaggregated into fungicides, herbicides and insecticides.

Industrial data are generally missing in ISIC Code 3512: Manufacture of fertilizers and pesticides[2/] and available information does not permit the assessment of size, international distribution and development of the production of pesticides. Production time series are either not available or incomplete for nearly all variables between the years 1975 and 1985. Data are also missing for many countries, among them important producers like Switzerland, United Kingdom, etc. Other information on production was not found, except scattered in secondary sources.

Organized information can also be purchased from commercial sources[3/]. Data are published and yearly updated on 16 countries, 30 product groups and 40 manufacturers. On-line information is not available. The Agrochemical Monitor is a bimonthly publication from the same source that provides regular information on recent developments.

1/ United Nations, Statistical Papers, Series M No. 34/Rev.2, Standard International Trade Classification, Rev. 2, New York (1975).

2/ United Nations, Statistical Papers, Series M No. 4, Rev.2, Add.1: Indexes to the International Standard Industrial Classification (ISIC) of all Economic activities, New York (1971).

3/ Wood, Mackenzie & Co. Ltd., Agrochemical Service, 100 Wood Street, London EC2P 2AJ.

2. Estimation of demand for pesticides

The knowledge of global demand for pesticides is important both for agriculture and for the fine chemicals industry. The FAO database did not contain information on pesticide consumption for about 30 per cent of the countries. In other cases, the national time series 1975-1985 of pesticide consumption were not complete. Sometimes, consumption data were published only for finished products. A need model has therefore been built to complete country coverage to match that of the trade database. Missing data in a time series were estimated by inter- and extrapolation or, in some cases, by the need model. Finished product statistics were converted into fine chemical data when this was the only option to get information consistent with other industry and trade variables.

The need model assumes that the estimated market for pesticides should be matched with production. It is the responsibility of the decision-makers to find the resources to cover this need and to organize production and distribution in an efficient way.

Table 1. summarizes the assumptions on application of pesticides in the treatment of different types of crops and fruits under various climatic conditions.

Table 1. Annual average frequency of treatments of agricultural products with pesticides

		Agriculture											
Climatic zone	Pesticide group	Intensive FC	Intensive CC	Intensive FR	Intensive GR	Semi-intensive FC	Semi-intensive CC	Semi-intensive FR	Semi-intensive GR	Extensive FC	Extensive CC	Extensive FR	Extensive GR
Cold oceanic	F	0.2	1.0	4.0	6.0	0.1	0.5	3.0	4.0				
	H	0.9	0.8	-	-	1.0	0.6	-	-				
	I	0.3	2.0	4.0	6.0	0.1	2.0	3.0	4.0				
Moderate continental	F	0.3	2.0	6.0	8.0	0.2	1.0	4.0	6.0	-	0.5	0.5	0.5
	H	1.1	0.8	0.3	0.3	1.0	0.6	0.2	0.2	0.1	-	-	-
	I	0.5	3.0	6.0	8.0	0.3	3.0	4.0	6.0	-	3.0	2.0	2.0
Subtropical	F	0.5	4.0	9.0	11.0	0.3	3.0	7.0	10.0	0.1	2.0	2.0	2.0
	H	0.8	0.5	0.3	0.3	0.5	0.5	0.2	0.2	0.1	0.1	-	-
	I	0.6	3.0	9.1	10.0	0.4	3.0	5.0	7.0	0.5	3.0	3.0	3.0
Tropical dry	F					0.1	0.5	0.5	1.0	-	0.3	0.2	1.0
	H					0.1	0.1	-	-	-	0.1	-	-
	I					0.2	1.0	2.0	2.0	0.1	1.0	1.0	1.0
Tropical rainy	F					0.3	2.0	4.0	3.0	-	1.0	1.0	2.0
	H					0.1	0.1	-	-	-	0.1	-	-
	I					0.5	4.0	4.0	4.0	0.3	2.0	3.0	3.0

Key: F: fungicides; H: herbicides; I: insecticides
FC: field crops; CC: cash crops; FR: fruits; GR: grapes

Decimal fractions in table 1. represent the percentage of the agricultural area where crops and fruits are treated with pesticides. The intensity category of agricultural production was determined at country level by the number of tractors, the area of planted and irrigated lands and fertilizer use in tons of NPK (nitrogen, phosphorus, potassium) per hectare of cultivated land.

Another determinant of pesticide finished product demand is the average quantity applied to a unit area of agricultural land (table 2.)

Table 2. Annual average dose of major pesticide groups (kg per ha)

Pesticide group	Quantity
Fungicides	6
Herbicides	8
Insecticides	4

It follows from the above assumptions that the demand for the three major groups of pesticides can be estimated by an econometric model for a given country once it has been classified according to climatic zones and degree of development of its agriculture and the area for the production is known for each group of agricultural products defined for the model.

119 countries were selected as potential consumers of pesticides (annex 2). The FAO database covered only eighty of these countries, therefore a non-reporter row was inserted in each global table to indicate separately the share of model estimates in the "World" total. Facts and estimates were aggregated into 14 geographical groups defined as UNIDO regions. The first comparison showed greater differences in some regions than expected. These could be reduced by introducing regional multipliers (table 3) in the model.

Table 3. Regional multipliers of pesticide demand

NA	North America	1.1
EN	North Europe	1.0
ES	South Europe	2.0
EE	East Europe	1.0
JP	Japan	1.0
OI	Other industrialized countries	1.0
LA	Latin America	1.0
AN	North Africa	1.5
TA	Tropical Africa	0.7
WA	West Asia	0.9
SA	Middle and South Asia	0.2
EA	East Asia	1.0
AS	South-East Asia	0.6
OA	Other Asia	0.9

The calculations were repeated with the final version of the model to yield data in table 4.

Table 4. Comparison of facts and model estimates for pesticide consumption 1975 and 1980 (thousands of tons of active ingredient)

UNIDO region	1975 facts	1975 estimates	1980 facts	1980 estimates
NA	497	436	464	509
EN	237	241	300	287
ES	124	126	141	143
EE	461	507	598	548
JP	30	31	36	37
OI	74	69	75	79
IR	1,422	1,410	1,612	1,604
LA	150	164	179	199
AN	45	42	78	65
TA	48	61	44	48
WA	48	52	65	66
SA	49	39	53	47
EA	15	26	33	29
AS	18	15	15	20
OA	161	150	155	224
DR	533	550	621	696
NR	117	118	135	138
World	2,073	2,077	2,368	2,439

Estimates in table 4. compare well with facts in the case of industrial countries, although they are not consistently lower or higher than facts for the years 1975 and 1980. The aggregate values for industrial regions practically do not differ from each other. Differences between facts and estimates are higher in some developing regions but the aggregate values for developing countries are acceptably close to each other and the world totals are not distorted. These facts were considered enough evidence to prove that the static demand model can be used to estimate current or future consumption.

3. Methodological remarks

Average annual pesticide unit prices were estimated by dividing the dollar value of the regional sub-totals by the corresponding quantities of imports for each year between 1975 and 1984. Table 5. illustrates the results for the years 1975, 1980 and 1984. These derived prices in table 5. should be considered only as rough indicators of the price trend in international trade. The period between 1975 and 1980 shows an overall increase in each region but the slope of the trend curve exhibits price fluctuation in many regions. The period 1980-1984 is an acceptable continuation of the trend until 1983 but 1984 figures show inexplicable jumps in some cases, e.g. from \$3.85 (1983) to \$9.49 (1984) in Latin America, or from \$4.18 (1983) to \$6.35 (1984) in South Asia.

1975 and 1980 prices in table 5. were used to convert quantities in values when value statistics were not available, mostly in case of non reporters.

Table 5. Average import unit prices for pesticide chemicals (dollars per kg)

UNIDO region	1975	1980	1984
NA	1.79	3.08	4.62
EN	2.85	4.69	4.13
ES	2.24	4.19	3.53
EE	2.85	3.45	4.42
JP	4.63	5.88	4.86
OI	2.38	4.22	9.17
IR	2.55	4.10	4.36
LA	1.95	2.59	9.49
AN	2.67	3.13	3.08
TA	2.07	3.07	3.53
WA	2.75	3.64	3.57
SA	1.34	2.10	6.35
EA	1.77	2.71	3.26
AS	2.86	4.01	6.58
OA	2.41	3.34	5.77
DR	2.12	2.94	5.03
NR	2.36	3.64	4.54
World	2.36	3.64	4.54

Table 6. Inflation and dollar exchange rate indices 1975-1986 (1975 = 100)

Country	Consumer price index 1975-1986	Annual mid-year exchange rate 1980	1984	1985	1986
France	275	99	204	210	162
Germany, Fed.Rep. of	147	74	116	120	88
Hungary	216	74	109	114	104
Italy	462	131	269	292	228
Japan	159	76	80	80	57
Spain	467	125	280	296	244
United Kingdom	298	96	166	171	151
United States	211				
Brazil	idc[a]	idc	idc	idc	idc
China	157	81	125	158	186
India	224	94	136	148	151
Korea, Rep. of	330	126	167	180	182
Mexico	idc	184	idc	idc	idc
Nigeria	551	89	124	135	219

[a] Inappropriate to deflate or convert into $US, national variables.

Data in Table 6. demonstrate that current value time series in national currencies and dollars differ greatly from each other for the period studied. For example, the changes both in the consumer price index and in the rates of exchange against the dollar are so high for Brazil and Mexico that they do not permit statistical interpretation of the figures a few years after 1975. The dollar had its lowest value in 1985 against the currencies of industrial countries listed in table 6, whereas it continued to gain ground against the currencies of the developing countries. These factors cause further difficulties in the international comparison of regional situations and trends.

IV. SECTORAL TRENDS AND CURRENT SITUATION

1. Global demand

Pesticides play an important role in both agricultural production and public health programmes. It has been estimated that pests destroy on average one-third of the world potential crop production[4/] so that pesticides together with integrated farm management are critical factors in increasing crop yields and preventing crop losses. Developing countries which rely on agricultural exports for much of their foreign exchange earnings need pesticides to improve their cash crop production and raise their own living standards. Meanwhile per capita food production is decreasing in many developing countries and pesticides are needed, among others, to achieve food self-sufficiency. There are important interlinkages between the pesticide sector and agro-based industries of special export interest to developing countries. Pesticides are also essential inputs in the control of vector-borne diseases such as malaria. On the other hand, pesticides are biologically active, therefore toxic substances and their careless or excessive use may be damaging to the environment and human or animal health. FAO, in co-operation with member countries and other international organizations, has elaborated guidelines on the harmonization of pesticide registration requirements and control procedures and more recently an international code of conduct on the distribution and use of pesticides in order to assist developing countries in the formulation of their own national regulatory standards.

Pesticide demand is primarily determined by climatic conditions, the number of hectares planted by crops and by the frequency of applications which, in turn, depend on the intensity level of agrotecnics.

Crop structure is another major determinant of the demand for major pesticide groups. Table 7. shows this relationship.

Table 7. Pesticide use 1986 for different crops
(percentage, millions of dollars)

Crops	Herbicides	Insecticides	Fungicides	Total pesticides	
	%	%	%	$	%
Fruits & vegetables	16.3	26.6	43.4	4,805	25.6
Rice	10.5	17.0	15.6	2,585	13.8
Maize	18.0	8.0	1.3	2,090	11.1
Cotton	4.7	25.2	1.7	2,010	10.7
Wheat	14.2	2.3	13.4	1,910	10.1
Soybean	17.4	2.9	2.0	1,755	9.3
Sugarbeet	5.7	3.0	1.5	735	3.9
Others	13.3	14.8	21.1	2,910	15.5
Total	100.0	100.0	100.0	18,800	100.0

4/ Information Research Ltd.: The emerging markets for pesticides in the developing countries, 1979.

The above-mentioned variables have the greatest impact on pesticide consumption but this does not mean that other factors are irrelevant. Social, macroeconomic and demographic factors such as general levels of economic and industrial development, standards of housing and nutrition, agricultural subsidy policies both in developing and in industrialized countries, status and protection of the external environment, patent and trade mark legislation, pricing regulations, age distribution of population, urbanization, etc., are important determinants of demand for pesticides. Pesticide registration and distribution systems, extent of irrigation, genetic plant variations, general development of health services, disease patterns, etc., also affect the demand for pesticides. Factors within the pesticide industry itself such as price levels, promotional practices, number of products on the market, competitive structure, etc., are also presumed to play a role.

Table 8. shows the quantities of pesticide fine chemicals consumed worldwide by the pesticide processing (formulation) industry in 14 geographical regions.

Table 8. Global pesticide consumption by UNIDO regions (thousands of tons of active ingredients, and percentage)

UNIDO	1975		1980		1985		Growth rate	
region	Amount	%	Amount	%	Amount	%	1975-80	1980-85
NA	496.5	24.0	463.6	19.6	500.6	20.5	-6.6	8.0
EN	236.8	11.4	299.8	12.7	323.0	13.2	26.6	7.8
ES	123.9	6.0	140.1	5.9	163.3	6.7	13.0	16.6
EE	460.8	22.2	598.3	25.3	680.3	27.8	29.8	13.7
JP	30.5	1.5	35.9	1.5	29.6	1.2	17.8	-17.5
OI	73.7	3.6	74.5	3.1	83.1	3.4	1.1	11.6
IR	1,422.2	68.6	1,612.1	68.1	1,779.9	72.8	13.4	10.4
LA	149.5	7.2	178.1	7.5	156.1	6.4	19.1	-12.3
AN	45.1	2.2	44.2	1.9	50.5	2.1	-2.0	14.2
TA	48.2	2.3	78.4	3.3	21.8	0.9	62.7	-72.2
WA	47.7	2.3	64.8	2.7	30.6	1.3	35.9	-52.8
SA	48.7	2.4	53.2	2.2	68.7	2.8	9.2	29.1
EA	15.4	0.7	32.8	1.4	22.0	0.9	113.1	-32.9
AS	17.7	0.9	14.7	0.6	19.2	0.8	-16.7	30.3
OA	161.3	7.8	155.4	6.6	160.3	6.6	-3.7	3.1
DR	533.7	25.7	621.7	26.3	528.2	21.6	16.5	-15.0
NR	117.3	5.7	134.0	5.7	137.2	5.6	14.2	2.4
World	2,073.2	100.0	2,367.8	100.0	2,446.4	100.0	14.2	3.3

Industrialized countries consumed about 73 per cent of the 2.45 million tons of world shipments of pesticide fine chemicals in 1985. Developing countries accounted for about one-fifth of global industrial consumption in 1985 but it should be mentioned that their share in global consumption decreased from about 26 per cent in 1975 and 1980 to 21.6 per cent in 1985. This can probably be attributed to the general global economic recession and the resulting scarcity of convertible currency in developing countries. Another important factor might be the unfavourable effect of agricultural commodity surpluses on world farm production which affects cash crops rather than food crops in developing countries. The structure of consumption is also changing towards smaller-dose, therefore lower tonnage, pesticide active ingredients. However, this trend is not yet likely to be reflected in regional aggregates.

If the regions are listed in decreasing order by specific consumption of pesticides, the following results are obtained (table 9.):

Table 9. Average consumption of pesticide active ingredients in UNIDO regions (kg/ha arable land)

Region	Consumption
JP	6.1
EN	5.4
ES	4.5
EE	2.5
NA	2.1
OA	1.4
OI	1.4
EA	1.1
LA	1.0
TA	0.9
AS	0.8
WA	0.5
AN	0.4
SA	0.3
IR	2.7
DR	0.7
NR	1.2
World	1.7

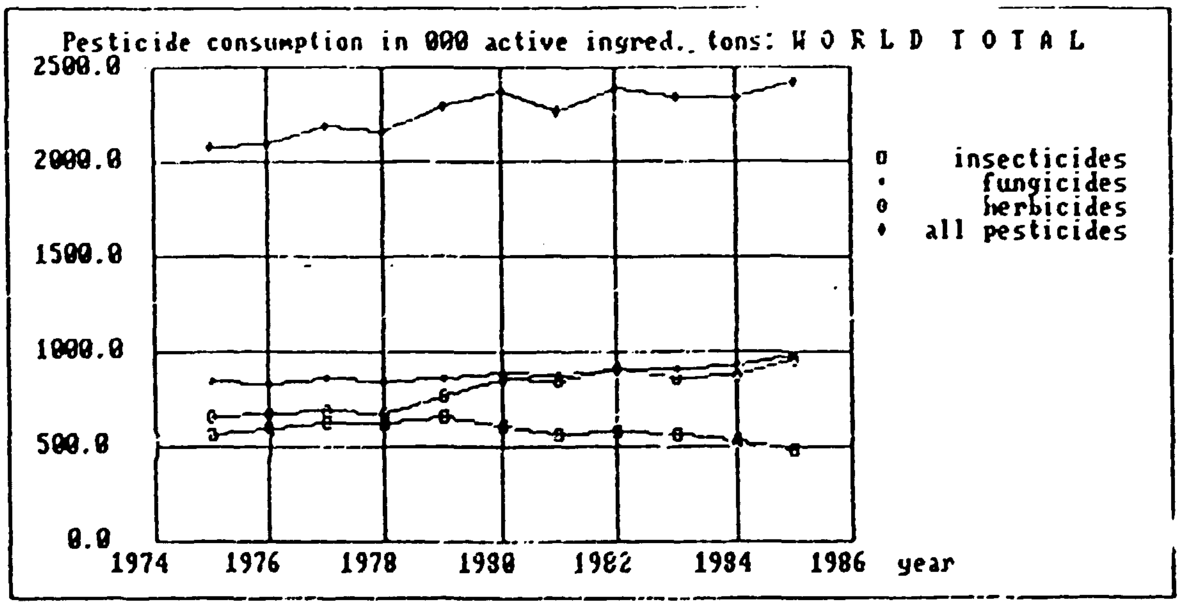
Table 10. shows the worldwide ranking of pesticides by major end use groups.

Table 10. Global consumption of major pesticide groups, 1975-1985
(thousands of tons of active ingredients, and percentage)

Pesticide group	World region	Amount	%	1 9 8 0 Amount	%	1 9 8 5 Amount	%	1975-80 Growth rate	1980-85 Growth rate
Fungicides	IR	602.7	71.4	642.0	72.1	730.9	73.9	6.5	13.8
	DR	193.7	22.9	197.7	22.2	201.9	20.4	2.0	2.2
	NR	47.8	5.7	50.4	5.7	55.9	5.7	5.4	11.0
	World	844.2	100.0	890.0	100.0	988.8	100.0	5.4	11.1
Herbicides	IR	566.7	85.7	733.6	85.5	824.2	86.5	29.4	12.3
	DR	57.3	8.7	78.5	9.1	75.3	7.9	37.1	-4.1
	NR	37.4	5.7	48.7	5.7	54.0	5.7	30.2	10.7
	World	661.5	100.0	860.9	100.0	953.4	100.0	30.1	10.8
Insecticides	IR	252.7	44.5	236.5	38.3	224.8	44.6	-6.4	-4.9
	DR	282.7	49.8	345.5	56.0	252.0	50.0	22.2	-27.1
	NR	32.1	5.7	34.9	5.7	27.4	5.4	8.7	-21.7
	World	567.5	100.0	616.9	100.0	504.2	100.0	8.7	-18.3

Figure 1. illustrates graphically the world-wide annual trend 1975-1985 for fungicide, herbicide and insecticide fine chemicals as well as for the sum of these groups defined as pesticide fine chemicals. The overall trend shows an increasing tendency. The 1980-1985 section of the curves indicate an increased global use of fungicides and herbicides but the consumption of insecticides decreased between 1980 and 1985.

Fig. 1. Pesticide consumption (thousands of tons of active ingredients)



Figures 2 and 3 show the distribution of insecticide and fungicide demands by industrialized regions (IC), Latin America (LA), Other Asia (OA), other developing regions (OD) and non-reporters (NR).

Fig. 2. Global distribution of insecticide demand

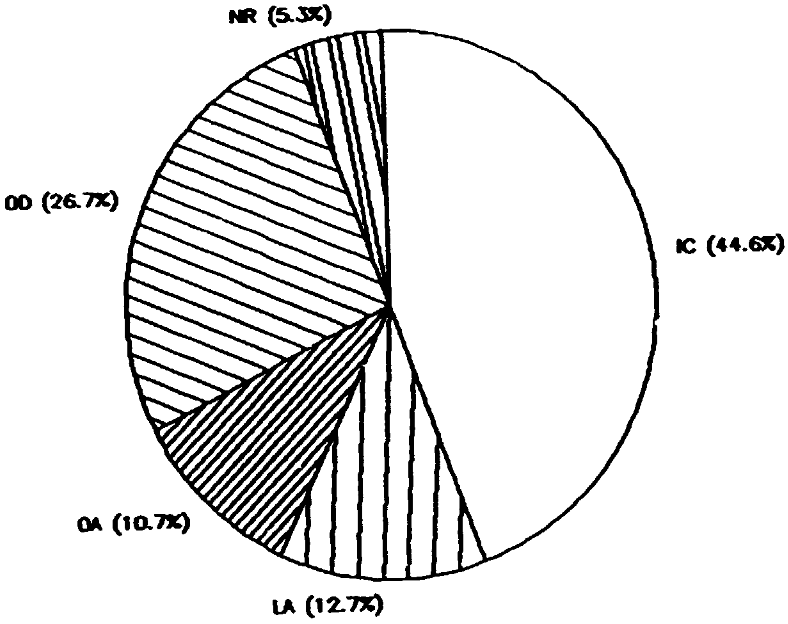
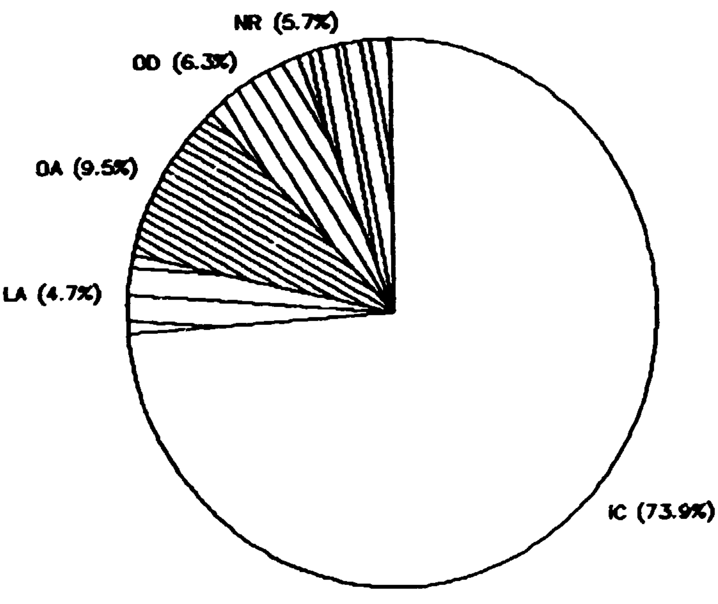


Fig. 3. Global distribution of fungicide demand



The global distribution of herbicide demand is not illustrated graphically because industrialized countries consume 86.4 per cent of the total sales, and the share of the other four aggregated groups in global consumption changes from 1.4 to 5.7 per cent.

World sales of pesticide fine chemicals (active ingredients) in 1985 were estimated to be about $12 billion at c.i.f. import prices (table 11.) which can be taken as equal to manufacturers' selling prices for sectoral research purposes. This value represents just more than 1 per cent of the global chemical industry shipments of $1,000 billion in the same year.

Table 11. Global pesticide consumption 1975-1985 by UNIDO regions (millions of dollars and percentage)

UNIDO	1975		1980		1985		1975-80	1980-85
region	Value	%	Value	%	Value	%	Per cent	change
NA	889.8	18.1	1,427.5	17.1	2,066.7	17.7	60.4	44.8
EN	673.8	13.7	1,407.1	16.9	1,297.6	11.1	108.8	-7.8
ES	277.4	5.6	586.9	7.0	549.0	4.7	111.6	-6.5
EE	1,313.8	26.7	2,065.8	24.8	2,797.9	24.0	57.2	35.4
JP	141.1	2.9	211.2	2.5	152.2	1.3	49.7	-27.9
OI	175.5	3.6	314.5	3.8	753.6	6.5	79.2	139.6
IR	3,471.4	70.5	6,013.0	72.0	7,617.0	65.3	73.2	26.7
LA	292.2	5.9	461.6	5.5	1,479.7	12.7	58.0	220.6
AN	120.4	2.4	138.3	1.7	152.3	1.3	14.9	10.1
TA	98.9	2.0	240.9	2.9	79.4	0.7	143.6	-67.0
WA	131.3	2.7	236.2	2.8	172.8	1.5	79.9	-26.8
SA	65.3	1.3	111.8	1.3	433.2	3.7	71.2	287.5
EA	27.3	0.6	89.0	1.1	70.7	0.6	226.0	-20.6
AS	50.7	1.0	59.1	0.7	128.6	1.1	16.6	117.6
OA	389.5	7.9	518.4	6.2	933.9	8.0	33.1	80.2
DR	1,175.6	23.9	1,855.3	22.2	3,450.6	29.6	57.8	86.0
NR	277.2	5.6	477.7	5.7	601.0	5.2	72.3	25.8
World	4,924.3	100.0	8,346.0	100.0	11,668.6	100.0	69.5	39.8

Value statistics should not be taken as indicators of trends as these are obscured by the changes caused by inflation and by dollar exchange rates particularly in the period after 1983.

