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EFFECTS OF PESTICIDES AND RELATED COMPOUNDS ON THE ENVIRONMENT

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Abstract - Pesticides are intentional biocides and consequently must have effects on organisms. As for unintentional side-effects in the environment, systematic evaluation procedures have been developed, which may serve today as models for other groups of chemicals. For comparison of pesticides with each other and with other environmental chemicals, a minimum test procedure is described. This profile analysis is intended to serve as a screening procedure and as a basis for selection of potentially harmful substances.

INTRODUCTION

Due to their intended biocidal activity and their widespread use in the environment, pesticides were the first chemicals identified as environmental hazards. The world-wide occurrence of so-called organochlorines could be assessed readily with the most sensitive and feasible analytical methodology available. This does not necessarily imply that organochlorines are the most harmful pesticides - other groups simply are not analysed easily. The potential environmental hazards of heavy metals were recognized mainly following the Minamata and Itai-Itai diseases which were caused by high local occurrences of methyl-mercury and cadmium respectively. Their impact was not recognized prior to their deleterious effects on human health.

The problem with polychlorinated biphenyls (PCBs) was recognized by accident due to their interference in organochlorine pesticide analysis. Such random findings demand a systematic approach in order to identify those substances which have a high potential for environmental effects. This need becomes crucial when realizing the methodological problems, the lack of background data in biological monitoring, and the controversis in biology and biochemistry in regard to causative agents and action mechanisms for demonstrated environmental effects. One example of this is the egg-shell thinning of some bird species caused by DDT and PCB.

Chemical factors influencing effects

It is only during the most recent years that systematic procedures for environmental chemical evaluation have been discussed; and, thus far respective regulatory actions are taken in only a few countries. The basic knowledge for these procedures is obtained from pesticide research, from pesticide evaluation and registration requirements as used e.g. by FAO/WHO (1), and from respective information on radioactivity. Thus, pesticides have become models for the evaluation of chemicals in general (2). This implies that different requirements should be applied to non-biocides.

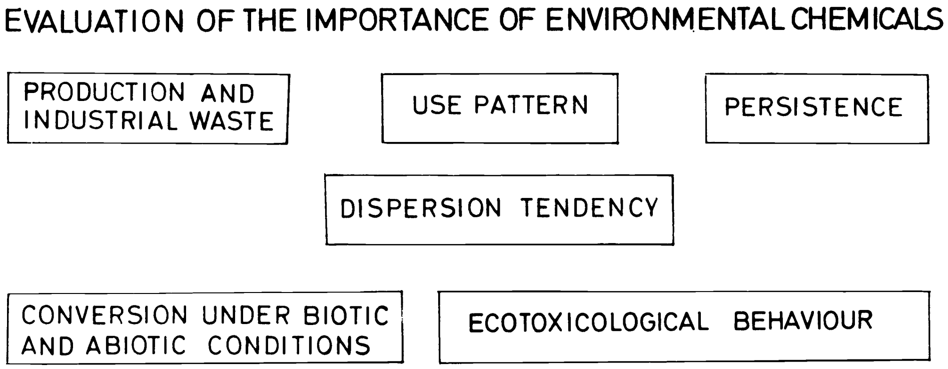


Fig. 1. Parameters for the evaluation of chemicals

In establishing generally applicable evaluation standards, several parameters, shown in Fig. 1, other than human toxicity must be considered. The production and utilization patterns are two of six parameters which determine the quantities of chemicals released into the environment as well as their regional or global distribution. Other parameters of equal importance are the persistence, the dispersion tendency, the conversion or degradation under biotic and abiotic conditions and the ecotoxicological behaviour. They are in some way included in pesticide regulations. A sensible and systematic use of these parameters could lead to a priority list of environmental hazards due to chemicals.

Land Surface of the Earth	$13,392 \times 10^9$ ha
agriculture	$1,424 \times 10^9$ ha
pastures	$3,001 \times 10^9$ ha
forests	$4,091 \times 10^9$ ha

Soil Input per Year	(no conversion, no evaporation or leaching)			
	world production mio. tons/year	kg/ha in area of use locally	kg/ha in area of use globally	kg/ha when distributed on total land surface
Pesticides	1	2 - 4	0.12 (a/p/f)	0.07
Nitrogen fertilizers	15	70	3.38 (a/p) 1.76 (a/p/f)	1.12
org. Chemicals total	150			11.2

Fig. 2. Estimation of chemical load to soil

Since effects of chemicals and changes in material environmental quality depend on concentrations of the respective man-made chemicals, the significance of produced (or marketed) quantities, industrial wastes resulting from production, and byproducts in the technical grade chemicals is obvious.

To arrive at the data given in Fig. 2 it is assumed that there is no conversion, evaporation or washing out, and the possible environmental contamination from pesticides, nitrogen fertilizers, or organic chemicals alone is considered. Especially the last column, the concentration on total land surface, gives an indication of the global impact of environmental chemicals. If all used pesticides were distributed over the entire land surface of the earth, a concentration of 7 mg/m^2 would result; the used nitrogen fertilizer would be present in concentrations of about 100 mg/m^2. Similar quantities could be obtained with other fertilizers (phosphate, potash). All organic chemicals distributed over the total surface would amount to more than 1 g/m^2 annually. Obviously, such an even distribution does not occur under natural conditions; also, most of the substances are mineralized and/or converted into natural products, as for instance fertilizers; some of the chemicals are degraded prior to finding their way into the environment. Consequently, the results of this mathematical example represent a maximum contamination.

	1950	1970	1985	Release in Env. 1970
grand total 10^6 t	7	63	250	20

Organic Chemicals - World Production

manufactured	10^6 t	natural sources	10^6 t
solvents	10	methane	1600
detergents	1.5	terpene type hydrocarbons	170
pesticides	1		
gaseous base chemicals	1	lubricating and industrial oils	2-5
miscellaneous	7		

Fig. 3. Estimate of world production of chemicals

The examples just given refer to today's output and consumption of chemicals. Projections for the next ten years predict a large increase. Figure 3 summarizes approximate production figures from 1950 and 1970 and the expected output in 1985. While all these figures are only estimates, they are sufficiently significant for consideration.

In 1950 the world production of synthetic organic chemicals amounted to 7 million tons; in 1970 it was already 63 million tons; for 1985, the author cited here estimates an amount near 250 million tons (Ref. 3). This is an increase of a factor of 2.5 for a ten year period. Recent published production figures from the USA and the FRG confirm this factor estimated for organic chemicals.