The value of the global market in 1985 for finished (formulated) pesticide preparations at consumer price level is estimated at about $16 billion. This value increased to about $17.4 billion in 1986 and $20 billion in 1987.

The twenty largest consumers in the world in 1985 are listed below:
(thousands of tons of active ingredients/year)

1.	USSR	508
2.	USA	363
3.	China	160
4.	France	101
5.	Italy	101
6.	Spain	74
7.	Australia	68
8.	Canada	64
9.	India	57
10.	Brazil	48
11.	UK	44
12.	Bulgaria	33
13.	Japan	31
14.	Germany,F.R.	30
15.	Greece	30
16.	Hungary	25
17.	Algeria	22
18.	Egypt	20
19.	Thailand	20
20.	Indonesia	19

The top ten users in developing countries in 1985 were the following:
(thousands of tons of active ingredients/year)

1.	China	160
2.	Brazil	48
3.	Algeria	22
4.	Egypt	20
5.	Thailand	20
6.	Indonesia	19
7.	Colombia	15
8.	Argentina	14
9.	Cuba	10
10.	Turkey	9

2. Global supply

2.1 International trade

SITC statistics contain both quantities and values on imports and exports for 1975 through 1986 of pesticide finished products. Word trade in pesticide finished products was analyzed in a UNIDO document [5/]. This study concluded that the salient feature of trade in pesticides is the dominance of industrialized countries whose ability to handle information effectively is a comparative advantage. In 1984, industrialized regions accounted for over 96 per cent of exports and 61 per cent of imports. Developing countries accounted for 3 per cent of exports but 22 per cent of imports.

5/ UNIDO PPD.69, Tariff and non-tariff measures in the world trade of pesticides (1987).

In developing countries imports exceed exports by as much as ten to one and the largest part of the exports are intra-regional. While the Latin American region (mainly Argentina, Brazil and Mexico) has traditionally been the leading exporter among the developing regions, exports from Asian regions (particularly from the People's Republic of China, the area of Hong Kong, the Republic of Korea and Malaysia) have grown more rapidly than the world export of pesticides in the last decade. Africa has experienced drought and famine in parts of the continent over a period of time which simultaneously brought dramatic decline in pesticide trade.

The weighted average tariffs, a tax on pesticide products as they enter a country, changed between nil and 19.4 per cent for all studied countries, the characteristic values being close from one to a few per cent.

There is some evidence that, like tariffs, non-tariff barriers tend to increase or escalate with the level of product fabrication. Price controls and volume controls introduce unequal treatment between domestic and foreign goods and demand becomes rather insensitive to changes in world market prices. Volume control, including licenses, quotas, even import prohibition, appears to be the most commonly applied non-tariff measure. Countries with price control measures were not identified in the database. Technical barriers, such as health and safety regulations, are documented to exist and are normally considered as part of domestic policy both in industrialized and in developing countries. National priorities on use or control will be determined by climatic conditions as well as the level of social concern directed towards the management of ecosystems.

The bulk of the pesticides exports of developing countries are destined to other developing countries. Nonetheless, liberalization in South-South trade may be a viable form of improving export prospects of present or potential producers of pesticides in developing countries. The trade restrictive effects of technical barriers will be mitigated as industrial evolution in developing regions continues, bringing with it the skills and complex organizational forms that international marketing activities required.

2.1.1 Imports

FAO statistics also give information on the volume and value of international trade at country level from 1975 to 1984. The FAO data are the basic input to the UNIDO database because they reflect trade in pesticide active ingredients and are assumed to be consistent with the consumption data which was considered an important factor in the estimation of apparent production values at the initial stage of the research programme. The quality of the raw trade data was checked and improved, when necessary.

Table 12. Global pesticide imports 1975-1985, by UNIDO regions (thousands of tons of active ingredients, percentage)

UNIDO	1975		1980		1983		1984		1975-80	1980-84
region	Amount	%	Amount	%	Amount	%	Amount	%	Per cent	change
NA	109.2	11.6	151.8	12.0	131.7	11.3	119.0	12.2	39	-22
EN	194.7	20.8	329.7	26.1	358.4	30.8	373.0	38.4	69	13
ES	34.4	3.7	27.9	2.2	39.9	3.4	32.1	3.3	-19	16
EE	76.8	8.2	116.9	9.2	64.4	5.5	36.3	3.7	52	-69
JP	9.4	1.0	15.5	1.2	11.1	1.0	15.8	1.6	64	3
OI	33.0	3.5	29.4	2.3	25.1	2.2	14.9	1.5	-11	-49
IR	457.5	48.8	671.2	53.1	630.7	54.1	592.3	60.8	47	-12
LA	150.7	16.1	153.2	12.1	120.1	10.3	34.[illegible]	3.5	2	-78
TA	49.9	5.3	80.9	6.4	35.2	3.0	24.9	2.6	62	-69
AN	44.5	4.7	32.2	2.5	39.9	3.4	23.8	2.4	-28	-26
WA	43.2	4.6	65.4	5.2	54.6	4.7	49.2	5.0	51	-25
SA	41.6	4.4	33.7	2.7	18.5	1.6	11.1	1.1	-19	-67
EA	13.4	1.4	37.1	2.9	39.8	3.4	29.7	3.0	178	-20
AS	17.9	1.9	17.2	1.4	17.5	1.5	22.3	2.3	-4	-34
OA	3.5	0.4	21.3	1.7	41.6	3.6	30.5	3.1	500	43
DR	364.7	38.9	441.1	34.9	367.2	31.5	215.2	22.1	21	-51
NR	116.1	12.4	152.4	12.1	167.6	14.3	166.7	17.1	31	9
World	938.3	100	1,264.7	100	1,165.5	100.0	974.3	100	35	-23

Table 12. shows the distribution of global imports by fourteen geographic regions. The 1984 figures are not to be relied on because data for the last available year are usually provisional and change in subsequent updates. For this reason 1983 statistics were also included in the table. The 38.9 per cent share of developing countries in world imports in 1975 decreased to 34.9 per cent in 1980 and 31.5 per cent in 1983.

Table 13. Global pesticide imports 1075-1985 by UNIDO regions
(millions of dollars and percentage)

UNIDO region	1975 Value	1975 %	1980 Value	1980 %	1983 Value	1983 %	1984 Amount	1984 %	1975-80 Per cent change	1980-94 Per cent change
NA	195.7	8.8	467.5	10.2	467.0	10.5	550.0	12.4	139	18
EN	554.1	25.0	1,547.6	33.6	1,400.9	31.4	1,542.6	34.9	179	0
ES	77.1	3.5	116.8	2.5	144.1	3.2	113.7	2.6	51	-3
EE	218.9	9.9	403.7	8.8	294.8	6.6	160.7	3.6	84	-60
JP	43.7	2.0	91.0	2.0	69.4	1.6	77.3	1.7	109	-15
OI	78.5	3.5	124.1	2.7	103.5	2.3	137.4	3.1	58	11
IR	1,167.9	52.7	2,750.7	59.8	2,479.7	55.5	2,581.7	58.4	136	-6
LA	294.5	13.3	397.2	8.6	462.5	10.4	326.0	7.4	35	-18
AN	118.9	5.4	100.7	2.2	108.3	2.4	73.4	1.7	-15	-27
TA	103.3	4.7	248.7	5.4	123.2	2.8	88.1	2.0	141	-65
WA	118.8	5.4	238.4	5.2	204.6	4.6	175.9	4.0	101	-26
SA	55.7	2.5	70.9	1.5	77.3	1.7	70.7	1.6	27	0
EA	23.7	1.1	100.7	2.2	90.1	2.0	96.8	2.2	325	-4
AS	51.2	2.3	69.9	1.5	68.4	1.5	74.5	1.7	35	8
OA	8.6	0.4	71.1	1.5	211.1	4.7	176.6	4.0	729	148
DR	774.7	34.9	1,296.7	28.2	1,345.5	30.1	1,082.0	24.5	67	-17
NR	274.3	12.4	554.7	12.1	642.5	14.4	756.4	17.1	102	36
World	2,216.9	100	4,602.1	100	4,467.7	100	4,420.1	100	108	-4

Figures for 1984 are provisional and will change in the subsequent updates particularly in developing regions where the change from 1983 to 1984 is always negative and 1984 values are significantly different from the former years.

The top twenty world importers in 1984 are listed below:
(millions of dollars)

1.	USSR	481
2.	France	417
3.	USA	399
4.	China	343
5.	UK	218
6.	Germany, Fed.Rep.	197
7.	Canada	194
8.	Belgium	190
9.	Iran	186
10.	Netherlands	150
11.	Italy	131
12.	Denmark	118
13.	Argentina	82
14	Egypt	81
15	Japan	77
16.	Czechoslovakia	75
17.	Poland	72
18.	Hungary	70
19.	Saudi Arabia	61
20.	Spain	55

The ten largest importing developing countries in 1984 were the following: (millions of dollars)

1.	China	343
2.	Iran	186
3.	Argentina	82
4.	Egypt	81
5.	Saudi Arabia	61
6.	Sudan	53
7.	Pakistan	51
8.	Colombia	33
9.	Cuba	33
10.	Malaysia	33

2.1.2 Exports

Table 14. shows the geographical distribution of global exports. Quantity statistics were scarcely available and did not permit calculation of average export unit prices. On the basis of general experience, export (f.o.b.) prices are usually about 8 per cent lower than the import (c.i.f.) prices. The quality of 1984 export data is the same as that of import statistics.

Table 14. Global pesticide exports by UNIDO regions, 1975-1985 (millions of dollars and percentage)

UNIDO	1975		1980		1984		1975-80	1980-84
region	Value	%	Value	%	Value	%	Per cent	change
NA	372.9	18.5	1,094.5	24.3	1,374.6	33.1	194	26
EN	1,321.3	65.6	2,794.5	62.1	2,309.8	55.6	111	-17
ES	52.7	2.6	94.2	2.1	22.3	0.5	79	-76
EE	20.9	1.0	27.7	0.6	38.7	0.9	33	-86
JP	70.7	3.5	140.6	3.1	217.7	5.2	99	55
OI	50.5	2.5	75.5	1.7	34.5	0.8	49	-54
IR	1,889.0	93.7	4,227.0	93.9	3,962.7	95.4	124	-6
LA	44.9	2.2	98.0	2.2	31.2	0.8	118	-68
AN	0.8	-	2.3	0.1	-	-	172	-
TA	5.1	0.3	8.7	0.2	0.7	-	69	-91
WA	6.7	0.3	9.1	0.2	3.2	0.1	35	-64
SA	2.8	0.1	1.7	-	2.2	0.1	-41	33
EA	2.2	0.1	7.0	0.2	14.6	0.4	212	111
AS	1.5	0.1	6.9	0.2	6.7	0.2	348	-5
OA	3.6	0.2	11.3	0.3	10.3	0.2	212	-8
DR	67.6	3.4	145.0	3.2	68.9	1.7	114	-52
NR	58.8	2.9	131.1	2.9	120.9	2.9	123	-18
World	2,015.4	100	4,503.1	100	4,152.5	100	123	-18

The top twenty exporters in 1984, at global level, were the following countries:

(millions of dollars)

1.	Germany, Fed.Rep.	837
2.	USA	708
3.	UK	562
4.	France	462
5.	Switzerland	385
6.	Belgium	255
7.	Netherlands	231
8.	Japan	216
9.	Italy	132
10.	Hungary	96
11.	USSR	48
12.	Brazil	59
13.	Hong Kong	37
14.	Israel	34
15.	Singapore	34
16.	Guatemala	33
17.	Denmark	33
18	Colombia	25
19.	China	18
20.	Romania	17

The ten largest exporting developing countries in 1984 were the following:

(millions of dollars)

1.	Brazil	59
2.	Hong Kong	48
3.	Singapore	34
4.	Guatemala	33
5.	Colombia	25
6.	China	18
7.	Costa Rica	11
8.	Korea, Rep.	10
9.	Malaysia	9
10.	Salvador	7

2.1.3 Price and availability of pesticide active ingredients

Questionnaires were sent to 77 suppliers, manufacturers and international trading houses in order to assess the open world market availability of pesticide fine chemicals essential in pest control as well as in the prevention and treatment of plant diseases prevailing in developing countries and/or demanded in large quantities in these markets (annex 3). The product patents have expired in the majority of cases. Exceptions are the synthetic pyrethroids and benomyl. The expiry years indicate the sum of the priority date[6/] plus twenty years, therefore they should be considered as conservative estimates. Informative net f.o.b. unit prices were requested for specific amounts of pesticide fine chemicals, packing included. Irrevocable letter of credit was indicated as method of payment and delivery was requested in three months time. The quality had to conform to internationally accepted standards.

6/ The Merck Index, Tenth Edition, Merck & Co., Inc., Rahway, N.J., USA (1983).

23 replies were received at the time of writing this working paper, 18 of them were positive. Table 15. shows that the majority of the surveyed pesticide active ingredients is a low price chemical commodity with a limited source of supply. When a range is given in the column "Unit price" it indicates the minimum and maximum of two to four quotations.

Table 15. Illustrative prices of pesticide active ingredients in open international trade (dollars per kg.)

Pesticide chemical	Unit price
Alachlor	3.00/1
Alachlor techn.	4.50
Atrazine 50%, flowable	2.25/1
Atrazine	3.30-4.25
Benomyl techn.	9.00-19.00
Butylate 70%, E.C.	4.00/1
Butylate techn.	6.00
Carbaryl	3.70
Carbendazim 50%, flowable	8.50
Carbendazim	12.50
Cypermethrin	52.00-58.00
Cypermethrin, 100% active ingredient	100.00-101.90
DDT	3.00
Dichlorvos techn.	3.30-3.60
Diuron tehcn.	4.80-7.50
EPTC 72%, E.C.	4.00/1
EPTC techn.	4.60
Fenvalerate	35.00-50.00
Folpet	8.00-10.00
Lindane	10.50-12.15
Malathion	2.25-3.10
Mancozeb 75%	4.00
Mancozeb	2.84-2.96
Maneb	2.35-3.02
Paraquat 47%	3.80
Paraquat	2.55/1
Parathion	2.25-4.50
Propachlor techn.	4.00
Propanil 36%, E.C.	2.45/1
Propanil	2.25/1
Propanil	2.80
Trifluralin 48%, E.C.	3.30-3.50/1
Trifluralin	4.40/1
Trifluralin 95-98%, techn.	4.65-5.00

No price has been received for the following active ingredients so they are qualified as pesticide chemicals not available in open international trade:

Amethryine
Captafol
Captan
Chlorothalonil
Deltamethrin
Linuron
Monuron
Phosphamidon
Simazine
Thiabendazole
Thiobencarb
Thiophanate methyl
Triadimephon
Zineb

Responders (annex 4) indicated that the following substances are regularly traded and not included in the survey:

Aluminium phosphide, 3-g. tablets ($12.50/kg)
BPMC
Carbofuran
Chlorpiriphos
Diazinon
2,4-D acid and its salts
DDVP
Endosulfan techn., min.95% ($7.50/kg)
Fenithrothion ($8.00/kg)
Glyphosate techn., min. 95% ($15-18.00)
MCPA acid and its salts
Mefluidide (plant growth regulator)
Methamidophos techn. (5.50/kg)
Methomyl
Methylparathion
MIPC
Monocrotophos techn.
Phenmadipham
Phosphamidon techn.
Sulphur, wettable
Surfactants (emulsifiers and wetting agents)
Temephos
Trichlorphon techn. ($2.85/kg)
Zinc phosphide techn. 80% ($3.25/kg)

Finally, substances regularly demanded and without source of supply are listed below:

Acephate techn.
Bentazon techn.
Carbofuran techn., 75%
Cyanuryl chloride
2,4-D acid
Dimethoate techn., 90%
ECTF
Fenitrothion techn., 70%
Methylparathion techn., 80%
Oxydemethon methyl techn.
Quinalphos techn.

Under other comments, it was indicated that technical know-how was available or turnkey basis for (a) a pesticide formulation plant, and (b) for a zinc phosphide plant[7]. Laboratory and field studies were also offered to provide full registration packages[8].

The questionnaire survey leads to the conclusion that pesticide fine chemicals, the basic material input for the generic pesticide processing industry, are scarcely available in open international trade. Most production seems to be captive and traded between headquarters and affiliates or licencees.

Price information is available also from secondary sources. These do not reflect real transactions or quotations but might provide useful indications of the price trend.

Table 16. Prices of selected pesticides in the USA (dollars per kg.)

Active ingredient	1985	1986	1987	Per cent change 1985-86	1986-87
Herbicides					
Alachlor	11.40	11.20	10.70	-1.8	-4.5
Atrazine	4.50	4.70	4.90	4.4	4.3
Butylate	6.90	6.80	6.70	-1.4	-1.5
Cyanazine	10.00	10.00	10.20	0.0	2.0
Metolachlor	13.40	13.30	13.30	-0.7	0.0
Trifluralin	14.20	13.80	13.90	-2.8	0.7
2,4-D	5.20	5.00	5.40	-3.8	8.0
Composite[a]	9.00	8.90	8.90	-1.1	0.0
Pesticides					
Carbaryl	8.50	8.60	8.60	1.1	0.0
Carbofurane	22.70	22.60	21.10	-0.4	-6.6
Chlorpyrifos	18.10	18.30	18.20	1.1	-0.5
Fonofos	19.50	19.40	19.20	-0.5	-1.0
Methylparathion	6.10	6.00	6.20	-1.6	3.3
Phorate	14.50	14.40	14.50	-0.7	0.7
Synth. Pyrethroids	119.90	112.90	107.60	-5.8	-4.7
Terbufos	21.60	21.60	21.60	2.0	0.0
Composite[a]	23.10	22.60	22.60	-2.2	0.0

a/ Includes all important active ingredients not listed separately.

Source: Chemical Engineering News, 65, No. 46, p.42, 16 Nov. 1987.

Prices in table 16. have been converted from $US/pound and the annual per cent changes were recalculated rounding up to one decimal point.

7/ All India Medical Corporation, P.O. Box 16806, Santacruz (E), Bombay-400 055, India

8/ CHEMOLIMPEX, P.O. Box 121, 1805 Budapest, Hungary.

2.2 Production

ISIC-based code 3512-16[9] contains statistical information on pesticide preparations (table 17).

Table 17. Global production 1976-1985 of pesticide preparations (thousands of tons)

UNIDO region	1976 Amount	1976 %	1980 Amount	1980 %	1985 Amount	1985 %
USA	618.8	24.2	665.9	23.6	719.7	25.1
W. Europe	435.1	17.0	674.7	23.9	874.1	30.5
USSR	275.6	10.8	285.4	10.1	347.7	12.1
E. Europe	229.5	9.0	221.0	7.8	258.7	9.0
Other industrial	13.8	0.5	33.3	1.2	20.1	0.7
IR	1,572.8	61.6	1,880.3	66.5	2,220.3	77.4
Latin America	42.9	1.7	102.3	3.6	107.6	3.7
AFrica	29.3	1.1	24.8	0.9	20.9	0.7
China	612.6	24.0	536.5	19.0	210.8	7.3
Rep.of Korea	180.0	7.1	166.5	5.9	163.0	5.7
Other Asia	114.6	4.5	115.4	4.1	147.2	5.1
DR	979.4	38.4	945.5	33.5	649.5	22.6
Total	2,552.2	100	2,825.8	100	2,869.8	100

The coverage of data is very good in Europe, whereas the other regional sub-totals represent samples because, e.g. Argentina, Mexico and Venezuela are not included in Latin America, neither are Malaysia and the Taiwan area in Asia nor Cameroon in Africa.

Pesticide production grew dinamically in Western Europe between 1976 and 1985 and in Latin America between 1976 and 1980. A significant growth can be registered in the Other Asia region between 1980 and 1985. Production stagnated in the other regions and significantly declined in China. A more detailed analysis of the data showed that the trend started to decline in China in 1978 and there was another drop in 1982. The planted agricultural area has decreased by about 400,000 hectares per year in China since 1978[10] and this explains the lower and lower demand for pesticides.

Since China represented about two thirds of the production in developing regions in 1976, its decreased output has negatively affected the share of developing regions in the global production. Apparent production of pesticide

9/ Industrial Statistics Yearbook 1985, Vol.II, Commodity Production Statistics 1976-1985, United Nations, New York, (1987).
10/ AGROW, Vol. 58, 2 March 1988, p.15.

chemicals was estimated from available consumption and trade data according to the following formula:

$$Papp = Consumption + Exports - Imports.$$

The results gave negative numbers in several regions for several years, therefore they were not accepted even as qualitative descriptors of production.

Time series of interesting sectoral data are available also from the industrial literature[11]. In 1987, 219 pesticide chemicals were produced in 291 plants in the USA. Eight companies (12 per cent of all companies) owned 150 plants (52 per cent of all plants). Six of the eight companies produced pesticides in all four categories. Most of the other 61 companies produced only one product, characteristic of the companies that were already well established in the chemical industry when they began producing pesticides.

Table 18. Trends for agricultural chemicals (millions of dollars, except as noted)

	1984	1985	1986	1987	Compound annual per cent change 1972-85	1980-85
Industry data						
Value of shipments	5,695	5,217	5,008	5,158	12.3	4.2
Value of shipments (1982$)	5,923	5,389	4,958	4,776	2.0	2.2
Total employment (000)	15.3	15.0	14.8	14.4	1.6	1.6
Production workers (000)	9.2	8.9	8.8	8.6	2.1	1.9
Ave.hourly earnings ($)	12.07	12.51	13.01	13.79	9.1	8.6
Product data						
Value of shipments	5,613	5,125	5,023	5,023	11.8	1.8
Value of shipments (1982$)	5,906	5,334	4,925	4,784	1.5	0.4
Shipments price index (1982 = 100)	95.2	96.3	102.1	101.6	9.4	1.6
Trade data						
Value of imports	266	361	373	415	19.8	12.9
Value of exports	1,406	1,267	1,328	1,487	14.1	0.7

Source: US Industrial Outlook 1988.

The comparison of industry and product data in table 18. shows that only a small value of pesticides is manufactured outside the sector classified as pesticide industry. Pesticide production registered a constant growth of about 2 per cent between 1972 and 1985. The value of production per capita (total employment) was $358,194 in 1987. The compound annual per cent changes were generally lower for the period 1980-1985 than for the period 1972-1985. This indicates that the pesticide industry has reached maturity level in the USA.

An analysis of production and sales at firm level (table 19.) gives a further insight into the pesticide chemical industry.

11/ US Industrial Outlook 1988, US Department of Commerce, International Trade Administration, Washington (1988).

Table 19. Global ranking and market share of pesticide manufacturers in 1986. (millions of dollars, percentage)

Rank	Company	Global Sales	Global Share
1.	Bayer	1,690	9.0
2.	Ciba-Geigy	1,315	7.0
3.	Monsanto	1,025	5.5
4.	Rhone-Poulenc	840	4.5
5.	ICI	820	4.4
6.	BASF	750	4.0
7.	Hoechst	690	3.7
8.	Dow	680	3.6
9.	Du Pont	660	3.5
10.	Shell	640	3.4
11.	Cyanamide	415	2.2
12.	Schering	390	2.1
13.	Stauffer	370	2.0
14.	Eli Lilly	355	1.9
15.	Röhm & Haas	310	1.6
16.	FMC	300	1.6
17.	Sandoz	265	1.4
18.	Kumiai	250	1.3
19.	Union Carbide	250	1.3
20.	Sumitomo	172	0.9
21-30	Sub-total	1,140	6.1
31-40	Sub-total	524	2.8
	Others	4,949	26.3
	Total world	18,800	100

Source: Wood Mackenzie & Co. Ltd.[12]

The top forty pesticide manufacturers in table 19. were from Western Europe, the United States and Japan in 1986. They accounted for about 74 per cent of the global sales in the same year. Sales of affiliates are aggregated in the total of the mother company. The group of "Others" includes companies mainly from eastern Europe, China, India and the Republic of Korea.

The leading twenty companies have been established as chemical producers since the beginning of the twentieth century, or before. Other characteristics they have in common are a world-wide marketing system of agrochemicals and/or pharmaceuticals as well as extensive experience in research and development of biologically active new products. These companies are engaged both in the active ingredient and in the formulation sub-sectors of the pesticide industry. They sell each other's products in countries where the market does not justify the establishment of own marketing organizations.

12/ Agrochemical Service, Update of the Agrochemical Companies Section, September 1987.

Some of them are developing their upstream operations into the production and sale of genetically engineered seeds.

The only exception to these characteristics is Kumiai Chemical which was set up in 1949 and has become the leading agrochemical supplier in Japan. Kumiai is a more than 90 per cent domestic market-oriented company which works in close collaboration with local agricultural co-operatives. Own R&D programmes and inward licencing are other key elements of success in Kumiai's industrial strategy.

State authorities control manufacture and trade of pesticides in China and in the USSR. State-owned enterprises enjoy a large degree of freedom both in production and in sales of pesticides in Hungary. Research projects at enterprises in Hungary are mainly targeted toward the manufacture of patent-expired active ingredients and generic pesticide preparations. The pesticide formulation sub-sector is particularly strong in the Republic of Korea because only technical grade agrochemicals are allowed to be imported.

V. THE FUTURE DEVELOPMENT OF PESTICIDE DEMAND

1. Factors affecting future demand.

The main factors that affect pesticide consumption have been quantified during the study, namely: geographical and climatic conditions, crop structure, development level of agriculture and size of cultivated land.

As regards the future demand, it was assumed that neither the geographic and climatic conditions, nor the crop structure would change significantly during the forthcoming decade. The area of cultivated land in 1990 and 2000 as well as the changes in the intensity level of agriculture, measured by the specific fertilizer consumption, number of tractors and extent of irrigation, were taken from FAO forecasts[13/]. The secondary factors were assumed to cause only minor changes in the future demand for pesticides during the forthcoming twelve years. The econometric forecast approach should ideally take int. ccount the demand for pesticides yet to be put on the market and alternatives to pesticide use. Since the demand for new pesticide chemical entities cannot be estimated with the UNIDO model, the practical solution was to generate scenarios for the currently used set of pesticides.

A pesticide-free agriculture was considered an unrealistic alternative as at to-day although FAO's experimental programme of Integrated Pest Management (IPM) has recently given encouraging results in Indonesia. The method consists of the identification of the pest (brown planthopper), promotion of the propagation of its natural predators, selection of a pesticide which is less effective against predators than against the pest and use this pesticide at the right time in the life cycle of the pest. As a result of the Indonesian experiment, the yields of rice farms rose by 20 per cent and $35 million (worth of pesticides) can be saved each year. The FAO has begun similar experimental programmes in Bangladesh, India, Malaysia, the Philippines, Sri Lanka and Thailand, and recently signed an agreement to start one in China[14].

Health and environment protection will impact on the research and development of new pesticides as well as on the investment and operating costs but will not decrease the demand for pesticides during the forecast period. Experience has shown that when conditions for the establishment and/or expansion of pesticide production units are favourable, capital is available both from national and and foreign sources. This statement leads to the conclusion that investment and capacity problems will not limit the supply of pesticides.

2. Trend analysis and projection

The pesticide fine chemicals concumption trend, with time as the only explanatory variable, was analyzed using a linear regression model on data for the period 1975-1984 and projections were made to the years 1990 and 2000. The results are shown in table 20.

13/ FAO, Agriculture towards 2000 (1978)

14/ C. Joyce, Nature helps Indonesia to cut its pesticides bill. New Scientist, 16 June 1988, p.35.

Table 20. Results of the trend analysis of pesticide consumption 1975-1984, and projections 1990 and 2000 (thousands of tons of active ingredients and percentage)

UNIDO region	1975 tons	1975 %	1980 tons	1980 %	1984 tons	1984 %	1990 tons	1990 %	2000 tons	2000 %
NA	497	24.0	464	19.6	447	19.1	419	16.1	382	13.0
EN	237	11.4	300	12.7	315	13.4	365	14.0	442	15.0
ES	124	6.0	140	5.9	155	6.6	172	6.6	[illegible]	7.0
EE	461	22.2	598	25.3	633	27.0	825	31.7	1078	36.7
JP	30	1.4	36	1.5	31	1.3	30	1.2	27	0.9
OI	74	3.6	75	3.2	82	3.5	85	3.3	93	3.2
IR	1,422	68.6	1,612	68.1	1,664	71.0	1,897	72.9	2,227	75.8
LA	150	7.2	178	7.5	156	6.7	165	6.3	174	5.9
AN	45	2.2	44	1.9	50	2.1	50	1.9	55	1.9
TA	48	2.3	78	3.3	22	0.9	30	1.2	5	0.2
WA	48	2.3	65	2.7	48	2.0	42	1.6	27	0.9
SA	49	2.4	53	2.2	68	2.9	80	3.1	99	3.4
EA	15	0.7	33	1.4	22	0.9	33	1.3	41	1.4
AS	18	0.9	15	0.6	19	0.8	15	0.6	14	0.5
OA	161	7.8	155	6.5	162	6.9	164	6.3	171	5.8
DR	533	25.7	622	26.3	547	23.3	558	21.4	544	18.5
NR	117	5.6	134	5.7	133	5.7	147	5.6	166	5.7
World	2,073	100.0	2,368	100.0	2,344	100.0	2,602	100.0	2,937	100.0

The overall historical trends are positive both globally and in the industrialized regions, although the growth of pesticide consumption has slowed down between 1980 and 1984. Consumption in the developing regions peaked in 1980 and strongly declined thereafter, in particular in the Latin American, Tropical African, West Asian and East Asian regions. This period coincides with the global economic recession and implies that the elasticity of pesticide demand to economic growth is very high. The mature markets of the generally richer and agrotechnically better defined industrialized regions seem to be less sensitive to the level of purchasing power and availability of convertible currency.

An interval of ten years is statistically insufficient to establish a trend and extrapolate it for another two to twelve years. This is the main reason why some projections for 1990 and 2000 make little sense and their lower confidence limit values have ended up even with negative values.

3. Need model

The second model, an agricultural production-based or needs approach, is a quantitative normative scenario based on the demand estimation model described in pages 5 and 7. The forecasts of future pestice demand are shown in table 21.

Table 21. Forecasts of pesticide chemicals consumption in 1990 and 2000. Scenarios A and B. (thousands of tons of active ingredients, and percentage)

UNIDO region	1990 A		1990 B		2000 A		2000 B	
	tons	%	tons	%	tons	%	tons	%
NA	515	16.4	481	17.5	529	13.4	479	14.3
EN	310	9.9	266	9.7	337	8.5	269	8.0
ES	198	6.3	172	6.3	268	6.8	220	6.6
EE	817	26.0	647	23.5	1,058	26.7	813	24.3
JP	39	1.2	34	1.2	39	1.0	33	1.0
OI	103	3.3	85	3.1	115	2.9	90	2.7
IR	1,982	63.2	1,683	61.2	2,345	59.3	1,903	56.8
LA	273	8.7	258	9.4	407	12.3	369	11.0
AN	68	2.2	63	2.3	101	2.6	91	2.7
TA	80	2.5	74	2.7	101	2.6	87	2.6
WA	81	1.9	78	2.8	106	2.7	101	3.0
SA	76	2.4	62	2.3	126	3.2	92	2.7
EA	48	1.5	38	1.4	58	1.5	44	1.3
AS	30	1.2	30	1.1	42	1.1	41	1.5
OA	323	10.3	311	11.3	447	11.3	433	12.9
DR	978	31.2	913	33.2	1,387	35.1	1,258	37.5
NR	178	5.7	156	5.7	224	5.7	190	5.7
World	3,137	100.0	2,752	100.0	3,956	100.0	3,351	100.0

The need model forecasts a continuous increase in demand for pesticides in developing countries, mainly because the assumptions of the FAO scenarios 1990 and 2000 are based on agricultural growth in these countries.

Table 22 shows demand scenarios A and B for the major pesticide and-user groups.

Table 22. Global consumption in 1990 and 2000 of fungicides, herbicides and insecticides (thousands of active ingredients, and percentage)

Pesticide group	UNIDO region	1990 A tons	1990 A %	1990 B tons	1990 B %	2000 A tons	2000 A %	2000 B tons	2000 B %
Fungicides	IR	730	68.9	590	66.3	850	64.1	686	60.8
	DR	330	31.1	300	33.7	473	35.6	443	39.2
	World	1,060	100.0	890	100.0	1,327	100.0	1,129	100.0
Herbicides	IR	902	86.7	803	86.1	1,079	81.1	842	78.5
	DR	138	13.2	130	13.9	252	18.9	230	21.5
	World	1,040	100.0	933	100.0	1,331	100.0	1,072	100.0
Insecticides	IR	350	40.7	290	37.5	416	38.6	375	38.7
	DR	510	59.3	483	62.5	661	61.4	585	60.3
	World	860	100.0	773	100.0	1,077	100.0	970	100.0

The figures in table 21 suggest that the relative importance of insecticides would increase from a share of 25 per cent in 1980 to about 39 per cent in 2000 at the expense of fungicides and herbicides. Developing countries will mainly be responsible for these changes.

Sums of world subtotals in table 22. are not equal to world totals in table 21. because the fungicide, herbicide and insecticide demand has not been forecast for the "non-reporter" regions.

VI. TECHNICAL FEASIBILITY OF PESTICIDE CHEMICAL PRODUCTION

1. Inorganic synthesis

A few inorganic chemicals such as elemental sulfur, slaked lime and copper compounds are still used as agricultural pesticides but their consumption trends and, consequently, industrial importance are declining. Their manufacture is technically simple. Economic feasibility of domestic production depends primarily on local avilability of mineral rocks and size of the home market, including other end-uses of the products.

2. Biosynthesis

Insecticidal properties of many plants and their extracts have been known since time immemorial. Some of these plants are still being used in a processed form, e.g., pyrethrum, the dried flowers of *Chrysanthemum cinerariaefolium* (Compositae), rotenoids occurring in *Derris*, *Lonchocarpus*, *Mundulea* and *Tephrosia* species (Leguminosae) and nicotinoids obtained from tobacco species (Solanaceae). Technical aspects of domestic production of natural pesticides may include agricultural cultivation of the plant but the starting material can also be an industrial by-product, e.g., tobacco waste.

The preparation of crude extracts (annex 5, page 89) does not call for special chemical techniques but standardization and stabilization of quality of the finished product might require proprietary know-how. The commercial importance of the botanical insecticides as agrochemicals is low, but their synthetic analogues have improved properties and compete effectively with other synthetic classes of insecticides.

Fermentation is used only exceptionally for the commercial manufacture of commodity pesticides. Many antibiotics developed for medical purposes were investigated for activity against plant pathogens. Agricultural antibiotics did not live up to high original expectations because many of them were unstable under field conditions, or showed phylotoxic side effects, or were found too expensive.

3. Organic synthesis

Organic chemicals account for the vast majority of the active ingredients in pesticide preparations, as well as for virtually all the technological and scientific progress in the pesticide industry. The about 800 organic compounds on the pesticide market are produced predominantly by chemical synthesis. Their chemical structure extends from simple aliphatic chains to complex ring systems.

Seventeen pesticide chemicals with important agricultural use in developing countries have been selected as a sample (annex 5) to analyze some aspects of the organic chemical manufacturing processes involved in their commercial scale synthesis. The checklist for the rudimentary analysis of the technical feasibility of studied processes is described below:

1. Number of conversions

2. Can these conversions be carried out in multipurpose batch reactors?

3. Special reaction conditions and utility requirements.

4. Industrial safety and environment protection hazards.

5. Availability of key starting materials and reactants in free trade.

The main findings of the first-level analysis are summarized in table 23.

Table 23. Rudimentary assessment of the technical feasibility of pesticide syntheses

Ser. No.	Pesticide	No. of steps	Multipurpose batch reactor	Special reaction conditions	Ind.safety environm. protect.	Available materials
1.	Alachlor	3	Y	N	R	Y
2.	Aldicarb	3	P	P	S	P
3.	Benomyl	1	P	P	S	P
4.	Captan	3	N	P	S	Y
5.	Carbaryl	2	P	P	S	Y
6.	Carbofuran	3	P	P	S	P
7.	2,4-D	4	Y	N	R	Y
8.	DDT	1	Y	N	R	Y
9.	Diazinon	4	Y	N	R	Y
10.	Dichlorvos	1	Y	N	R	Y
11.	Malathion	2	Y	N	R	Y
12.	Nicotine	1	Y	N	R	Y
13.	Parathion	3	Y	N	P	Y
14.	Pyrethrins	1	Y	N	P	N
15.	Pyrethroids	1	Y	N	R	N
16.	Toxaphene	1	Y	P	R	Y
17.	Zineb	2	N	P	S	Y

<u>Code</u>: Y = yes; N = no; P = partly; R = regular; S = special

Each step in the manufacturing process consists of a chemical conversion and several unit operations (dissolution, distillation, crystallization, etc.). The number of steps extended from one to four in the studied processes but it should be mentioned that the analyzed degree of backward integration does not represent the economic optimum in several cases, e.g., benomyl or pyrethroids. The chemical conversions involved in the manufacturing processes are classified below:

- addition
- amination
- carbamylation
- chlorination
- condensation
- cyclization
- dimerization
- esterification
- exchange of functional groups
- oxime-formation
- phosgenation, and
- rearrangement
- resolution

The workhorse of the industry is the glass-lined or stainless steel multipurpose batch reactor[15/] equipped with agitator and heat-exchange jacket. Auxiliary equipment may include reflux condenser, external heat-exchanger, feeding tanks, receivers, etc. Nominal reactor volumes usually change between 2 and 5 cubic meters. In principle, these reactors can be used for the production of several pesticide chemicals but in practice each battery of reactors and complementary equipment for unit operations are used for the production of a single commodity chemical due to economic scale constraints of about 10,000 tons, or more, of bulk chemicals output per year. Last-step production of specialty chemicals, e.g., pyrethroids, from advanced intermediates, may be an exception to this rule.

The last steps in the syntheses are practically always batch operations but increasing backward integration towards organic chemicals favours the use of continuous reactors. Process economy, industrial safety and environment protection aspire to similar goals: better yields, standard or improved quality, less by-products, minimum waste disposal costs and maximum safety arrangements. These considerations play also an important role in the development of special purpose reactors, in particular for dangerous conversions or when undesirable side reactions take place under non-optimized conditions. Such reactors reduce operational risks (accidental explosion or leaking) because the amount of dangerous reactant is relatively small at any given time, therefore disaster consequences are automatically decreased.

Special reaction conditions such as very high temperature, very high pressure, etc. were not encountered during the analysis. Sometimes external cooling seemed to be necessary to control vigorous exothermic reactions. These cases were qualified with P (partly) in the "Special reaction conditions" column.

The manufacturing processes vary from easily manageable syntheses to very hazardous, high-level technologies.

Some general conclusions on dangerous chemicals and conversions can be drawn from illustrative aspects of handling, shipping, storage and use of methylisocyanate (MIC). For instance, MIC must be protected by a blanket of dry nitrogen (dew point -40°C or below) while in bulk storage and during transfer operations. Bulk storage tanks must be equipped with monitoring alarms, pressure relief valves, a caustic soda scrubber to neutralize escaped liquid MIC, and a flare to burn escaped MIC vapours. Inventories of MIC should be kept as low as possible. Ideally, MIC should be produced at site and sent directly to the production unit, with no side streams going to storage. All the above technical requirements increase the industrial safety component of investment and operation costs. Enterprises in countries with hot climate and without domestic MIC production - therefore with large inventories - have a comparative disadvantage over their favourably placed competitors.

15/ The multipurpose batch reactor is a reaction vessel available from many sources. It usually has the form of a tank, is equipped with some means of agitation and provision for heat transfer to regulate temperature of the reaction mixture between -10°C and 300°C, is made of stainless steel and glass or enamel-lined steel and is connected to steam (less than 25 bar pressure), compressed air (less than 5 bar) and vacuum (higher than 10 mbar pressure). Its nominal capacity varies between 0.5 sq.m. and 8 sq.m.

Training and experience in handling dangerous chemicals are important factors for preventing industrial accidents. Therefore, personnel turnover at the plant should be as low as possible, particularly in operations and maintenance. Detailed safety audits should be conducted at regular intervals, independently from production and machinery maintenance operations and it must be emphasized that safety review is a continuous process. Similar considerations apply to working with phosgen and carbon disulfide to mention other examples of reactants encountered in annex 5.

World Bank[16/] guidelines for preventing and controlling industrial hazards are modeled after those of the European countries. Under these guidelines, a plant manager would have to:

- Know where hazardous materials are present in the plant, and what processes could lead to emergencies.
- Provide outlines of primary preventive measures such as proper design, construction, inspection, maintenance, and operation of storage vessels and process systems.
- Provide special measures for preventing potentially hazardous leaks that could lead to major accidents.
- Show measures for limiting the extent of major accidents.
- Provide workers at the site with data, training, and equipment for preventing and handling any emergencies.
- Specify special local circumstances in procedures such as potential extent of hazardous impact, location, population density, meteorology, and topology.
- Provide a full safety case. This is the centerpiece of the whole set of guidelines.

A full safety case, for example, may state that the integrity of pressure vessels has been assured by the strict application of appropriate design codes, operating duties, and maintenance and inspection procedures, in support of an assumption that the sudden failure of pressure vessels has been dismissed as a possible cause of a major accident.

Information required in a full safety case would be, for example, names of chemicals, description of possible hazards wherever chemicals could be isolated or lost from process vessels, the percentage of concentration, and main impurities. It would contain a map showing risks to surroundings, indicating where substances are stored and processed, numbers of people working in the vicinity, and population and land use distribution around the site. It would describe the management system in place for controlling any event, including the training of persons working at the site, and arrangements made to ensure design, construction, testing, operation, and maintenance of the plant. And it would point out potential sources of accidents, with conditions or events that could bring one about, locate weak spots along the line, and specify measures to control and minimize consequences.

Pesticide chemicals are biologically active substances and they pollute the environment by definition. This statement implies that each production waste stream (gas, liquid or solid) as well as ordinary effluents from clean-up activities must be treated before being disposed of. Most studied schematic flow diagrams include recovery operations and waste treatment steps

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16/ Chemical and Engineering News, p.11, 8 April 1985.

in the manufacturing process, or indicate that a waste stream should be incinerated, or biologically treated. The environment protection component of pesticide chemical investment and manufacturing costs is also high, particularly the continuous in-process monitoring activities which require many expensive quality control instruments in many cases.

Key starting materials and reactants such as 1-naphthol and methylamine for carbaryl synthesis may be purchased in principle but phosgene, as already discussed, should preferably be produced on the spot due to industrial safety and environment protection considerations. The same considerations apply to many reactants, therefore pesticide chemical plants should be self-sufficient in dangerous chemicals, or should be located close to factories producing such chemicals. Such cases were qualified with P in table 23 because importation is theoretically possible but economically counterindicated and may even be prohibited by local regulations. Key intermediates for patented specialty chemicals, e.g., pyrethroids, are scarcely available in free trade, or not at all.

In summary, a typical pesticide chemical synthesis involves several steps, the last step being the coupling of two to three reactants called key intermediates. The majority of the studied pesticides is a chemical commodity which can economically be produced only on a large scale in a dedicated plant. Backward integration should be such as to start production from organic chemical reactants available in free trade. Some of the chemical conversions are dangerous and their management requires high-technology as regards information handling as well as automation in storage, production and maintenance operations. Industrial safety and environment protection aspects should be integrated parts of the production system from design through construction to every day operations. These factors are also significant components of investment, production, and R & D costs.

VII. TECHNICAL FEASIBILITY OF PESTICIDE FORMULATION

A United Nations publication[17] in English, French and Spanish, describes in detail the pesticide processing industry. An abstract of this publication is given in annex 6. Each chapter contains many references and bibliography. The specific processes involved in the formulation of pesticides are discussed in sufficient detail for the industrial manager, therefore only general technical block schemes for solids (dusts, wettable powders, and water-soluble powders), and for liquid preparations (emulsifiable concentrates, oily concentrates, and aqueous concentrates) are shown in figures 4 and 5 respectively.

The unit operations of the process for the manufacture of solid and liquid pesticide dosage forms are: particle size reduction, weighing, dissolution, mixing with auxiliary materials, homogenization, and/or filtration. These unit operations are generally considered safe both from health and accident-risk points of view as long as the industrial safety regulations are observed. In-process and quality control methods are publicly available. The industrial safety and environment protection component of investment is low, about 5 per cent of the total capital costs. The capacity of the machinery and equipment is convertible so several preparations can be produced in the same dosage form production line.

1. Formulation of dusts and powders

Solid pesticide formulations are homogeneous powder mixtures consisting of active ingredients and added substances.

1.1 Dusts (D)

Dusts or dusting agents are the oldest and least expensive pesticide formulations. They consist of a physical mixture of active ingredients and suitable inert carrier/diluent in finely dispersed form (10-40 microns). Ingredient concentrations may vary from 0.1 to 20 per cent. Dusts are applied undiluted.

1.2 Wettable powders (WP)

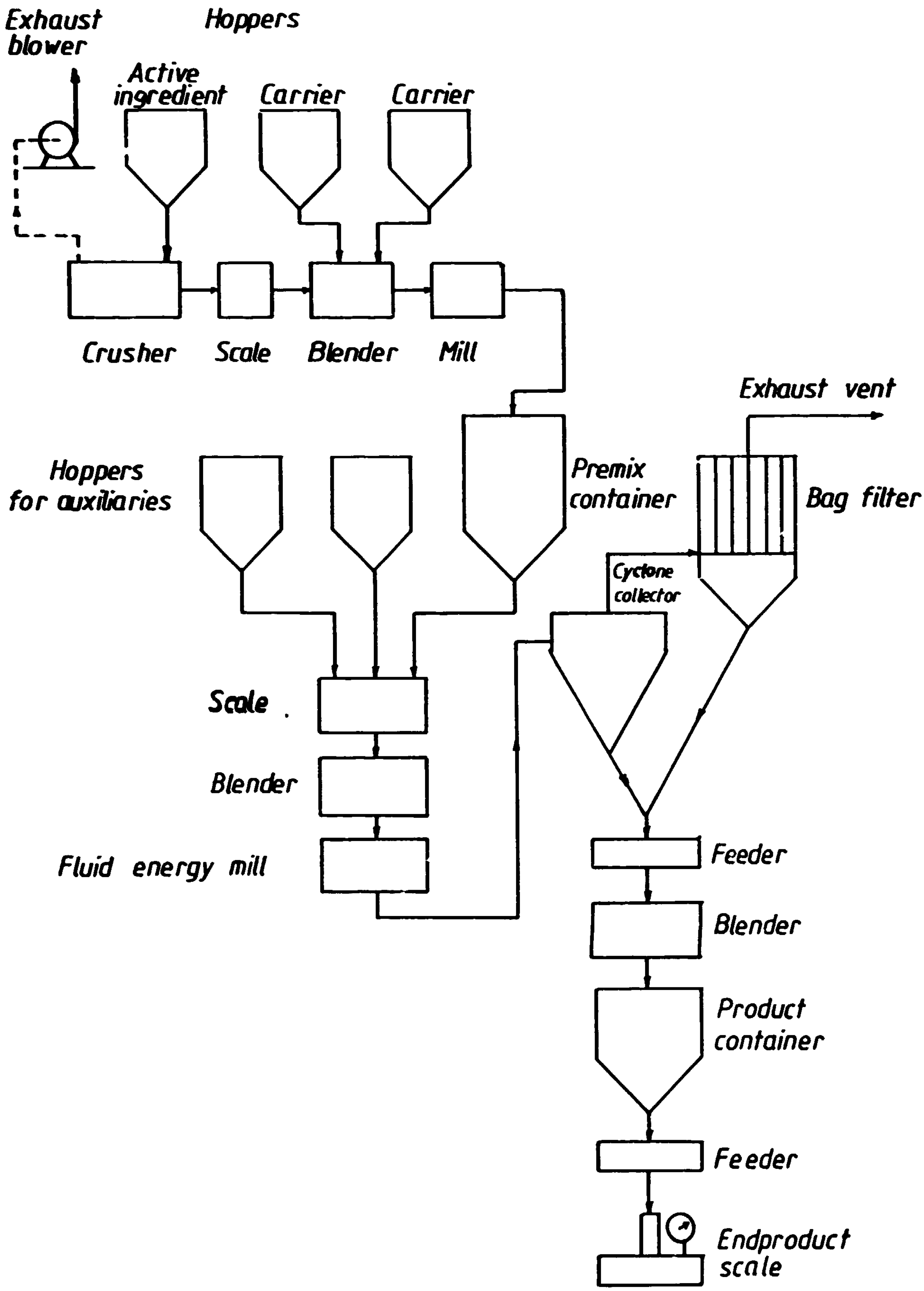
Wettable powders are solid formulations which can be dispersed in water to produce stable suspensions. The concentrates are usually diluted with water to 0.1-5 per cent active ingredient content to obtain the so-called "spray solution". Wettable powders contain 20-60 per cent active ingredient, 30-60 per cent carrier/diluent, 2-5 per cent dispersing agent, 1-5 per cent surfactant and various auxiliaries in small amounts.

1.3 Water soluble powders (WSP)

These are solid formulations of water soluble active ingredients and are applied as sprays.

17/ UNIDO publication ID.297, Sales No.: S.83.II.B.3, Formulation of pesticides in developing countries, United Nations, New York, 1984.

Figure 4. Solid formulation plant products



1.4 Process technology

The formulation processes of the above listed products are the same from technological points of view. Two unit operations are involved: (a) mixing (blending) and (b) comminution (crushing, grinding, pulverizing and micronizing). Mixing is usually carried out in batch blenders (kneaders, ribbon-blenders, etc.) while various types of conventional mills can be used for comminutive operations. Fluid energy ("jet") mills are generally used for the final milling. Feeders, metering devices, scales, conveyors, packing machines, and exhaust system make up the system. The flow diagram of a typical dry formulation process is shown in figure 4.

The active ingredient is first usually crushed for uniform mixing with the different carriers. The components are weighed and mixed in the blender. The second comminution produces finer particles so a more homogeneous mixture goes to the premix container. In the second blender, other auxiliaries are added and mixed with bulk material. The fluid energy mill completes the comminution to the final particle size. A final blending stage is necessary to arrive at a really homogenous end product.

2. Liquid formulations

Liquid pesticide formulations are homogeneous or non-homogeneous liquid systems consisting of active ingredients, solvents, and emulsifiers. The flow diagram of a liquid formulation process is shown in figure 5.

2.1 Emulsifiable concentrates (EC)

EC are popular formulations, simple to manufacture and easy to apply. Typical composition: 20-70 per cent active ingredient, 5-10 per cent emulsifier, 20-75 per cent solvent. After dilution with water, they form ready-to-use oil in water emulsions.

2.2 Oil concentrates (OC or OSC)

They consist of active ingredients and light mineral oils. The product is diluted with a low-cost miscible oil prior to field application.

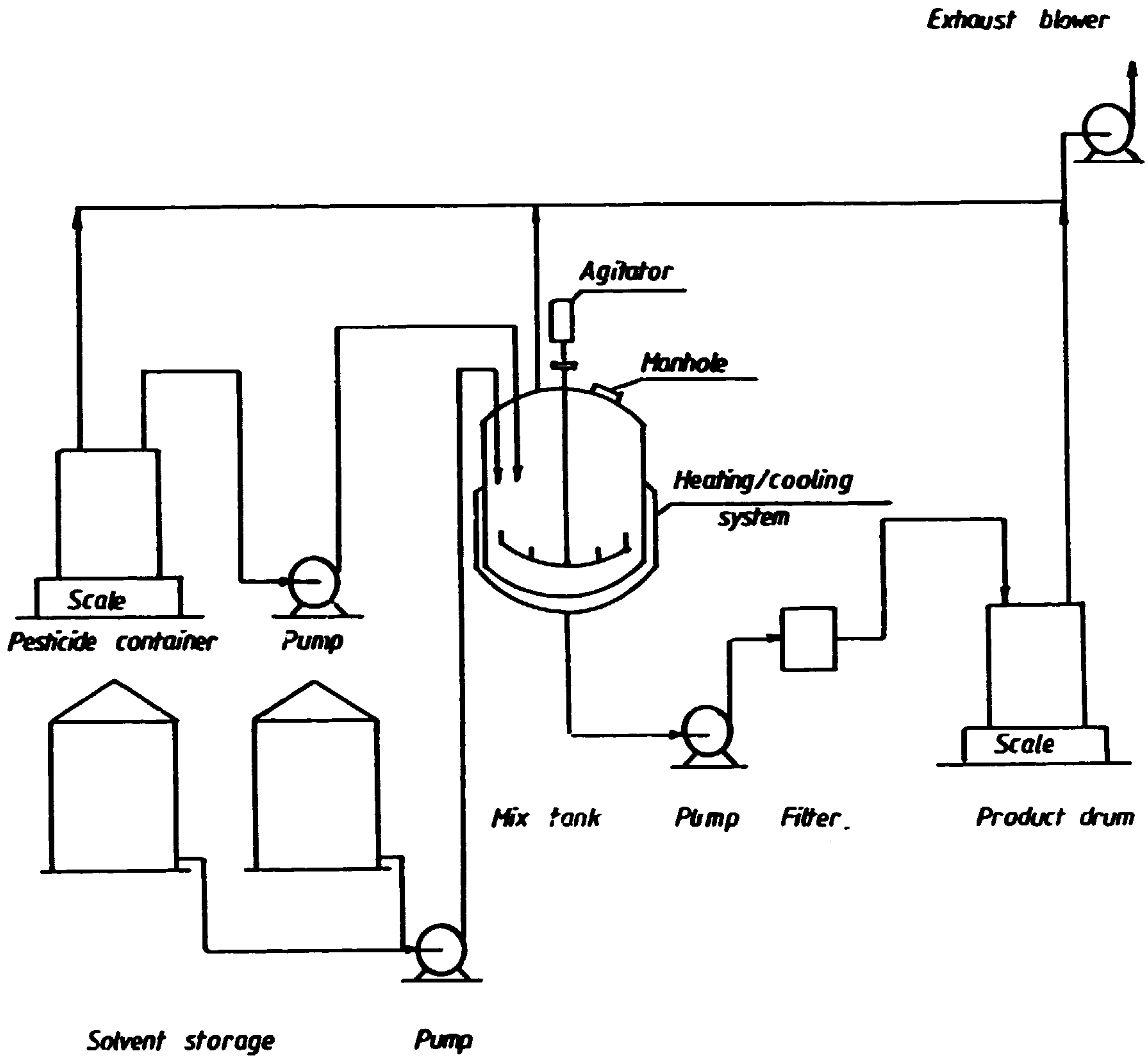
2.3 Ultra low volume formulations (ULV)

ULV oil concentrates are active ingredients in solvents of medium viscosity and of low volatility. They are used undiluted, therefore they do not contain emulsifiers.

2.4 Water soluble concentrates (WSC)

Aqueous concentrates are organic acid salt solutions in water with an acid equivalent content of about 30-50 per cent. They are miscible with water.

Figure 5. Liquid formulation plant products



2.5 Liquid formulation processes

The formulation processes are basically similar for all liquid pesticides. They involve mixing and dissolution of the ingredients, filtration and filling of the product.

The components are metered into a closed, jacketed, glass-lined vessel equipped with agitator. When all ingredients are dissolved - in some cases heating is necessary - the batch is pumped into a storage tank. Before packing, the liquid formulation product must be filtered in conventional cartridge filters or in equivalent closed-system clarification filters.

VIII. NEW PRODUCT RESEARCH AND DEVELOPMENT

The whole history of the pesticide industry demonstrates the commercial importance of R&D activity. The spectacular growth observed in the early 1980s was the result of the success of extensive research work creating new and efficient pesticides with selective advantages for the farmers. Pesticides have a relatively short commercial life cycle. New and better products constantly leave laboratories and pilot plants and challenge the old compounds, or create completely new markets. It is therefore important to review the R&D system in this industrial sector.

1. Registration

A special feature of pesticide R&D which makes it closely related to the pharmaceutical sector follows from the potential health and environment hazards related to the use of biologically active chemical compounds. Pesticides are intended to kill the unwanted living species without doing harm to others, first of all man. It must be proven for every product that no environmental or health hazards will result from its appropriate use. Pesticides should be licenced for sale (registered) before they are marketed.

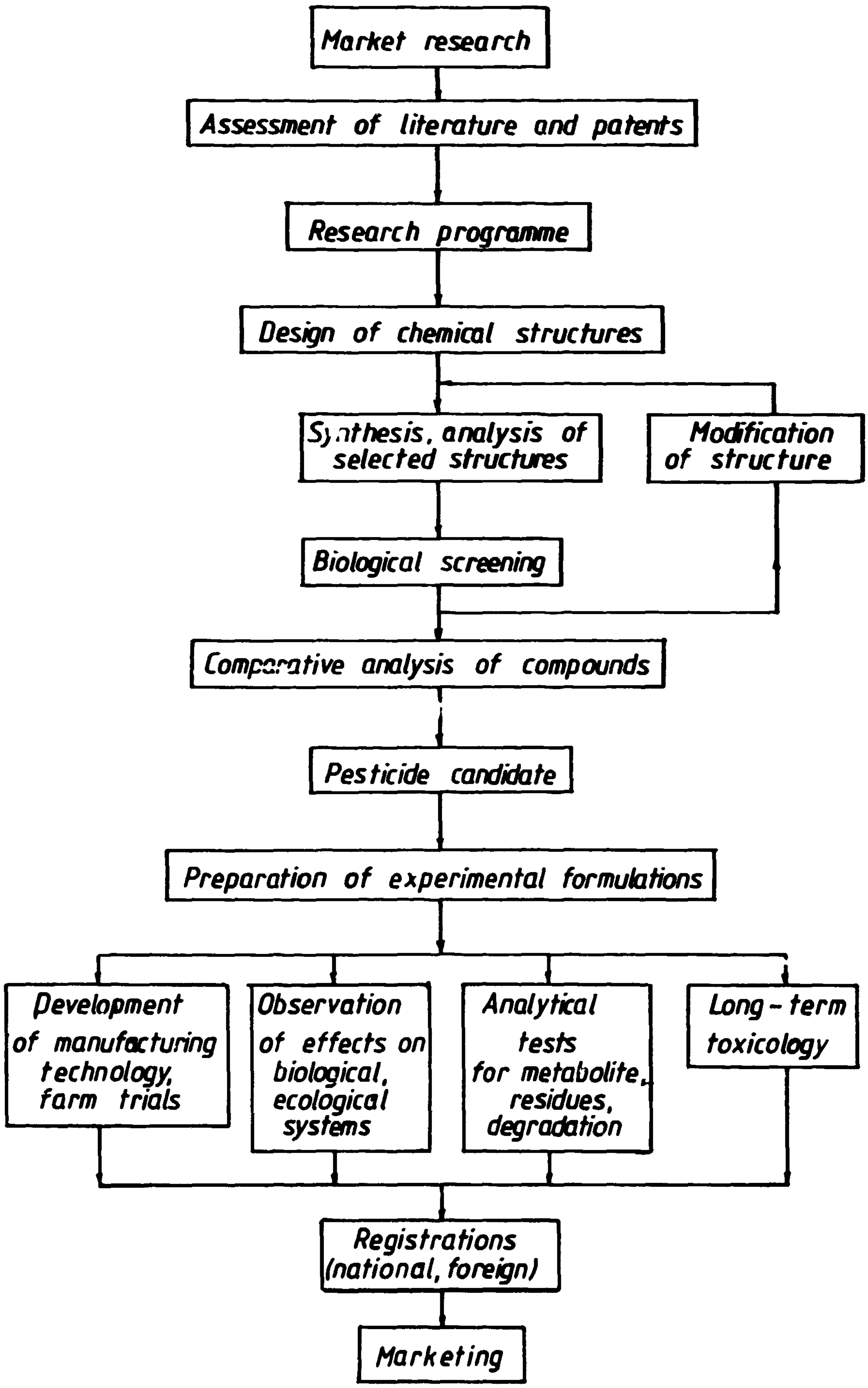
Regulatory authorities require scientific evidence of efficacy, safety and stable good quality.

2. R and D process in the pesticide fine chemicals industry

Figure 6. shows the phases of research for the discovery and development of a new pesticide chemical entity (NPCE). A two-step approach is necessary. Market research from one side will outline the product characteristics required. Chemical structure analysis, assessment of literature and patents will, from the other side, orient towards such chemical compounds which can have the desired effects and have a chance of being synthetized from available raw materials at acceptable costs. This phase can take one to three years.

The second phase is laboratory work. Compounds of the selected family are synthetized and tested pharmacologically for the desired effect (screening). Those having adequate effect undergo further toxicology testing to prove their acceptability from the health and environment points of view. Many compounds go through this process until a single one is found which looks to be a good candidate for field trials. This period usually takes from three to six years.

Figure 6. Simplified flow chart of pesticide research



The compound which successfully passed the laboratory tests enters the third phase, the field tests on small experimental plots. Approval from the regulatory bodies is necessary before undertaking these trials. In this phase several activities are carried out roughly in parallel over a period of two to five years:

(a) Elaboration of quality control methods and standards;
(b) Process development;
(c) Stability tests of different dosage forms;
(d) Studies on efficiency (to demonstrate activity);
(e) Acute and chronic toxicity studies (for the protection of users, consumers of agricultural products, crops, household and wild animals and the external environment);
(f) Development of formulations for field experiments;
(g) Extended field biological assessment.

When all these tests and investigations give satisfactory results, the documents are presented to the regulatory authorities for registration. The cost of R & D work can be recovered only by world-wide marketing. Therefore the registration process in the home country must be repeated for every country where the product will be marketed. There are countries where the registration of a product approved in a country with renowned regulatory practice is relatively simple, but even so, further delay and expenses occur.

The last step, marketing, involves much advertising, training, and other costs. The development of a new pesticide from the concept to the marketing, takes from 7 to 18 years at a cost of 20-50 million dollars on the average.

R & D expenditures can be classified by major groups as summarized in table 24.

Table 24. Share of different research fields in total cost

	Western Europe	USA
Discovery of new compounds	67%	67%
Development of existing products	17%	25%
Registration and protection	16%	8%

3. R & D activities of the leading manufacturers

The leading manufacturers invest 10-15 per cent of their pesticides sales volume in research and development (table 25.). This is only one of the features characterizing the outstanding efforts deployed in this direction. Large research centers are built and expanded not only for the pure chemical work, but also for the similarly important pharmacological testing processes and toxicological investigations. In the last years, genetic engineering has also gained importance in agrochemical research.

For example, BAYER is building a new Agricultural Chemical Centre on a 62-hectare plot in Mannheim, Federal Republic of Germany, at a cost of $133 million. In the second half of this decade, when it will be fully operative, the Centre will employ a staff of 1200 to carry out research in the fields of chemistry, biology and environmental protection, and in every branch of the plant production. A world-wide advisory service will also be available.

Another example is the Basle Research Centre of CIBA-GEIGY (Switzerland) that can simulate any climatic conditions in the world by programmable regulation of different factors, such as light, temperature, and relative humidity. In this way they can study the behaviour of insects, plant pathogens and weeds collected from all parts of the world, and can investigate the efficacy, toxicity and stability of the applied formulations in laboratory scale.

In 1984 Monsanto started a new Research Centre for Physiological Sciences in St. Louis (USA). The cost amounted to $150 million. The Centre includes 250 laboratories, 26 greenhouses of high standard and 123 computer-aided breeding chambers. An international network of regional biological experimental stations is linked to the headquarters.

Table 25. Pesticide R&D expenditure 1986 of major companies

Company	Agrochemical sales (millions of dollars)	Agrochemicals R&D (millions of dollars)	R&D (percentage of "own sales")
Bayer	2,380	195	11.5
Ciba-Geigy	1,780	148	11.3
Rhone-Poulenc	1,105	86	10.2
Monsanto	1,067	94	9.2
ICI	1,040	86	10.5
Shell	1,005	76	11.9
BASF	925	84	11.2
Hoechst	890	98	14.2
Du Pont	780	84	12.7
Dow	770	681	10.0
Schering	640	62	15.9
Am. Cyanamid	458	45	10.8
Sandoz	422	40	15.1
Stauffer	405	40	10.8
Eli Lilly	389	45	12.7
Kumiai	350	22	8.8
Rohm & Haas	347	34	11.0
FMC	340	48	16.0
Un.Carbide	300	32	12.8
Sankyo	290	16	13.4

<u>Source</u>: Wood-Mackenzie & Co. Ltd., Agrochemical Service, September 1987.

A new field in research work is genetic engineering where the genetic code of plants is manipulated in order to breed new species resistant to non-selective herbicides or to insects and other pests. This new field diversified the activities of chemical companies in the control of agricultural production through seed production. For example, Imperial Chemical Industries Ltd. (ICI) first created a joint venture with the Cardop group of Sweden. The affiliates of this group are among the leading specialists of plant and seed culture. Then it bought the Gast Seed Co. which is the third biggest cereals development company in the UK, as well as the Société Européene de Semences in Belgium. Thus ICI has become the largest company in the world in seed R&D, as well as the largest producer of seeds outside the USA. Some other leading pesticide producers also follow this line, but more cautiously.

4. Trends in pesticide research and development

4.1 Active ingredient research and development

Process development is an important field of research and can lead to substantial improvement of the process economics but the most important effect of R&D on the future of the whole industry will definitely come from the discovery of new compounds.

The actual trends must be reviewed separately for the three main pesticide groups.

4.1.1 Herbicides

This commercially most important group is also the main research field of large manufacturers. The main activities are outlined below:

- Development of selective systemic products such as the phenoxy-alkan derivates controlling monocotyledonous and dicotyledonous weeds;

- Development of new pre-emergent and post-emergent herbicides;

- Molecular modification of existing compound groups with promising possibilities for new individual compounds, like the sulphonil-urea derivatives;

- Development of plant growth regulators. These are natural plant hormones, the synthetic analogues of the indole-3-acetic acid. This group has already produced many patents and papers but little industrial production or field application is reported yet. The next ten years could bring some very interesting results also in commercial utilization.

- Development of safeners. Herbicides generally damage crop plants too, but they are not as affected as the weeds due to a certain internal or external control system. Still, there is some phytotoxicity depending on the plants and the herbicides applied. The safener added to the herbicide protects the germinating crop from the harmful effects of the herbicide. The first safeners were introduced in maize. Since then, other safeners have been marketed for other crops (sugar beet), which resulted in the revival of seemingly outdated old herbicides (EPTC). The research on safeners has many promising possibilities in the future. Emphasis is placed on N,N-diallyl-2,2-dichloroacetamide and its derivatives which increase tolerance of maize to thiocarbamates.

- Herbicide resistant seeds. Work is continuing intensively and genetic engineering will probably bring several species to the market in the nineties.

4.1.2 Insecticides

Research is equally oriented towards the conventional product groups and the new, third generation ones.

Pyrethroides. The development looks for more efficient compounds applicable in smaller quantity. The main difficulty is the increasing toxicity of the new products.

Phosphoric acid esters. Research is mainly oriented towards new formulation methods.

Carbamates. The Bhopal catastrophe has caused a serious setback of research in this group. Carbofuran compounds do not seem to be able to replace the carbamates. Since the market is good and the active ingredient itself cannot be rejected, a safe synthesis route would be the solution.

Inhibitors of chitin synthesis. Substances inhibiting chitin synthesis of insects have long been known but due to various reasons (price, problems of application techniques, etc.), they are not widely applied in practice. Products from this group of activity could have an important role in the future.

Antifeeding products and inhibitors of oviposition. Several products are known with such effect (e.g. salts of alkali and alkali earth metals, isothiocyanates, inorganic and organic acids and bases, organic tin compounds, aromatic hydrocarbons and chinones, alcohols, aldehydes and ketones, tertiary amines, carbohydrates and glucosides, alkaloids and terpenes, etc.) but no sufficient information on the factors influencing the insect behaviour or on the mode of action of these materials is available in order to draw general conclusions. So there seems to be a long way to the commercialization of these products.

Pheromones and antipheromones. Much research work is devoted to this promising new field. Actual results are rather scarce so far.

Analogues of juvenile hormones. The three juvenile hormones known up to now are isopropanic acid esters with very similar structure. Compounds with structures both similar to and very different from the basic molecules may imitate the effect of juvenile hormones in the insects: they prolong the larval phases and delay pupation. Nowadays more than 1000 juvenile hormones are available, but only few of them are used. These compounds are expensive, unstable, the time of application is critical and their effects are seen only with a great time delay.

Analogues of ecdyson hormones and hormone antagonists. The moulting (ecdyson) hormone is a polyhydroxysteroid. Overdosage causes early and partial pupation in most of the cases.

Lack of moulting and pupation can be induced not only by the overdosage of juvenile hormones but also by the lack of moulting hormone or the inhibition of its action. Theoretically there are two ways of attack:

- to prevent biosynthesis of the ecdyson, or

- to inhibit its action.

In the USA a group of insect physiologists has studied for a decade the action of ecdyson-antagonists of the steroids with modified structure. Investigations made with N-containing cyclic and aliphatic compounds as well as with steroids resulted in useful and valuable data on the steroid metabolism of insects, but have not so far produced insecticides suitable for practical use. With the same aim, Japanese researchers synthetised steroid-allenes and found that the mode of action of the two compounds with the same structure and action differs much from each other. One inhibits the transformation of the absorbed steroids into ecdyson, while the other inhibits the development of the hormonal effect.

Chemosterilants. Because of the difficulties and expenses encountered during the production of sterile males under laboratory conditions, several investigations have been made in vivo for the chemical sterilisation of the natural insect population. A disadvantage is that most of the chemosterilants are mutagenic.

Avermectines. A group of very complicated organic compounds produced by a fungal species (streptomycis avermitilis) in a bioreactor (fermentation process); it has nematicidal and miticidal effects. It is effective in very small doses, usually added to pyrethroids, and surpasses the effect of traditional insecticides. It is an experimental product and assumed to be environmentally safe.

These biological methods are today only a promising perspective. The next fifteen years will probably bring many commercially exploitable results, but further time will be necessary for their general world-wide application.

4.1.3 Fungicides

Ergosterin biosynthesis inhibitors (EBI). They are the leading compounds of our days. Their further development and the different possible combinations are being widely investigated. Further interesting results are expected.

Benzimidazoles. Their widespread use, mainly in Europe, led to the development of resistant species. This is the main problem and new variants overcoming this resistance are being studied.

Morpholines. Promising compounds, especially in the field of the anti-resistance effect. They can reduce the resistance development of the pest against EBI.

Acylalanines and dicarboximides are under research to overcome resistance effects, similar to the morpholines.

4.1.3 Formulation technology

Two main fields of development are under intensive research and give hope for new results: the use of different auxiliary materials in the formulations and the development of new formulation techniques.

The new auxiliary materials can improve the efficiency of active ingredients and reduce their adverse effects.

Adjuvants eliminate drifts caused by wind which is the most common constraint of the spraying techniques. Aerial and ground applications often cause environmental damages by the fact that the pesticides applied in fine droplets (mainly insecticides and herbicides) drift to sensitive areas in the vicinity. (e.g. a hormonal herbicide can damage grapes, or insecticides can contaminate vegetables produced for immediate consumption, etc.).

In order to prevent drifts, the surface tension of the elemental drops is increased, thus they do not break down further into drops of very small size. The adjuvants applied are different kinds of colloids.

Extenders

If mixed to pesticides, these compounds prolongate their action and degradation time. They are usually organic adhesives (cazein, protein, available in developing countries, etc.) forming a special film on the leaves of the plant which contains the active ingredient. With the gradual degradation of the adhesive, the active ingredient is dissolved and activated. With this technique the use of many old herbicides is becoming advisable (which would be advantageous to developing countries) and the contaminating effect on the environment is also significantly decreased since the active ingredient is fixed to the plant and cannot be carried by the wind.

The new formulation techniques tend to arrive at the same results, but by other means. The most important new method is the preparation of products with controlled release properties. They contain the active ingredient in a non-directly accessible form, thus neither degradation, nor toxic effects can be expected and they release it only gradually thus ensuring a continuous dosage. The microencapsulation and the retard granulation techniques belong to this field, but ongoing research can produce several other methods with similar effects. Controlled release will play an important role in the environment and health protection since the active ingredient is not directly accessible and the number of applications can also be reduced.

Other formulation techniques endeavour to reduce the cost and improve the efficiency of the application. The most important field is the ULV method, but research is active in many other fields too.

4.1.5 Application technology

The same goals are set for the development of application technology. New machines, equipment and methods are sought. The most promising are electrostatic and electrodynamic spraying and the new mechanical methods like controlled drop application.

IX. TYPOLOGY OF DEVELOPING COUNTRIES

Developing countries can be classified according to the stage of development of their pesticide industry (table 26).

1. Countries without manufacturing facilities

Countries with a small domestic market usually belong to this group. The low level of pesticide utilization and/or the geographically limited area prevents any economical manufacturing activity. If the specific consumption is low but the potential size of the market is large enough, prospective inventors should engage in importation and distribution of pesticide preparations and start acquiring experience in registration and quality control procedures.

2. Countries with formulation plants

Where the use of pesticides had reached an attractive level, set by the size of the pesticide market and specific consumption, local formulation was established. Many countries meet the market volume criterion but non-availability of active ingredients in free trade, non-tariff barriers to entry (patents, registration dossier, etc), and the lack of a professional distribution system are formidable constraints in exploiting the opportunities.

3. Countries with active ingredient manufacture

Production of inorganic pesticides was not taken as active ingredient manufacture because this can be done in nearly any country where the demand exists and the raw materials are available.

The small number of countries belonging to this group shows that a relatively developed organic chemical industry is a prerequisite for the domestic production of pesticide active ingredients. A few of these countries already export and are building up a regional market presence.

4. Countries with research capabilities for the development of new active ingredients.

Research is costly and time-consuming; it is concentrated in the large research centres of the market leading enterprises. To go from the manufacturing of active ingredients to the development of original products is the first step in going from domestic to international[18/].

5. Countries with capabilities for worldwide marketing activity

International trade is even more concentrated than production and it is also very expensive to build up an own international marketing organization. Enterprises in developing countries might increase their moderate exports to surrounding countries but none of them will reach global sales in the forthcoming decades.

18/ Some of the developing countries engaged in pesticide chemical production might have the capability of discovering new active ingredients but none of them has the venture capital and professional expertise to develop these active ingredients into pesticide products for world-wide marketing.

Table 26. Classification of countries according to their pesticide manufacture possibilities

1. Countries without manufacturing facilities

Angola	Mongolia
Benin	Mozambique
Botswana	Namibia
Central African Rep.	Niger
Cyprus	Senegal
Equatorial Guinea	Somalia
Gabon	Togo
Gambia	Uganda
Guinea	Uruguay
Guyana	United Arab Emirates
Honduras	Western Sahara
Kampuchea	Yemen Arab Rep.
Lebanon	Zambia
Malawi	Zimbabwe
Mauritania	

2. Countries with formulation plants

Bangladesh	Iraq
Burma	Jamaica
Bolivia	Jordan
Burundi	Kenya
Cameroon	Lybian Arab J.
Chile	Madagascar
Colombia	Malaysia
Costa Rica	Morocco
Côte d'Ivoire	Nigeria
Cuba	Pakistan
Dominica	Sri Lanka
Ecuador	Syria
Ethiopia	Tanzania
Egypt	Tunisia
Ghana	Viet Nam
Guatemala	Zaire
Iran	

3. Countries with pesticide chemical production

Algeria	Indonesia
Argentina	Korea, Rep. of
Brazil	Mexico
China	Thailand
Hongkong	Turkey
India	

X. CONCLUSIONS

1. Publicly available statistical data on pesticide fine chemicals and formulated products are useful to assess past sectoral trends and current situation (with three to four years of delay) in consumption and international trade at regional and global levels of aggregation. The same sources frequently do not permit situation analysis at country level. Statistics are only exceptionally available on individual products. Organized database on production does exist but its cross-country coverage is unsatisfactory and the time series are incomplete.

2. The pesticide sub-sector of the fine chemicals industry has a history of about 50 years. The global value of the active ingredient market was about $12 billion out of the $1 trillion world chemicals business in 1985. The pesticide chemical market is international in character and producers in countries with large domestic market are also export-strategy oriented. In fact, the top 40 companies are all from industrialized countries and they control about 74 per cent of the world market as well as the relevant production and marketing know how. Active ingredients are scarcely available in open international trade even after the product patents have expired. In such a context, there are industrial opportunities for developing countries, in particular in Argentina, Brazil, China, India, Mexico and Nigeria. Once commodity pesticide chemicals become freely available in international trade, opportunities for generic formulation will substancially improve. Niche competitors can be expected to emerge and gain strength mainly in specialty chemical trade.

3. The pesticide market has reached a slow but continuously growing maturity stage in industrialized regions using modern technology in agriculture whereas developing countries are in the exponential growth section of the market life cycle curve. The share of developing regions was over 30 per cent in worldwide consumption and about 25 per cent in imports. They produced 21 per cent and exported about 2 percent of the global demand in 1984. Market scenarios suggest that future growth of demand for established pesticides can mainly be expected in the developing regions.

4. The share of developing countries is about 50 per cent in the use of insecticides, over 20 per cent in fungicides and less than 10 per cent in herbicides. These global market shares indicate immediate production priorities in developing regions. This structure of demand is dominated by patent-expired, established pesticides. The impact of new chemical entities from R&D will be much less on future pesticide use in developing countries than in industrialized regions. No industrial scale alternatives to the use of pesticides are on the horizon to-day.

5. FAO studies have demonstrated that 25 to 45 per cent of the potential agricultural yield is lost to-day and about half of this loss could be saved by the systematic use of pesticides. Such savings have been estimated to exceed three to four times the costs of plant protection.

6. Biologically active substances represent potential hazards to health and external environment in general. Pesticides are no exception to the rule. Unsatisfactory manufacturing and transport practices and inappropriate use of pesticides might lead to serious consequences, even to disasters, and this is the reason why their production, domestic distribution and international trade is strictly regulated. On the other hand, the technical and management know-how has been developed to reduce industrial safety and environment pollution risks to socially and economically desirable levels.

7. The pre-requisite of the safe and economic use of pesticides, or the first step towards industrialization, is the establishment and efficient operation of an adequate handling, distribution and technical advisory network which delivers the right kinds of good-quality pesticides to the farmers at the right time and at the lowest possible cost. The technology package of this phase of sectoral development includes mainly marketing and business management know-how, namely, registration file, current demand, methods for short-term forecasts, finance, storage, inventory control, quality monitoring and distribution.

8. The initial production of pesticides might extend from the simple packaging of finished products imported in bulk to the manufacture of pesticide dosage forms starting from active chemical ingredients. The technology package includes what has been listed in the former paragraph plus formulation and packaging process technology, good manufacturing practices, quality control and formulation design. The availability of pesticide fine chemicals, excipients (added substances) and packing materials in well-defined and stable quality at internationally competitive prices is the techno-economic pre-requisite for the establishment and expansion of local pesticide formulation facilities.

9. Production of organic chemical pesticide active ingredients and intermediates should be considered only in those countries where the fine chemical industry has already a few years of tradition or the main criteria for the establishment of a domestic market-oriented pesticide chemical industry are met, unless there exist special comparative advantages, e.g., local availability of copper ores, or plants containing biosynthetic pesticide fine chemicals which can be extracted economically. Formulation and production of active ingredients should always be conceived within an integrated system of operation which extends backwards into organic chemical industry and forwards into marketing of finished products. Such an integrated approach would have an important impact on the economy of domestic production as well as on safety of manufacture and environment protection.

The additional technology hardware and software for this stage of industrial development includes process design, process research with pilot plant facilities, process engineering, good manufacturing practices of fine chemical production, and in-process control and automation. Existence of complementary industries, e.g., chemical machinery and equipment, research and quality control instruments, etc., is a comparative technical advantage.

10. Research and development of new pesticide chemical entitities is a high-technology and venture capital intensive process. The minimum threshold value of new product R&D spending is in the region of $20 million per year and expenses can only be recovered if the finished product is sold all over the world. This, in turn, requires an efficient international marketing organization operating in most industrialized countries which has been considered beyond the realistic possibilities of developing countries.

11. Key factors of smooth technology transfer and operation in all stages of industrial development depend on continuous availability of working capital including convertible currency for the purchase of imported goods and services, specially trained manpower, efficient domestic machinery and equipment maintenance services and effective trouble-shooting within the company. Long term, at least 10 years, technical co-operation with an experienced partner is probably the most important criterion of effective overall technology transfer.

XI. INDUSTRIAL STRATEGIES FOR DEVELOPING COUNTRIES

Developing countries are important markets for pesticides and their share in global demand is expected to increase further as modern agrochemical cultivation techniques become more and more widespread in these countries, therefore new production capacities should be established here. Local production is particularly important in the case of those pesticides which are used in the cultivation of crops prevailing in developing countries. Profitability is the overall criterion of investment in the private sector. A project is usually considered attractive in the public sector if it is technically feasible and economically acceptable in the start-up period and profitable in the long run.

Special importance of non-tariff barriers to entry in the pesticide industry favours co-operation strategies (joint ventures, long-term technical co-operation and licencing agreements) rather than turn-key or down payment alternatives. Another point in favour of co-operation strategies is the limited availability of patent-expired active ingredients in international trade

1. Purchase of finished pesticide products

This strategy is recommended for enterprises in countries with the lowest pesticide application rate and/or where the necessary quality assurance, sales registration, independent government quality control and GMP regulations as well as distribution and agro-technical advisory networks have not reached an advanced development stage. Available industrial investment resources in these countries should be used for the establishment of these prerequisites through engaging in domestic trade. Alternatively, such resources may be used for the production of goods which offer better economic opportunities on the domestic market and can be sold without prior approval from agricultural, health and environment protection government authorities.

2. Manufacture of formulated pesticide preparations

The main criteria for the establishment of a domestic market-oriented pesticide formulation industry include:

(a) The above-outlined prerequisites for the imports and domestic sales of finished pesticide products;

(b) A growing pesticide preparation market of $10 million or more per year and a selection of products which offers an economically feasible opportunity for local production;

(c) Experience in the registration, importation, storage and domestic distribution of pesticide preparation (or similar sophisticated goods, e.g., pharmaceuticals);

(d) Availability of pesticide active ingredients and auxiliary materials at competitive prices for local formulation;

(e) Availability of technical information required for the registration of products prior sales and formulation technology for the manufacture of pesticide application forms in standard and stable quality;

(f) Availability of managers with extensive experience in the formulation and marketing of pesticides.

(g) Capability of conducting formulation R&D and related activities, such as stability tests, field trials, etc. The strategy of enterprises in this group of countries is generally oriented towards four main goals: to build up and maintain the image of a reliable supplier of good quality pesticide preparations, to sell at competitive prices, to raise the level of pesticide use through continuous availability of products and expansion of the distribution network, and to exploit production capacity to the maximum possible extent.

(h) Sound design and construction of the plant to satisfy health, industrial safety and environment protection requirements, and to enable economic operations.

(i) An industrial policy which supports production in the first ten years of operation.

Local pesticide formulation reduces foreign currency spending, contributes to the education and training of technical manpower, in particular in handling and processing hazardous materials.

Dosage form manufacturers can secure supply of pesticide fine chemicals also through customs synthesis, particularly when a patent-expired fine chemical substance is not available in international trade. They might also consider the manufacture of simple inorganic chemicals or the extraction of biosynthetic organic fine chemicals from domestic plants, if their production is economically feasible due to local availability of starting materials. In fact, domestic production of inorganic pesticides and active ingredients of botanical origin is technologically independent from the manufacture of fine chemicals.

3. <u>Manufacture of pesticide fine chemicals</u>

The main criteria for the estalishment of a pesticide fine chemical industry include:

(a) The prerequisites described for the imports of pesticides and establishment of a local formulation industry.

(b) A growing pesticide preparation market of about $250 million per year.

(c) The quality of the locally produced pesticide fine chemicals should meet, in all respects, the requirements of the formulators.

(d) Willingness of the domestic formulators to buy from sources other than established suppliers and/or licensors.

(e) Domestic or regional availability of basic industrial chemicals and chemical building blocks;

(f) Continuous availability of utilities such as electrical power, water and sewage systems;

(g) Availability of top managers and chemists or engineers with extensive experience in the manufacture of fine chemicals;

(h) Capability of conducting chemical process research and development on an industrial scale;

(i) An industrial policy which supports domestic production in the first ten years of operation and stimulates exports to industrialized countries in the long run.

No single criterion should be taken as a barrier to entry. For instance, pesticide chemical manufacturers with forward integration to the pesticide preparation market will consider their own market share rather than the total value of the domestic market when studying the technical and economic feasibility of local fine chemical production.

Pesticide active ingredients are usually produced by enterprises with experience both in fine chemical industry and marketing of formulated preparations. Their main strategic goal is to guarantee the continuous supply of key materials for their own upstream operations and to sell the excess production in international trade. Exports of pesticide fine chemicals, however, is an enterprise-to-enterprise business today because international trading houses do not deal with this category of goods.

4. Discovery of new pesticide chemical entities

Pesticide product innovation is a high technology package that requires the financially and professionally efficient management of sophisticated research and development facilities. The venture capital invested in new product R&D can only be recovered if the pesticide preparation is sold on all major markets. This requires deep knowledge of industrial property systems and regulatory requirements in practically all industrialized countries as well as own distribution system in major markets. Enterprises which are capabie of discovering safe and effective pesticides, but do not have the necessary capital to develop such molecules for international sales, should licence their intellectual property at an early stage to partners with world-wide marketing experience.

5. Global marketing

The share of developing countries in exports was 2 per cent in 1984. The top forty companies are all from industrialized countries. These facts imply that enterprises from developing countries are not involved in global trade and the small volume exports probably have a neighbouring country trade character. World-wide marketing of pesticide preparations is beyond the current realistic strategic objectives of enterprises from developing regions. North-South and South-South co-operation in increasing the availability of pesticide active ingredients in open international trade would give an impetus to the development of the pesticide formulation industry in developing regions.

Annex 1

to the Global Review of the Pesticide Industry

Glossary of terms and definitions

Activator: A substance that accelerates or increases the total effect of a pesticide.

Algicide: A chemical intended for the control of algae in ponds and lakes, marshes, irrigation and drainage canals, also in water that is stored or is being used industrially.

Allomone: A chemical or mixture of chemicals produced by one organism that induces a response in an individual of another species that is favourable to the emitter. Many plants produce secondary substances classified as allomones that repulse insects to prevent them from feeding.

Annual weed: A weed which develops from a seed, blooms, produces seed and dies, all in the same year. Examples are common chickweed and crabgrass.

Antidote: An antidote is a substance intended to counteract the effects of a poison. It should be prescribed or administered only by a physician. Medical advice can be obtained from a Poison Control Center, for the correct antidote. The particular pesticide must be determined by a label check, for example, before an antidote can be prescribed.

Antifeeding compound: Material which does not repel but induces insects to stop feeding within a short time. The insects often refuse to eat untreated food afterwards. Starvation results through an irreversible adverse effect upon the insect. Largely experimental.

Antimetabolite: A compound accepted by insects as though it contained normal food components (amino acids, vitamins, etc.) but which blocks growth. It may interfere with enzyme secretion in the insect gut or permanently upset the nervous system concerned with normal functioning of the gut. Experimental.

Attractant: A substance which lures insects from distances to traps or poison bait stations. The most successful lures, when available, are the specific secretions of particular insect species or their synthetic chemical equivalents. Many attractants in long use are food lures such as sugar sirups or other substances.

Bactericide: A chemical used to kill bacteria.

Bacteriostat: A material to prevent growth or multiplication of bacteria.

Bait: A food or other substance used to attract a pest to a pesticide or to a trap where it can be destroyed.

Biorational pesticides: Defined as including pest control agents and chemical analogues of naturally occurring biochemicals. Viruses, bacteria, protozoa, fungi are considered biorational pesticides.

Botanical insecticides: Insecticides derived from plant materials. Ground plant parts (flowers, leaves, stems, roots) may be used directly or their extracts employed after more or less refinement. Essential oils from plant sources are often used as attractants or repellents. Vegetable oils are often ingredients of pesticide preparations. Plant gums and finely ground waste products such as walnut shells have miscellaneous uses in such preparations.

Broadleaf plant: Any plant with a flat leaf. In weed control it refers to non-grassy types of herbaceous plants.

Broad spectrum pesticide: A general purpose pesticide which can be used against a large number of pests on a wide range of crops.

Chemosterilisants: Compounds such as aphamide, aphlolate, tepa and metepa which sterilize insects sexually to prevent reproduction.

Cholinesterase: A body enzyme necessary for proper nerve function that is destroyed or damaged by organic phosphates or carbamates taken into the body through any path of entry.

Cholinesterase-inhibiting pesticides: A class of pesticides having related pharmacological effects for which the Environment Protection Agency has limited the total amount for residue purposes.

Common name: The name assigned to pesticide active ingredient by the International Standards Organization or adopted by national standards authorities to be used as a generic or non-proprietary name for that particular active ingredient only.

Compatibility: The ability of two or more substances to mix without objectionable changes in their physical or chemical properties, or without reducing effectiveness of any individual component.

Coupling agent: A solvent that has the ability to solubilize or to increase the solubility of one material in another.

Crop tolerance: Various crop species and varietes differ in their sensitivity to chemicals. For instance, corn will grow in land that has been treated with the herbicide atrazine while soybeans cannot grow on that same land even in the following year. Corn is an example of crop tolerance to atrazine.

Cumulative pesticides: Those chemicals which tend to accumulate or build up in the tissues of animals or in the environment (soil, water).

Curative pesticide: A pesticide which can inhibit or eradicate a disease-causing organism after it has become established in the plant or animal.

Defoliant: A preparation intended for causing leaves to drop from crop plants such as cotton, soybeans or tomatoes, usually to facilitate harvest. Compare desiccant.

Degradation: The process by which a chemical compound is reduced to a less complex compound by the action of microorganisms, water, air, sunlight, or other agents.

Desiccant: A preparation intended for artificially speeding the drying (loss of moisture) of crop plant parts such as cotton leaves and potato vines. Compare defoliant.

Diapause: A physiological state of arrested development, generally resulting from physical stimuli, such as temperature and light, that provides the insect a means of surviving unfavourable periods.

Drift: Drift is the movement of a portion of the airborne particles of a dust or spray away from an intended point of application. Dusting is done frequently in early morning when the air is quieter than later in the day. Windy days are poor for spraying. Sensitive crops at a great distance may be injured by drift of herbicides.

Emergence: Emergence, in connection with herbicide usage, refers to the time when the first leaves of a plant appear above the soil surface. The expression "at emergence" refers to treatment applied during the visible emerging phase of the specified crop or weed.

Emulsifiable concentrate: Produced by dissolving the pesticide active ingredient and an emulsifying agent in an organic solvent. A solvent substantially insoluble in water is usually selected since water-miscible solvents have not in general proved feasible. Strength usually stated in kilos of active ingredient per litre of concentrate.

Encapsulated pesticides: Pesticides enclosed in tiny capsules (or beads) of thin polyvinyl or other plastic material to control release of the chemical and extend the period of diffusion, thus providing increased safety to applicators as well as to the environment.

EPA: The Environmental Protection Agency (EPA) in the US is responsible for controlling the various aspects of environmental pollution (air, water and earth). Included are pesticide regulations such as residue tolerances of a product, re-entry standards, protective clothing.

Fungicide: Fungicides are used on farm crops preferably as protective rather than curative treatments, being applied to the surface of the plant in water suspensions or dusts before the attack of a fungus. Deciduous fruit trees and numerous vegetable crops and ornamentals, a well as germinating seeds are usually subject to attack unless protected.

Fungistat: A chemical that prevents the germination of fungus spores or the growth and development of mycelium while in contact with the fungus, but does not kill it.

Herbicide: A chemical intended for killing a weed, grass, or brush, or interrupting their normal growth.

Insecticides: A substance or mixture of substances intended to prevent, destroy, repell or reduce the amount of any insects which may be present in any given environment.

Integrated pest management: A pest management system that, in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest populations at levels below those causing economically unacceptable damage or loss.

Juvenile hormone: A hormone produced by an insect in the process of its immature development which maintains its nymphal or larval form. Experimental work is under way attempting to utilize the hormone (now synthesized) or some similar synthetic chemical as an insecticide to control insects by preventing their maturity.

Label: The written, printed, or graphic matter on, or attached to, the pesticide; or the immediate container thereof and the outside container of the wrapper of the retail package of the pesticide.

Life cycle: The complete succession of development stages in the life of an organism.

Molluscicide: A compound used to control slugs and snails (mollusks) which are crop and garden pests. Snails are also intermediate hosts of parasites of medical importance to man. These pests belong to the mollusk group Gastropoda; hence the name gastropocide is sometimes applied to molluscicides when used especially against slugs and snails.

Monophagous: Limited to a single kind of food, as in the case of the weevil which restricts its feeding to the cotton plant.

Mutagenic: The property of a substance or agent to produce genetic changes in living cells.

Nematicide: A material, often a soil fumigant, to control root-infesting nematodes on crop plants.

Nematode: A member of a large group (phylum Nematoda), also known as threadworms, roundworms, etc. Some larger kinds are internal parasites of man and animals. Nematodes, sometimes called eelworms, injurious to plants are microscopic, slender, worm-like organisms in the soil, feeding on or within plant roots or even plant stems, leaves, and flowers.

Non-persistent pesticide: A pesticide that does not remain active in the environment more than one growing season.

Non-selective pesticide: A pesticide that is toxic to a wide range of plants or animals without regard to species.

Oligophagous: Restricted to a few kinds of food. For instance, the common cabbage worm feeds on plants related to the cabbage, such as turpins, mustard, and other plants of the crucifer family.

Pest: Any organism which injures man, his property, or his environment, or which annoys him. Such organisms include principally certain insects, nematodes, fungi, weeds, birds, and rodents, or any other terrestrial aquatic plant or animal life, or virus, bacteria, or other organisms (except microorganisms living on or in man or other living beings).

Pesticide: Any substance or mixture of substances intended for preventing, destroying, or controlling any pest, 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 which may be administered to animals for the control of insects, arachnids or other pests in or on their bodies. The term generally includes substances intended for use as a plant-growth regulator, defoliant, desiccant or fruit thinning agent or agent for preventing the premature fall of fruit and substances applied to crops either before or after harvest to protect the commodity from deterioration during storage and transport.

Pheromone: The location and the mutual recognition of the the male and female of an insect species are brought about by various sensory expedients, the most common of which is a chemical sex attractant secreted by special glands of one or both sexes. These secretions are called pheromones.

Plant growth regulator: A preparation which, in minute amounts, alters the behavior of ornamental or crop plants or the produce thereof through physiological (hormone) rather than physical action. It may act to accelerate or retard growth, to prolong or break a dormant condition, to promote rooting, or in other ways.

Repellent (insect): Oil of citronella, prior to World War II, was the standard insect repellent. Now, many other compounds, much more effective, are in use. These include benzyl benzoate for chiggers; dimethyl phthalate for mosquitoes and mites; and ethyl hexandiol, indalone and dimethyl carbate for mosquitoes, chiggers, and fleas. Various combinations of these are used as all-purpose repellents.

Residual herbicide: A weed killer that persists in the soil and kills weeds as they germinate.

Residual insecticide: A compound that kills insects which may come into contact with the insecticide which remains on or in a treated location even after a long time.

Rodenticide: A preparation intended for the control of rodents (rats, mice,etc.) and related animals (such as rabbits).

Seed protectant: A pesticide chemical applied to seeds before planting to protect them from injury or destruction by insects, fungi, and other soil pests, and to prevent seed decay and damping off of new seedlings.

Selective pesticide: A pesticide that is toxic to some pests, but has little or no effect on other similar species. Example: some fungicides are so selective that they control only powdery mildews and no other fungi.

Systemic fungicides: Fungicides that are systemic in action, i.e., are translocated to other parts of the plant than those originally hit.

Systemic pesticide: Pesticide that is translocated to other parts of a plant or animal than those to which the material is applied.

Annex 2

to the Global Review of the Pesticide Industry

Definition of UNIDO regions used in statistical tables

1. North America (NA)

Canada
Puerto Rico
USA

2. North Europe (EN)

Austria	Italy
Belgium	Netherlands
Denmark	Norway
Finland	Sweden
France	Switzerland
Germany, Fed. Rep. of	United Kingdom
Ireland	

3. South Europe (ES)

Greece	Spain
Portugal	Yugoslavia

4. East Europe (EE)

Albania	Hungary
Bulgaria	Poland
Czekoslovakia	Romania
German Democratic Rep.	USSR

5. Japan (JP)

6. Other industrialized (OI)

Australia	New Zealand
Israel	South Africa

7. Latin America (LA)

Argentina	Guyana
Bolivia	Honduras
Brazil	Jamaica
Chile	Mexico
Colombia	Nicaragua
Costa Rica	Panama
Cuba	Paraguay
Dominican Republic	Peru
Ecuador	Uruguay
Guatemala	Venezuela

8. North Africa (AN)

Algeria
Egypt
Libyan Arab Jamahiriya
Morocco
Tunisia

9. Africa South of Sahara (TA)

Angola
Benin
Botswana
Burundi
Centrafrica
Equat. Guinea
Ethiopia
Gabon
Gambia
Ghana
Guinea
Kenya
Liberia
Madagascar
Malawi
Mali
Mauritania
Mozambique
Namibia
Niger
Nigeria
Senegal
Somalia
Swaziland
Togo
Uganda
Un.Rep.Cameroon
Un.Rep.Tanzania
Western Sahara
Zaire
Zambia
Zimbabwe

10. West Asia (WA)

Cyprus
Iran
Iraq
Jordan
Lebanon
Oman
Saudi Arabia
Syrian Arab Rep.
Turkey
United Arab Emirates
Yemen
Yemen, Dem. Rep.

11. Middle and South Asia (SA)

Bangladesh
Burma
India
Pakistan
Sri Lanka

12. East Asia (EA)

Hong Kong
Korea, Rep. of
Thailand

13. South-East Asia (AS)

Kiribati
Indonesia
Malaysia

14. Other Asia (OA)

China
Dem. Kampuchea
Korea, Dem.People's Rep.
Laos, People's Dem. Rep.
Mongolia
Vietnam

Annex 3

to the Global Review of the Pesticide Industry

Illustrative list of pesticide active ingredients of major importance to developing countries

	Patent expiry[1/]
Herbicides	
Alachlor	1987
Ametryn	1979
Atrazine	1980
Butylate	1979
Diuron	1976
EPTC	1979
Linuron	1980
Monuron	1971
Paraquat	1979
Propachlor	1978
Propanil	1978
Simazine	1979
Thiobencarb	...
Trifluralin	1983
Insecticides	
Carbaryl	1979
Cypermethrin	1994
DDT	1964
Deltamethrin	1995
Dichlorvos	1980
Fenvalerate	1994
Lindane	1960
Malathion	1971
Parathion	1967
Phosphamidon	1979
Fungicides	
Benomyl	1990
Captafol	1983
Captan	1971
Carbendazim	1981
Chlorothalonil	1986
Folpet	1971
Mancozeb	...
Maneb	1963
Thiabendazole	1982
Thiophanate methyl	1989
Triadimefon	1993
Zineb	1974

1/ The years given in this column should be taken as general indicators of the global expiry date of product patents. Investment decisions should be based on patent research.

Annex 4

to the Global Review of the Pesticide Industry

List of companies selling pesticide chemicals in intermediate trade

1. Agrolinz, Agrarchemikalien GmbH
   att.: Dipl.Ing.Dr. Franz Stöffelbaur,
   Information Manager — Phone: (07232) 591-0
   St. Peter Str. 25 (P.O. Box 21) — Telex: 02 1324
   4021 Linz — Fax: (0732) 583 32
   Austria — DVR 051 7364

2. Akzo Chemicals BV
   att. Mr. F.P.A.M. van der Zalm,
   Sales Manager
   P.O.Box 975 (Stationstraat 48) — Phone: (033) 643911
   3800 AZ Amersfoort — Telex: 79322
   The Netherlands — Fax: (033) 637448-19149

2. All India Medical Corp., (AIMCO)
   att.: Mr. Pradeep P. Dave, Managing Partner
   Akhand Jyoti, 8th Road, (P.O. Box 16806)
   Santacruz East — Phone: 612 4831, 612 5287
   Bombay 400 055 — Telex: 011-74538 AIMC IN
   India — Cable: ZINCTOX

4. A/S CHEMINOVA
   att. Mr. Ole Petersen, Project Mgr.
   P.O. Box 9
   7620 Lemvig — Phone: 07 83 41 00
   Denmark — Telex: 665 14 CHEMV DK

5. CHEMOLIMPEX, Hungarian Trading Co.
   for Chemicals
   att.: Ms. V. Neudold, Head, Export Dpt.
   Deák Ferenc U 7-9 (P.O.Box 121) — Phone: 361 183 976
   H-1805 Budapest — Telex: 22-4351
   Hungary — Fax: 179-444

6. Compañía Química S.A.
   att. Sr. Miguel Flugelman,
   Gerente de Agroimpulso
   Sarmiento 329
   1041 Buenos Aires — Phone: 312-3016
   Argentina — Telex: 23438 COBA AR

7. Dow Chemical France
   att. M. Horacio Percossi,
   Director of Marketing
   B.P. 31-1090, Route des Crétes
   Sophia-Antipolis - Les Bouillides
   06561 Valbonne Cedex
   France

8. Du Pont Far East Inc.
att.: Mr. R.D. Grossman, Sales and Dev. Mgr.
Agricultural Products Dept.
#07-01 World Trade Centre
Singapore 0409 — Phone: 011-65-279-3485

9. EXCEL Industries Ltd.
att. Mr. V. Ranganathan
Senior Export Executive
184-87, S.V. Road (P.B. 7474)
Jogeshwari West — Phone: 57 1431
Bombay-400102 — Telex: 011 7107EXEL IN
India — Cable: EXCEL JOGESHWARI

10. Fermenta Plant Protection Co.
att. Mr. Jerry Pauley, Product Manager
5966 Heisley Rd.(P.O.Box 8000)
Mentor, OH 44061-8000 — Phone: 216-357-4100
USA — Telex: 196 191 FPPC UT

11. Gilmore Inc.
att.: Mr. Roger Gilmore, President
1755 N.Kirby Pkwy, Suite 300
Memphis, TN 38119-4367 — Telex: 68 [illegible]90 22
USA — Fax: (901) 757-9367

12. National Organic Chemical Industries Ltd., (NOCIL)
att.: Mr. K.M. Kappor, Sales Manager Agrochemicals
257 Swami Vivekanand Road, — Phone: 640 7041, 640 6714
Bandra, Bombay 400 050 — 640 3326, 640 1402
India — Telex: 112296 NCL IN
Cable: PETRONOCIL

13. Productos OSA sacifia
att. Sr. Norberto Chutrau, Presidente
Av. de Mayo 1161, ler. piso
1085 Buenos Aires — Phone: 37 81 39, 37 35 24
Argentina — Telex: 17340 OSA AR

14. Química Estrella S.A.C.I.e.I.
att. Sr. Eric Pintar,
Gerente División AGCHEM
Av. de los Constituyentes 2995
1427 Buenos Aires (Suc. 27) — Phone: 541 52 7847
Argentina — Telex: 17754

15. Química Lucava, S.A. de C.V.
att. Sr. E. Esquiliano, Director Comercial
Camino a Tepalcapa 224
Apdo. Postal 59
54900 Tultitlan, Edo. de Mexico — Phone: 872-2110
Mexico — Telex: 171320 QLUME

16. Ratzoff Delta Co. and Agroquímicas de Guatemala S.A.
att. Sr. A. Ricardo Ortega S.,
Vice-Presidente de Ventas
Edificio Real Reforma, 3er Nivel
Av. La Reforma 13-70, Zona 9
Guatemala, Guatemala

Phone: 63860,67962,316159
Telex: 5991 QUIGUA GU GUATEMALA C.A.
Cable: AGROQUIMSA

17. Rohm and Haas Co., European Operations
att. Mr. G.D. Baxter,
Marketing Manager Ag. Chem. Europe
Chesterfield House, Bloomsbury Way
London, WC1A2TP
England

Phone: 01-242-4455
Telex: 24139
Cable: ROHMHAAS LONDON ENGLAND

18. Sumitomo Chemical Company, Ltd.
att. Mr. C. Satake, Manager Marketing Dpt.
Mgr.Marketing Dpt., Plant Protection Div.
15, 5-chome, Kitahama
Higashi-ku, Osaka
Japan

Phone: (06) 220-3745
Telex: SUMIKA J63823
SUMIKA J63824
SUMIKA J0522-7541
Cable: CHEMISUMIT OSAKA

19. Taiwan Tainan Giant Industrial Co., Ltd.
att. Mr. Steve Yang, Marketing Manager
191, Sec. 2, Ming Shen Road,
Tainan, Taiwan
People's Republic of China

Phone: 06 2793170
Telex: 71592 YONYU

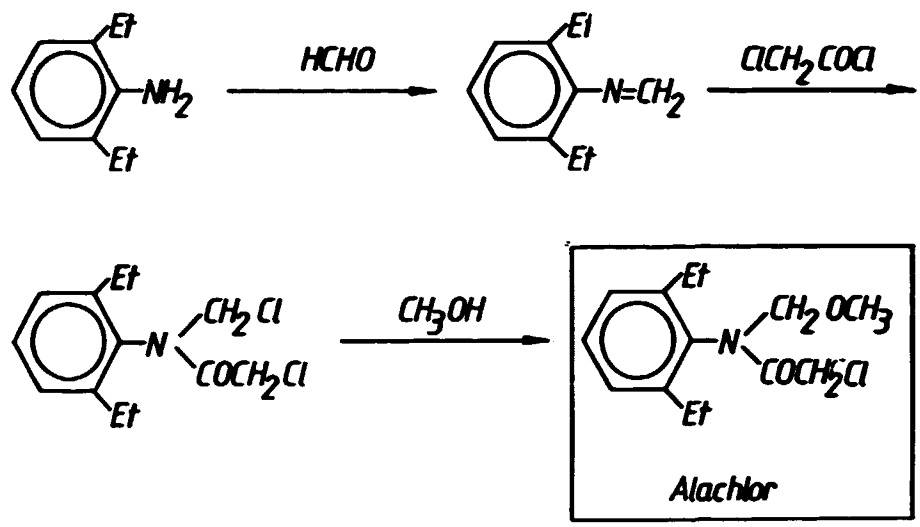
Annex 5

to the Global Review of the Pesticide Industry

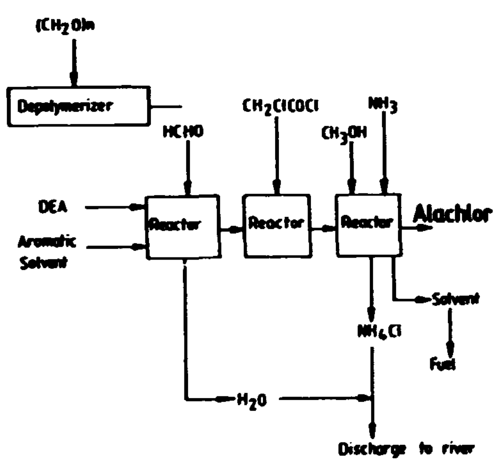
Desk analysis of technical information on pesticide chemicals

Alachor

1. Agricultural use: pre-emergence herbicide used primarily in the cultivation of maize, rice and soybeans.
2. Other use: none
3. Inventor: Monsanto (1967)
4. CAS registry number: [15972-60-8]
5. Scheme of chemical synthesis



6. Schematic block diagram of the manfacturing process



7. Rudimentary assessment of technical information

The synthesis consists of three steps. The conversions can be carried out in multipurpose batch reactors. No special reaction conditions or utilities are required. None of the conversions appears to represent industrial safety or environment pollution hazards unusual in fine chemical plants.

The key starting materials: -2,5-diethyl-aniline (DEA), chloroacetyl chloride and paraformaldehyde, are available in free trade. A similar synthesis route but slightly different reactants are used in the manufacture of butachlor, metolachlor and propachlor.

Aldicarb

1. Agricultural use: systemic insecticide suitable for the treatment of problems occurring in rice.

2. Other use: acaricide, nematocide

3. Inventor: Payne et al. (1966)

4. CAS registry number: [116-06-3]

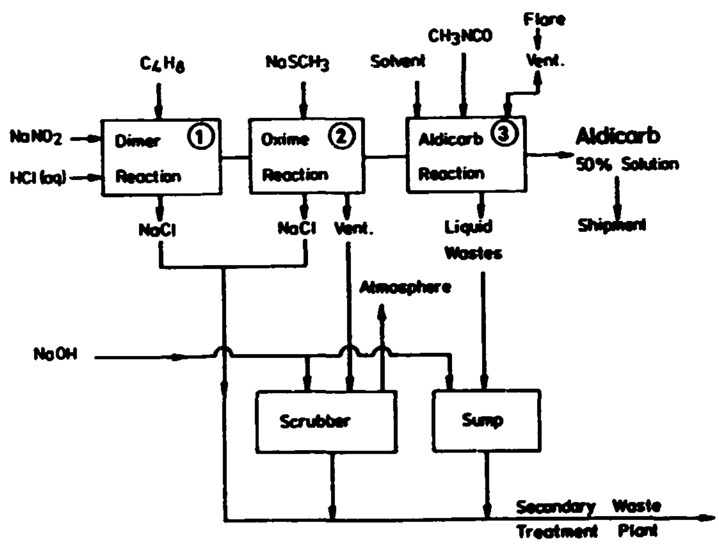
5. Scheme of chemical synthesis

$$(CH_3)_2C{=}CH_2 + NaNO_2 + HCl \longrightarrow [(CH_3)_2CClCH_2NO]_2 + CH_3SNa \longrightarrow$$

$$CH_3SC(CH_3)_2CH{=}NOH + CH_3NCO \longrightarrow \boxed{CH_3SC(CH_3)_2CH{=}NOCONHCH_3}$$

Aldicarb

6. Schematic block diagram of the manufacturing process



7. Rudimentary assessment of technical information

The synthesis consists of three steps. The conversions can be carried out in multipurpose batch reactors. Reaction conditions seem to be normal but efficient cooling is probably required in the methylisocyanate (MIC) step. Special industrial safety and environment protection measures should be taken during the storage and handling of all reactants, in particular MIC.

The key starting materials and reactants - isobutylene (isobutene) and sodium methanethiolate (methyl mercaptan sodium) - are not available freely in international trade. MIC should be produced on site.

Benomyl

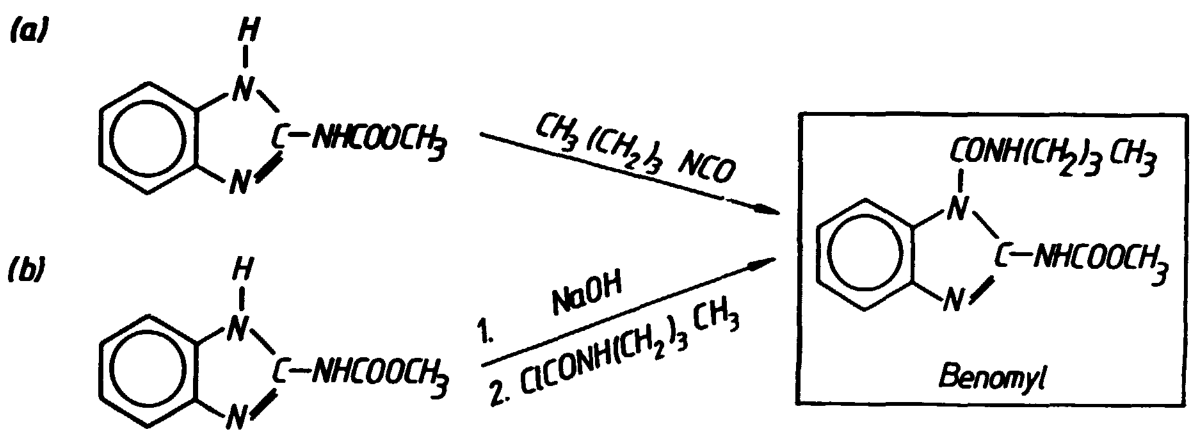
1. Agricultural use: fungicide used widely in orchards, vineyards and small grains.

2. Other use: ascaricide, veterinary authelmintic.

3. Inventor: Adams, C.D. and Schlatter, R. (190 to Du Pont)

4. CAS registry number: [17804-35-2]

5. Scheme of chemical synthesis



6. Schematic block diagram of the manufacturing process

   Not available

7. Rudimentary assessment of technical information

Route (a) consists of one step, although butylisocyanate (BIC) is usually produced on site by reacting n-butylamine with phosgene, a very dangerous chemical itself. Isocyanate addition reactions are exothermic and need efficient cooling. Special industrial safety and environment protection measures should be taken during the storage and handling of BIC. Route (b) is one step longer but the salt formation and subsequent condensation reactions are easier to handle. The steps involved in both routes can be carried out in multipurpose batch reactors.

The key starting materials and reactants - carbendazim, BIC and butylcarbamoyl chloride - are not available freely in international trade. BIC should be produced on site.

Captan

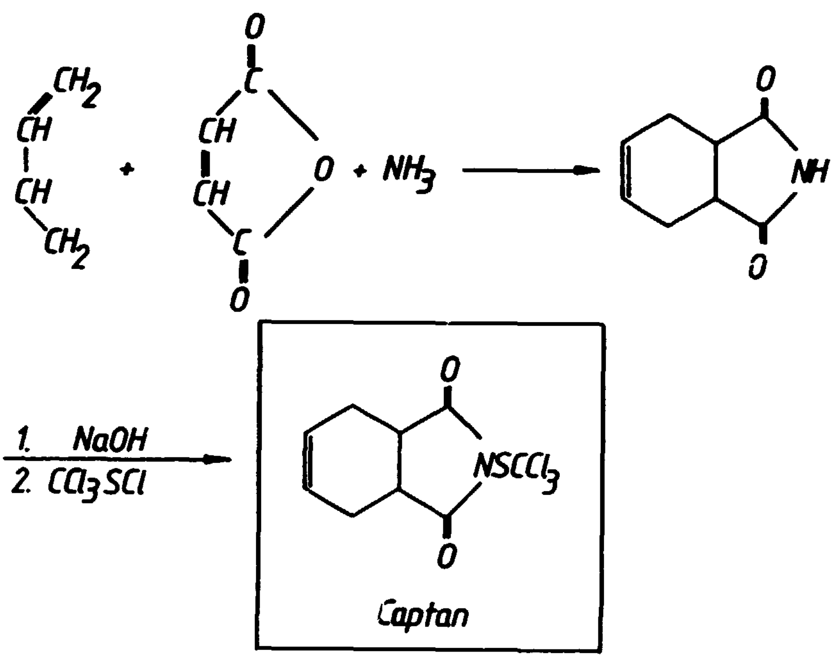
1. Agricultural u non-systemic, protective fungicide mainly used in orchards and c .e.

2. Other use: bacteriostat in soap.

3. Inventor: Kittleson, A.R. (1951 to Standard Oil)

4. CAS registry number: [133-06-2]

5. Scheme of chemical synthesis

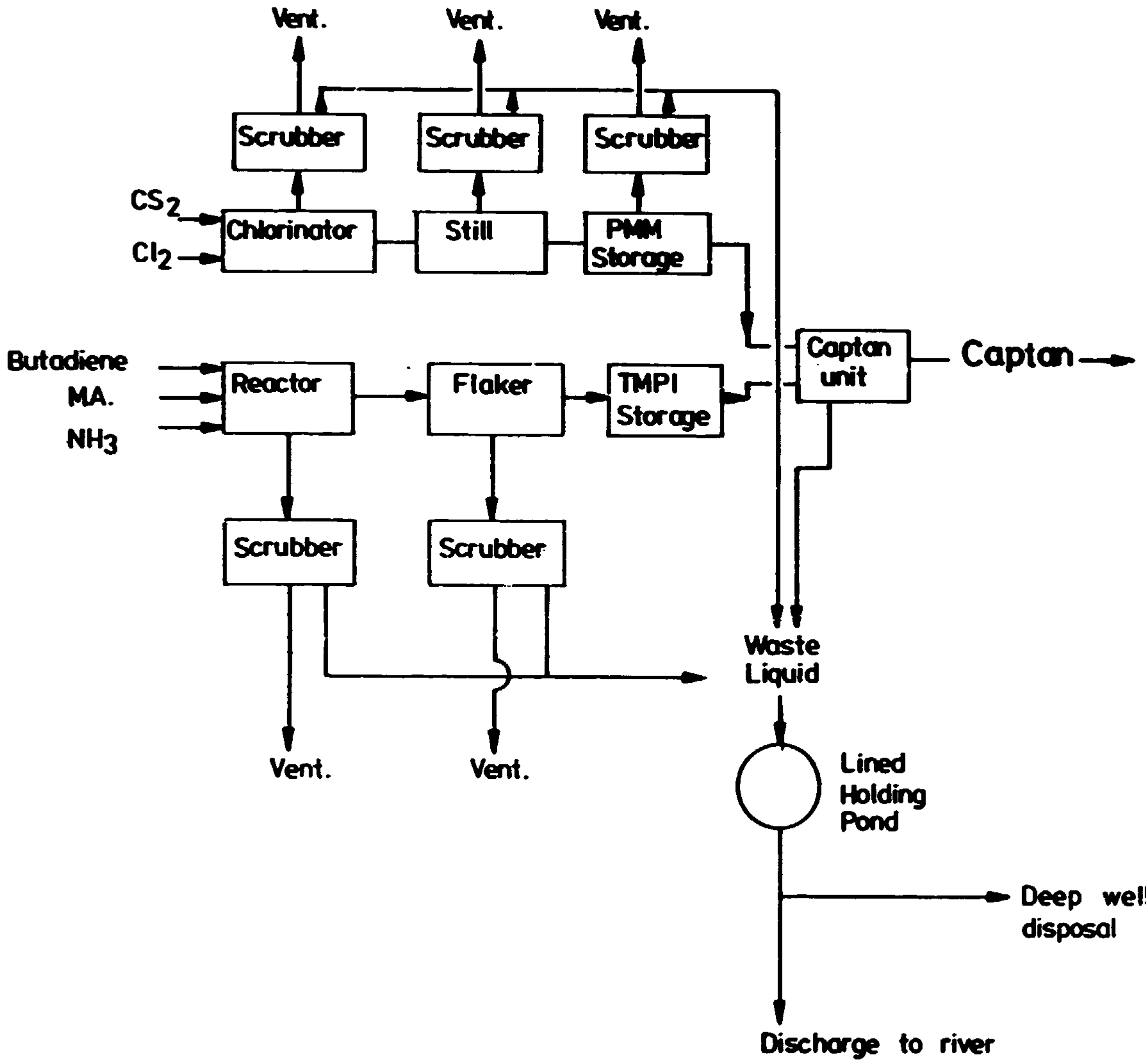


6. Rudimentary assessment of technical information

1,3-Butadiene, maleic anhydride (MA) and ammonia are cyclized into tetrahydrophthalimide (THPI) which is converted into sodium salt and subsequently condensed with perchloromethyl mercaptan (PMM). PMM may be produced by chlorination of carbon disulphide in the presence of iodine as the catalyst. Both conversions are preferably carried out in dedicated reactors. The cyclization step is usually carried out at a high temperature. Carbon disulphide is a poisonous, very flammable liquid which represents acute fire and explosion hazard.

The key starting materials and reactans are available in international trade. PMM should be produced on site.

7. Schematic block diagram of the manufacturing process



Carbaryl

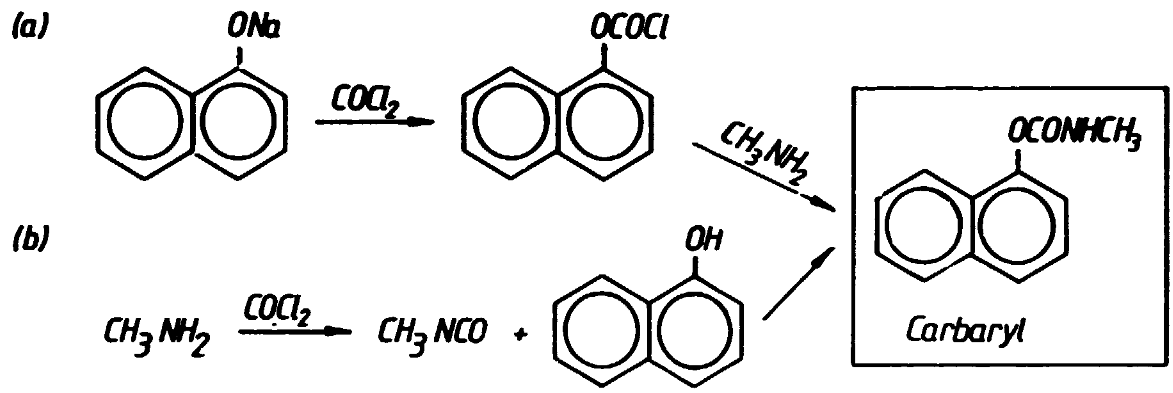
1. **Agrochemical use**: contact insecticide suitable for the treatment of problems occurring in rice.

2. **Other use**: external veterinary parasiticide.

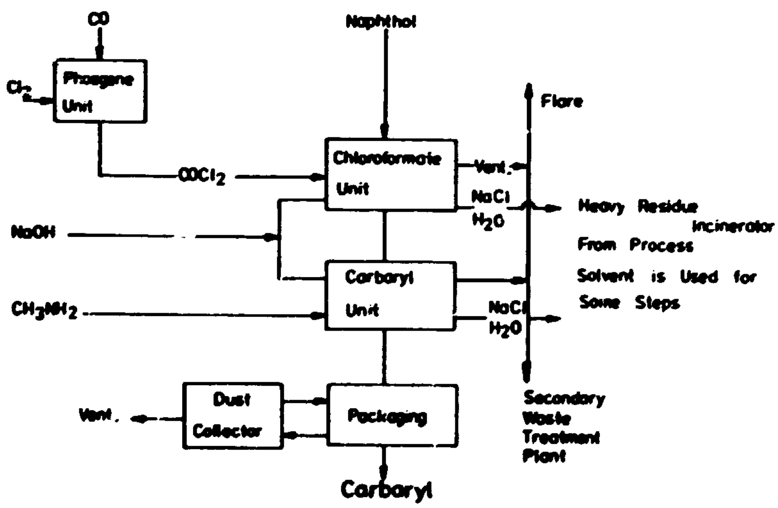
3. **Inventor**: Haynes et al. (1957).

4. **CAS registry number**: [63-25-2]

5. **Scheme of chemical synthesis**



6. **Schematic block diagram of the manufacturing process**



7. Rudimentary assessment of technical information

Naphthalene, a product of coal tar distillation, is catalitically oxidized to 1-naphtol usually outside the pesticide chemical industry. Conversions in route (a) may be carried out in multipurpose batch reactors. The phosgenation step represents a high safety and environment pollution risk in the process because phosgene is a strong poison which has also been misused as a war gas. Methylamine is irritating to eyes, skin and the respiratory tract. By-products must be incinerated, solvents recycled and effluents biologically treated before being discharged into the industrial sewage system.

The methylisocyanate (MIC) step in route (b) is exothermic and tends to be vigorous. Efficient cooling is necessary but the conversion can be carried out in multipurpose batch reactions.

The key starting materials and reactants are available in international trade. Phosgene and MIC should be produced on site.

Note: THE CARBARYL PRODUCTION PLANT AT BHOPAL IN INDIA WAS THE SCENE OF THE IMPORTANT METHYLISOCYANATE LEAK IN NOVEMBER 1984. THE DISASTER AFFECTED, IN SOME WAY, 320,000 PERSONS OUT OF BHOPAL'S TOTAL POPULATION OF ABOUT ONE MILLION, ABOUT 14,000 SERIOUSLY.

Carbofuran

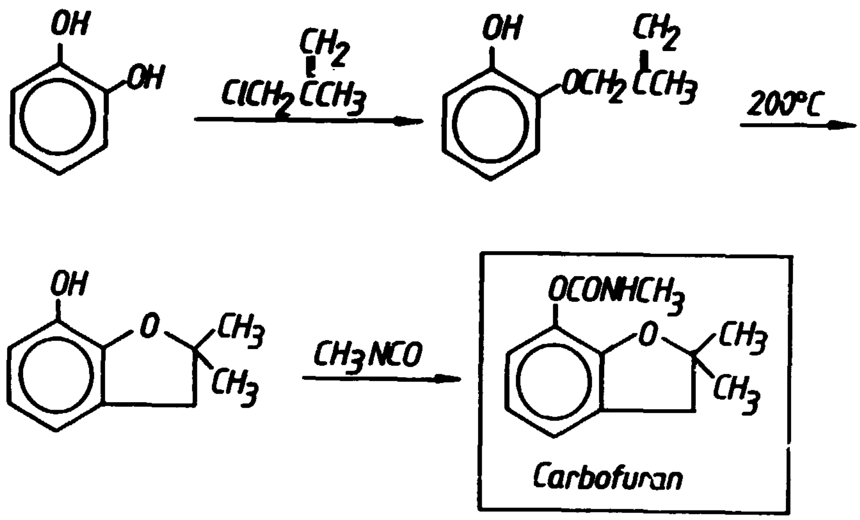
1. Agricultural use: systemic insecticide, acaricide and nematocide

2. Other use: none

3. Inventor: Bayer (1964)

4. CAS registry number: [1563-66-2]

5. Scheme of chemical synthesis

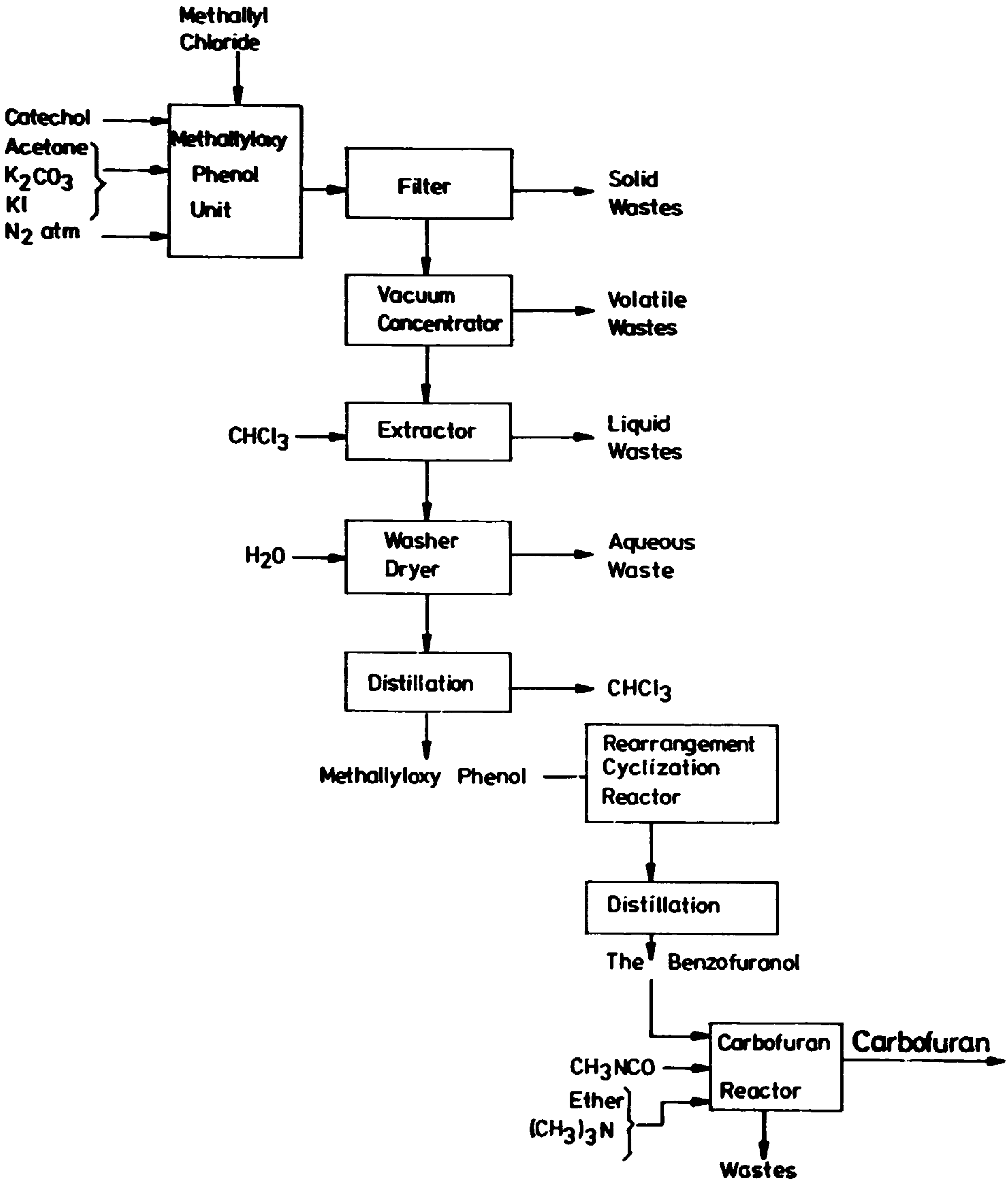


6. Rudimentary assessment of technical information

The synthesis consists of three steps which can be carried out in multipurpose batch reactors. The methallyloxyphenol formation is carried out in nitrogen atmosphere and several unit operations are subsequently used to remove the different by-products. The rearrangement and cyclization step is conducted at 200°C. The methylisocyanide (MIC) addition reaction involves a high industrial safety and environment pollution risk.

(Pyro)catechol is available in international trade but it might be difficult to purchase methallyl chloride. MIC should be produced on the spot.

7. Schematic block diagram of the manufacturing process



2,4-D

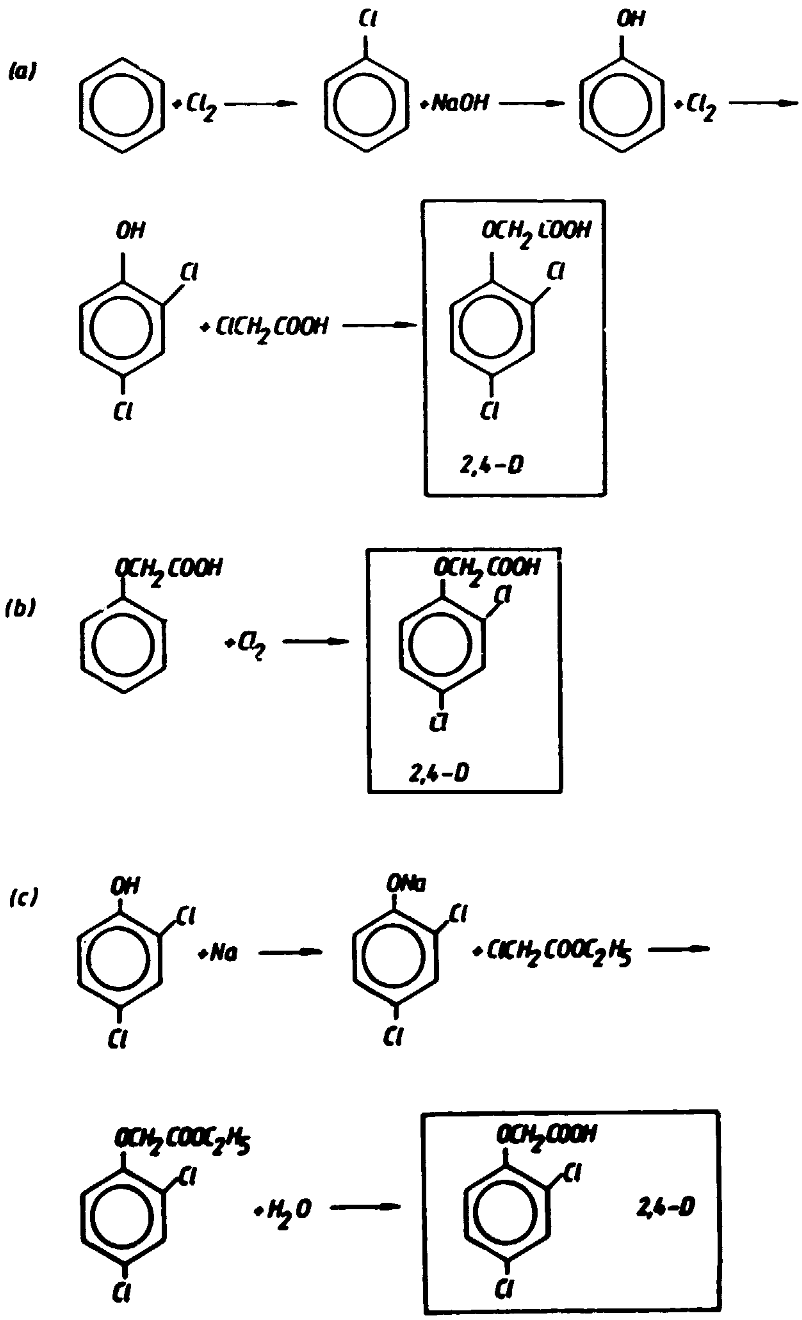
1. Agricultural use: post-emergence herbicide widely used in cereals, also in rice.

2. Other use: none

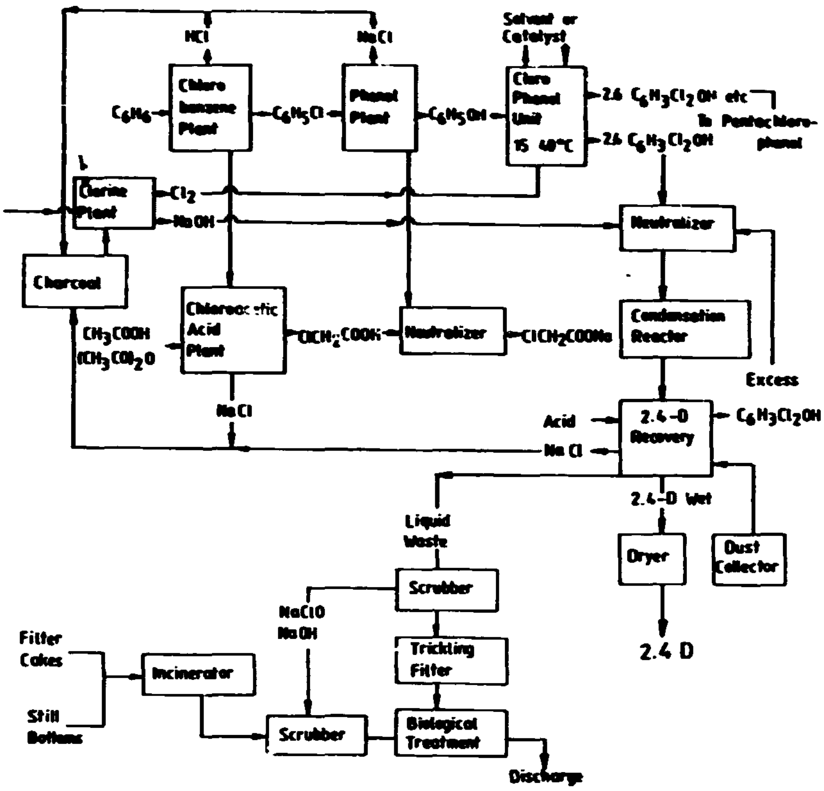
3. Inventor: Foster (1942)

4. CAS registry number: [94-75-7]

5. Scheme of chemical synthesis



6. Schematic block diagram of the manufacturing process



7. Rudimentary assessment of technical information

The syntesis usually starts from 2,4-dichlorophenol and route (a) is followed. This conversion can be carried out in multi-purpose batch reactors. No special reaction conditions or utilities are required. None of the conversions appears to represent industrial safety or environment pollution hazards unusual in fine chemical plants. The full backward integration shown in the block diagram needs a dedicated plant, of course. Environment protection related investment and operation costs are significant. The disposal of the by-products of phenol chlorination could create problems unless they can be converted into useful chemicals.

The key starting materials are available in free trade. 2,4-DB is the butyric acid homologue of 2,4-D. Other important hormone weed-killers include MCPA and MCPB which have a similar chemical structure and synthesis route as 2,4-D but the starting material is 2-methyl-4-chlorophenol produced from o-cresol obtained in coal tar distillation.

DDT

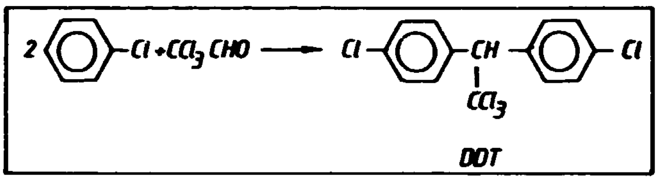
1. Agricultural use: organochlorine compounds have only a limited use in agriculture since DDT was banned in the USA in 1970, in the Fed. Rep. of Germany in 1971 and in Brazil in 1983.

2. Other use: pediculicide, insecticide in the health care sector.

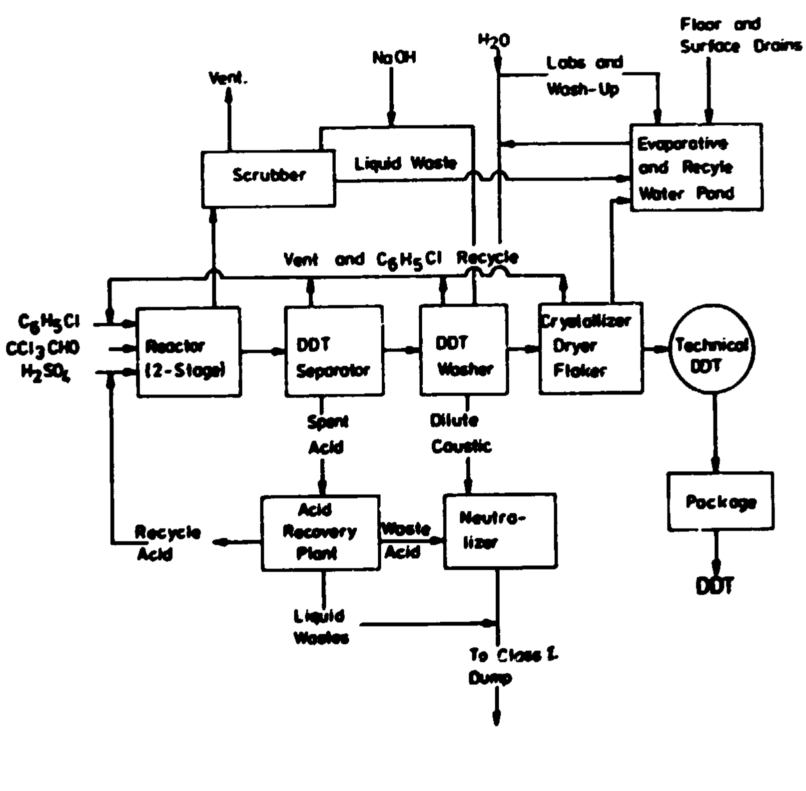
3. Inventor: Müller, P. (1944 to Geigy)

4. CAS registry number: [50-29-3]

5. Scheme of chemical synthesis



6. Schematic block diagram of the manufacturing process



7. Short description of the manufacturing process

Excess chlorobenzene is used to obtain good yields of DDT and the molar ratio of chlorobenzene to chloral may vary from 2:1 up to 4.5:1. A ratio of from 2.3:1 to 3.2:1 is recommended, with from 2.9:1 to 3.0:1 being a particularly preferred ratio.

The formation of DDT is exothermic, releasing about 210 calories per gram when oleum is used as the condensing agent. Thus the reactants are initially cooled to a temperature in the range of 0°C to 30°C and cooling is continued to maintain the reaction temperature in this range. The production of DDT is carried out at atmospheric pressure.

The batch preparation of DDT may be carried out in a closed reaction vessel equipped with an agitator and a jacket and/or internal cooling coils. An external heat exchanger circuit may also be used to provide effective heat transfer. Early DDT production reactions were of glass-lined construction but it has been found satisfactory to use steel vessels which are, of course, more economical.

8. Rudimentary assessment of technical information

The one-step synthesis can be carried out in multipurpose batch reactors. No special reaction conditions or utilities are required. Industrial safety hazards are not unusual. Environment protection investment and operation costs are high.

The key starting materials are available in free trade.

Diazinon

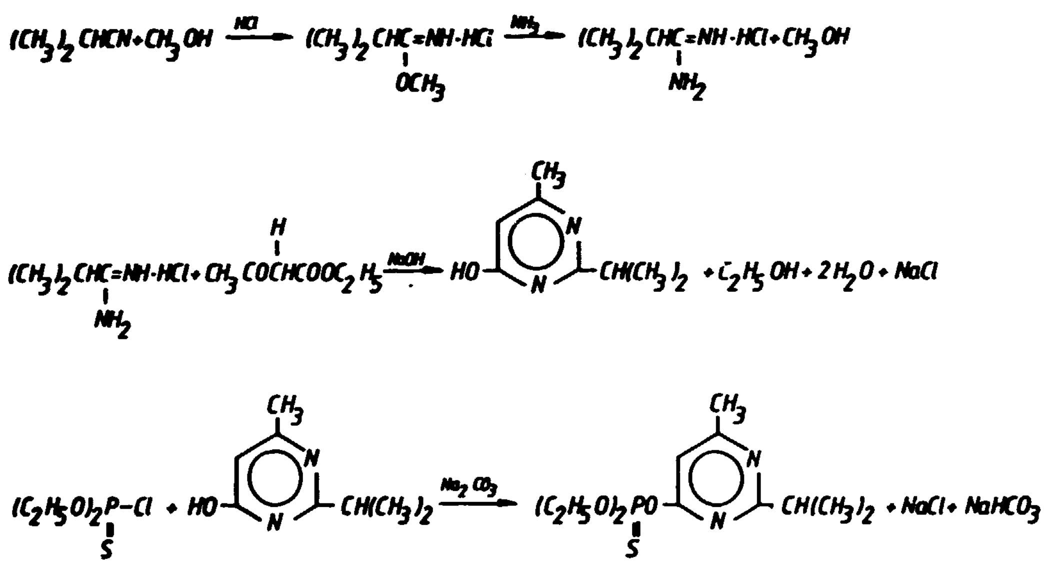
1. **Agricultural use**: insecticide widely used in cotton

2. **Other use**: none

3. **Inventor**: Gysin and Margot (1956 to Geigy)

4. **CAS registry number**: [333-41-5]

5. **Scheme of chemical synthesis**

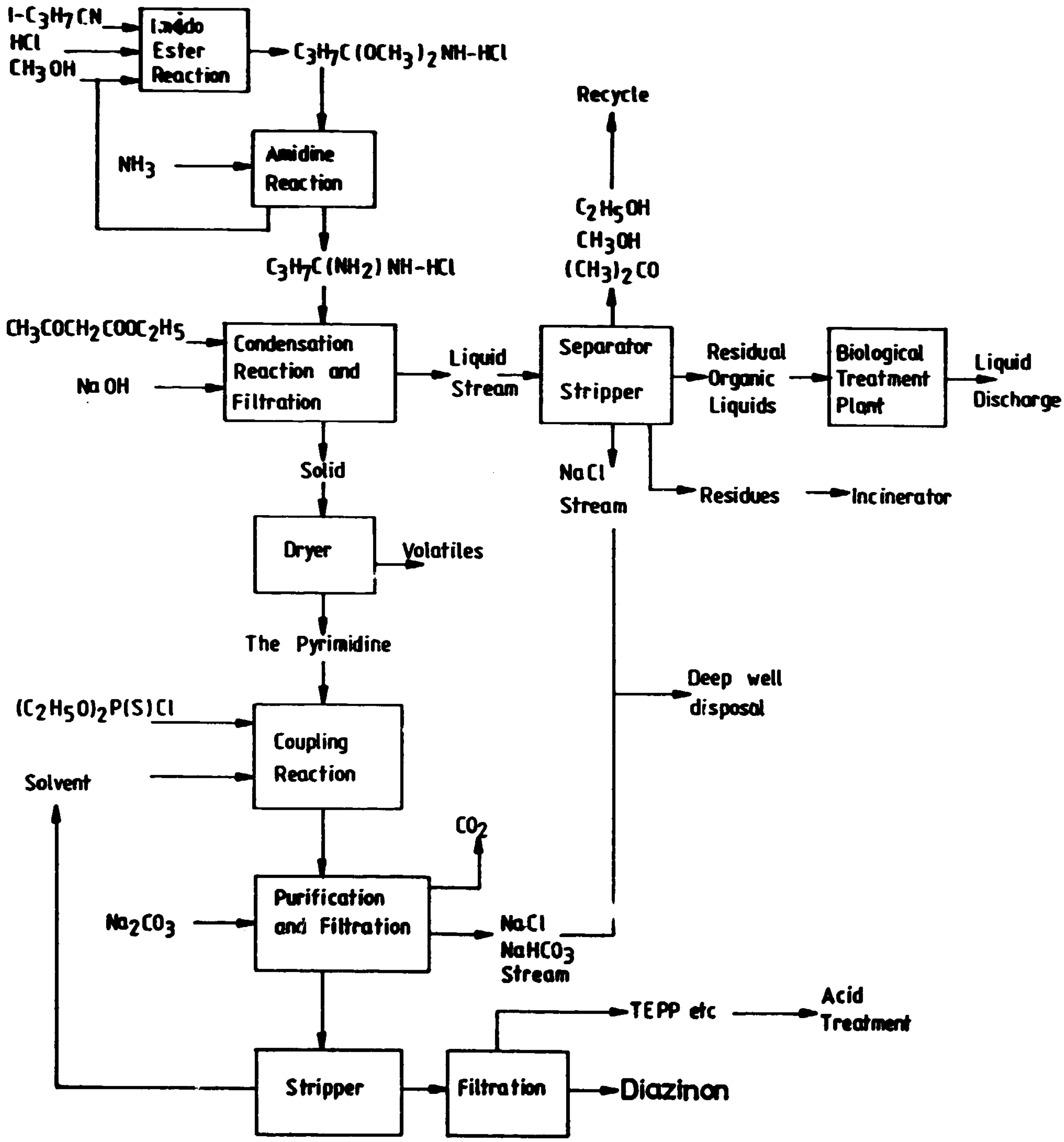


6. **Rudimentary assessment of technical information**

The synthesis consists of four conversions which can be carried out in multipurpose batch reactors. No special reaction conditions or utilities are required for the synthesis. Industrial safety risks are not unusual in the fine chemical industry. Environment protection component of investment and operation costs is high.

The key starting materials and reactants are available in free trade.

7. Schematic block diagram of the manufacturing process



Dichlorvos

1. Agricultural use: insecticide.

2. Other use: veterinary anthelmintic and insecticide.

3. Inventor: Whetstone and Harman (1960) tp Shell.

4. CAS registry number: [62-73-7]

5. Scheme of chemical synthesis

$$(CH_3O)_3P + CCl_3CHO = (CH_3O)_2POOCH{=}CCl_2$$

Dichlorvos

6. Schematic block diagram of the manufacturing process

Not available.

7. Short description of the manufacturing process

The feed materials are chloral and trimethyl phosphite. The reactants are usually employed in about equimolar quantities but lesser amounts of either reactant may be employed. A broadly applicable range of mol ratios of the reactants may be from 1:10 to 10:1. A preferred range is from 2:1 to 1:2. The reaction is exothermic. Temperatures of 10°C up to 150°C may be used. The reaction is usually concluded by heating from 50°C to 120°C.

The reaction is carried out at essentially atmospheric pressure. The time required for completion of the reaction is short, varying from 10 minutes to an hour or two. The exothermic reaction is usully carried out in the presence of inert solvents to assist in temperature control. Suitable solvents include benzene, toluene, ether, dioxane or hexane. No catalyst is needed in this process.

The reaction may be carried out in a stirred, jacketed kettle of conventional design. The reaction product can be separated from the reaction mixture when its separation is desired by conventional techniques such as distillation, extraction with selective solvents or the like. For some uses, separation of the product from the crude reaction mixture may be unnecessary.

8. Rudimentary assessment of technical information

The one-step synthesis can be carried out in multi-purpose batch reactors. Industrial safety risks and environment pollution hazards are not unusual in fine chemical industry.

The reactants are available in free trade.

Malathion

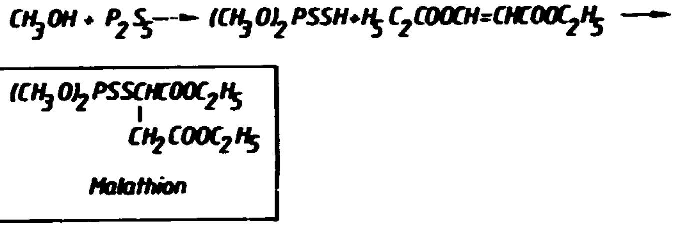
1. <u>Agricultural use</u>: insecticide.

2. <u>Other use</u>: pediculicide, ectoparasitide.

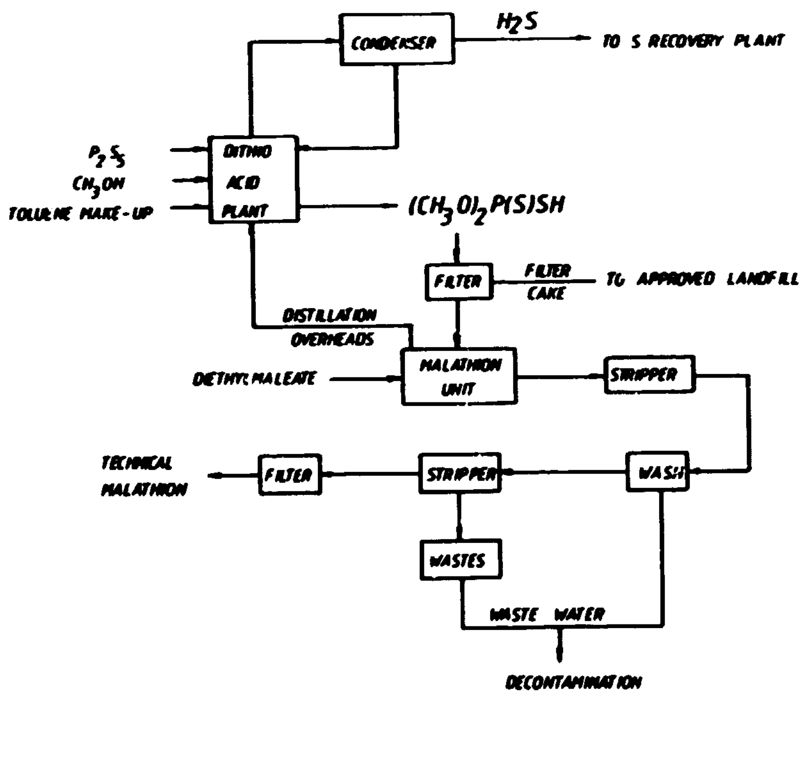
3. <u>Inventor</u>: Cassaday (1951) to American Cyanamide.

4. <u>CAS registry number</u>: [121-75-5]

5. <u>Scheme of chemical synthesis</u>



6. <u>Schematic block diagram of the manufacturing process</u>



5. Short description of the manufacturing process

The manufacture of malathiom consists of two steps. First o,o-dimethyl hydrogen phosphodithioate is produced from phosphorus pentasulfide and anhydrous methyl alcohol. Then the phosphodithioate is reacted with diethylmalate to produce the technical end product which is an amber liquid of 95 per cent purity.

First step: o,o-dimethyl hydrogen phosphodithioate is prepared in a 1:4 molar ratio from P_2S_5 and methylalcohol in a jacketed glass-lined reactor provided with an aluminium reflux condenser. The charged alcohol is heated to 35°C, then the phosphorus pentasulfide is added slowly to the alcohol. The process is exothermic, thus cooling is necessary. The temperature of the mixture should be kept around 45°C. After having added the required amount of P_2S_5, the temperature of the mixture is raised to about 85°C and this temperature is maintained for 2 or 3 hours, after which the products are cooled to room temperature and the acid is filtered out.

Second step: Condensation is preferably carried out in a solvent such as toluene, in the presence of an antipolymerization compound (hydroquinon) to inhibit the polymerization of the maleate. For this step an agitated, jacketed steel reactor may be used. Reaction temperature may vary in the range of 20 to 150°C and reaction time is 16 to 24 hours. At the end of the process the reaction mixture is washed, separated, filtered and concentrated in vacuum to give the malathion as residue. Overall yield is about 70 per cent based on phosphodithioate.

8. Rudimentary assessment of technical information

The synthesis consists of two conversions which can be carried out in multipurpose batch reachers. Reaction conditions and utility requirements are normal. Industrial safety risks are not unusual in the fine chemical industry. Hydrogen sulfide is an unpleasant by-product which should be carefully handled. Environment protection measures represent a significant part of investment and operational costs.

Key starting materials are available in free trade.

Nicotine

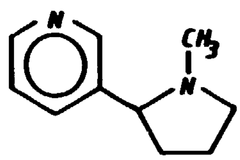
1. Agricultural use: insecticide

2. Other use: veterinary ectoparasiticide. Has been used as a veterinary anthelmintic.

3. Inventor: no applicable.

4. CAS registry number: [54-11-5]

5. Structural formula



6. Short description of the manufacturing process

Commercial nicotine is entirely a by-product of the tobacco industry. Technical quality nicotine is prepared from waste tobacco by steam distillation in the presence of an alkali, followed by extraction with trichloroethylene and subsequently with dilute sulphuric acid. Nicotine is highly toxic, therefore it should be handled with great care.

Parathion

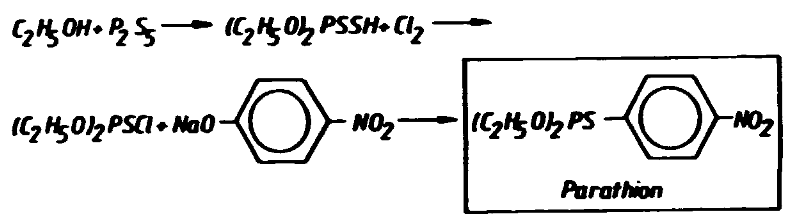
1. Agricultural use: insecticide

2. Other use: acaricide

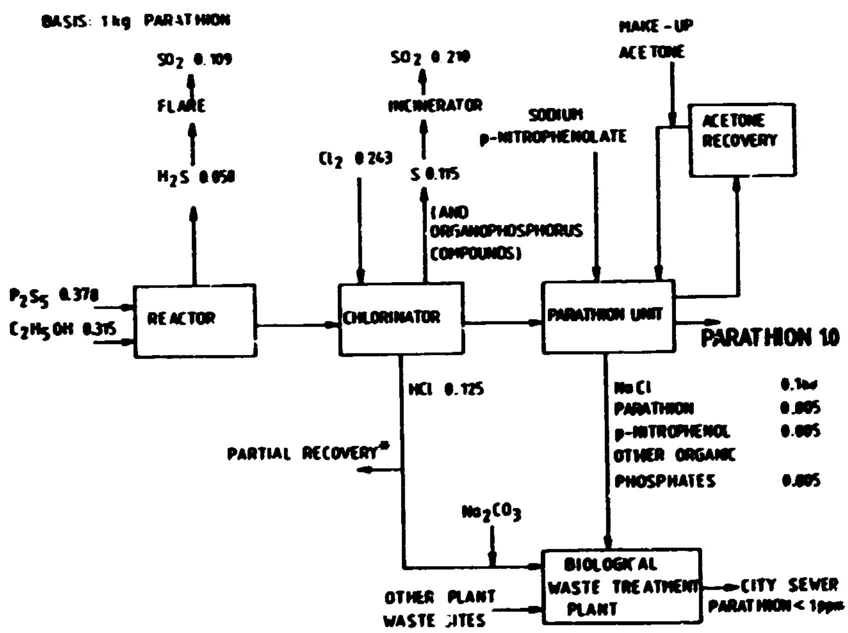
3. Inventor: Thurston (1946)

4. CAS registry number: [56-38-2]

5. Scheme of chemical synthesis



6. Schematic block diagram of the manufacturing process



* APPROXIMATELY 80 PERCENT RECOVERY AS 32 PERCENT BY WEIGHT HCl IN WATER

7. Rudimentary assessment of technical information

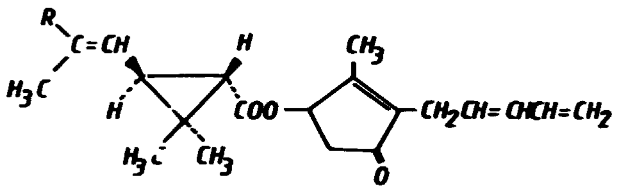
Parathion synthesis consists of three steps which can be carried out in multipurpose batch reactors. Reaction conditions and utility requirements are regular. The process flow diagram contains chemical conversion factors and additional information (solvent, by-products, regulatory standards for parathion concentration in treated waste water, etc.).

Sulphur dioxide generated in stages 1 and 2 should be absorbed and neutralized. Industrial safety and environment pollution risks are not unusual in fine chemical plants.

Key starting materials and reactants are available in free trade.

Pyrethrins

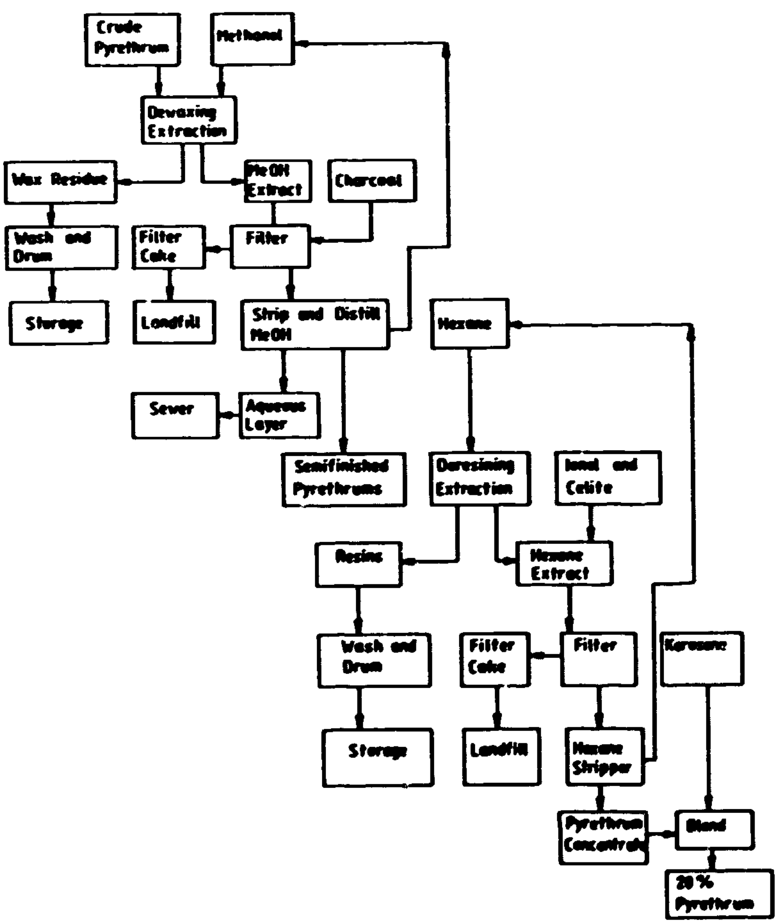
1. Agricultural use: none
2. Other use: household insecticide
3. Inventor: not applicable
4. CAS registry number: not applicable
5. Structural formula



$R = CH_3$ Pyrethrin I.

$R = COOCH$ Pyrethrin II.

6. Schematic block diagram of the manufacturing process



7. Short description of the manufacturing process

Pyrethrins are the active insecticidal constituents of pyrethrum flowers. They are manufactured by extraction from natural sources as per flow diagram above. Pyrethrins oxidize rapidly and become inactive in air, therefore they cannot be used as agrochemicals.

Pyrethroids

1. Agrochemical use: crop insecticides

2. Other use: health and household insecticides and veterinary ectoparasiticides.

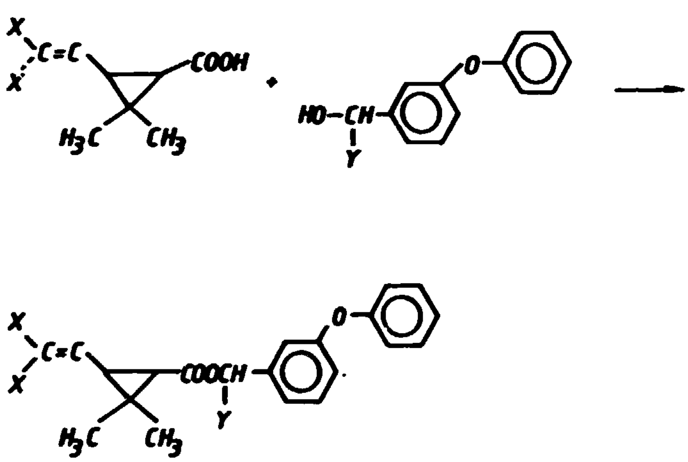
3. Inventor: Elliot, M. and others (1973) to NRDC.

4. CAS registry number

Cypermethrin:	[52315-07-8]
Deltamethrin:	[52918-63-5]
Fenvalerate:	[51630-58-1]
Permethrin:	[52645-53-1]

5. Short description of the manufacturing process

Pyrethroids, the synthetic analogues of pyrethrins, were stabilized by exchanging the methyl groups with halogen substituents in the unsaturated side chain of chrysanthemic acid and by using chemically stable alcohols instead of pyrethronolol for esterification. The last step of pyrethroid syntheses is illustrated below:



	X	Y
Permethrin	-Cl	-H
Cypermethrin	-Cl	-CN
Deltamethrin	-Br	-CN

Innovative chemical extensions of the core structure have introduced new chrysanthemic acid derivatives and other acids in pyrethroid chemistry but they have usually maintained the use of cyano-(3-phenoxy-phenyl)-methanol. The optical isomers of the racemate have great differences in their insecticidal activity, hence resolution is frequently used in the synthesis.

Toxaphene

1. Agricultural use: insecticide

2. Other use: none

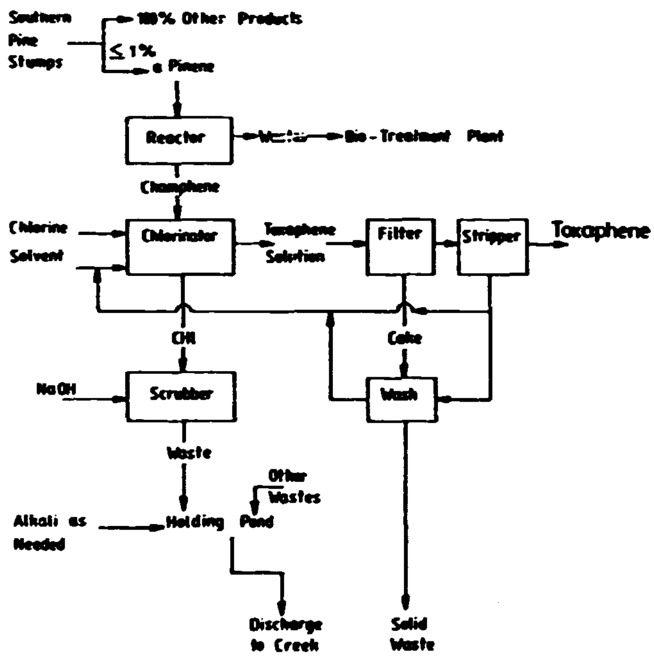
3. Inventor: Buntin (1951) to Hercules Powder

4. CAS registry number: [8001-35-2]

5. Scheme of chemical synthesis

Toxaphene is a very complex, but reproducible mixture of at least 177 C_{10} polychloro derivatives, having an approximate overall empirical formula of $C_{10}H_{10}Cl_8$. It is produced by the chlorination of camphene to 67–69% chlorine by weight.

6. Schematic block diagram of the manufacturing process



7. Short description of the manufacturing process

Lead-lined, glass-lined or nickel-clad vessels may be used for this reaction. The vessel should be equipped with a heat-exchange jacket, a reflux condenser and a well for the ultra-violet lamp. The carbon tetrachloride solvent is removed from the reaction product by distillation under reduced pressure after HCl and excess chlorine have been blown out. The residue from the distillation is allowed to solidify.

8. Rudimentary assessment of technical information

The process consists of one step unless camphene is prepared from alfa-pinene on site. The chemical conversions can be carried out in multipurpose batch reactors. Reaction conditions and utility requirements are normal. Industrial safety and environment protection risks are not unusual in fine chemical plants. The key starting materials are available in free trade.

Zineb

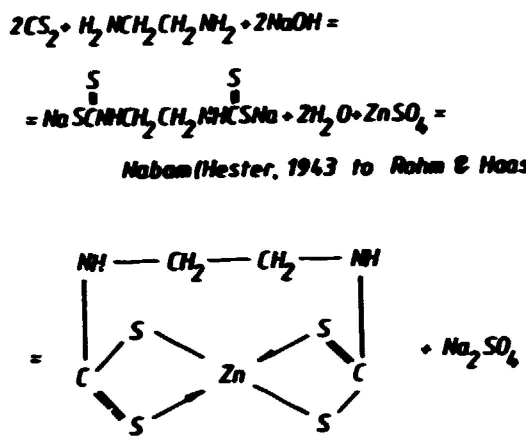
1. Agrochemical use: fungicide.

2. Other use: none

3. Inventor: Luginbuhl (1954) to du Pont

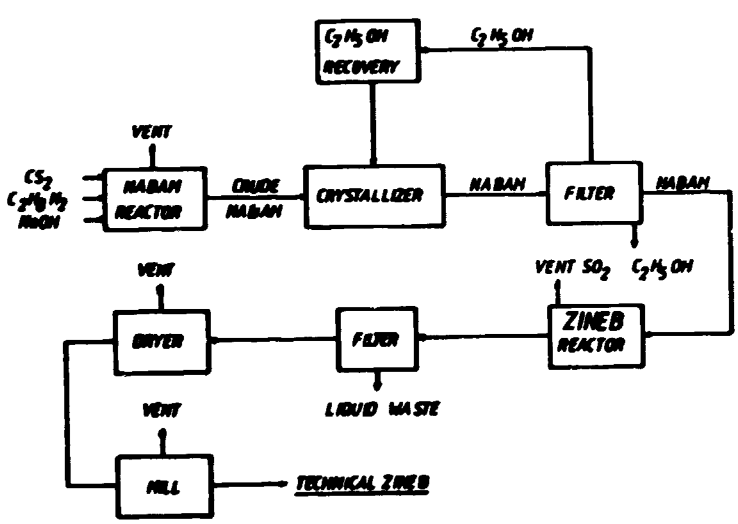
4. CAS registry number: [12122-67-7]

5. Scheme of chemical synthesis



Zineb

6. Schematic block diagram of the manufacturing process



7. Short description of the manufacturing process

Zineb is produced from the intermediate nabam. For nabam the following raw materials are used: carbon disulphide, ethylene diamine, sodium hydroxide and a water soluble zinc salt.

The first step of the process is a two-phase reaction of carbon disulphide and ethylene diamine in equimolar ratio in the presence of two mols of sodium hydroxide, in an agitated, jacketed steel reactor. The carbon disulphide is slowly added to the ethylene diamine - aqueous sodium hydroxide solution under agitation and external cooling (maximum temperature 25°C). After two hours of reaction time the mixture is set to a solid substance (nabam + impurities). This substance is purified by recrystallization from anhydrous ethyl alcohol.

This first step can be preferably carried out as a continuous process in a packed column. This type of operation permits a 40-fold reduction of the reactor volume for the same output, and it is also safer than the batch process.

In the second step Zineb is produced from aqueous nabam by precipitation (on the addition of aqueous solution of a zinc salt, e.g. zinc sulphate). The product is filtered, dried and disaggregated to a fine powder.

8. Rudimentary assessment of technical information

The process consists of two steps. Nabam is preferably synthetized in a dedicated reactor. Reaction conditions and utility requirements are normal. Carbon disulphide consitutes a particular industrial safety and environment pollution risk.

The key starting materials - carbon disulphate, ethylenediamine and water-soluble zinc salts - are available in free trade.

The same process equipment is also suitable for preparing other dithiocarbamic acid derivatives like maneb, mancozeb and TMTD.

Annex 6

to the Global Review of the Pesticide Industry

Formulation of pesticides in developing countries
(Abstract of UNIDO ID/297)

This document is synthetized from thirteen independent studies which give a well-conceived general aproach to a comprehensive picture of problems connected with the formulation of pesticides.

The first article deals with the role of pesticides in developing countries. Based on figures demonstrating pest effect (one third of potential production is lost), statistical analysis is used to prove the usefulness of pesticides in the reduction of these losses. Warning against inappropriate use (e.g. overdosage) completes the picture before pointing to the present low pesticide use in the developing world.

The second paper entitled "Principles of pesticide formulation", gives a broad picture of the whole field: Definitions of different solid and liquid application forms, a detailed description of the properties and characteristics of active ingredients and various auxiliary materials, introduction to the principles of formulation, the choice of ingredients and auxiliaries based on required physical and chemical properties.

The third study deals with establishment, construction and operation of pesticide formulation plants. Site selection and environmental protection criteria introduce the subject, then the principles governing concept and design are summarized. A detailed description of the operations involved at different stages of the process gives the criteria for appropriate equipment and flow sheet selection. Several flow sheets and process descriptions illustrate the · neral principles exposed. Layout, safety and environmental protection measures complete the picture.

The fourth article uses the description of a formulation plant and its infrastructure to define the criteria for the construction of a local pesticide formulation plant. Market, availability of the necessary raw materials and other factors entering the decision are explained. Based on this technical analysis, a method and an example are presented for the economic feasibility calculation. Future trends of formulation plant development close the section.

Marketing and distribution is the subject of the fifth study. The database and the methodology of a market study are described in an applied form to the specific case of pesticide formulation plants.

The next three chapters deal with quality control, environmental control, safety and health protection aspects together show the particular importance of the role of laboratory work in a pesticide formulation plant. Safety, health and environmental protection is the subject also of the next three studies, but in different stages of distribution from the plant to the farmer. The ninth study deals with professional hygiene and health protection in the formulation plant itself; the tenth explains the measures to be taken during transport, storage and handling of the pesticides as well as handling of empty packaging material, while the eleventh points to the important question of labelling, placing particular emphasis on the responsibility of the formulation industry towards the user.

Tne last study deals with one of the most important subjects: the registration system and process in developing countries: how it should be organized, what criteria should be applied, and which objectives could be set.

We would appreciate it very much if you completed the questionnaire below and returned it to UNIDO, Industrial Policy and Perspectives division, Industrial Statistics and Sectoral Surveys Branch, D-2015, P.O. Box 300, A-1400 Vienna, Austria.

Q U E S T I O N N A I R E

Global review of the pesticide industry

(Please check appropriate box)

	yes	no
1. Were the data contained in the study useful?	/_/	/_/
2. Was new information provided?	/_/	/_/
3. Was the analysis sound?	/_/	/_/
4. Did you agree with the conclusions?	/_/	/_/
5. Were the format and style easy to read?	/_/	/_/
6. Do you wish to be put on our documents mailing list?	/_/	/_/

7. Any other comments?

Name (in capitals) ....

Institution (please give name and and full address) ....
....
....
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Date: ....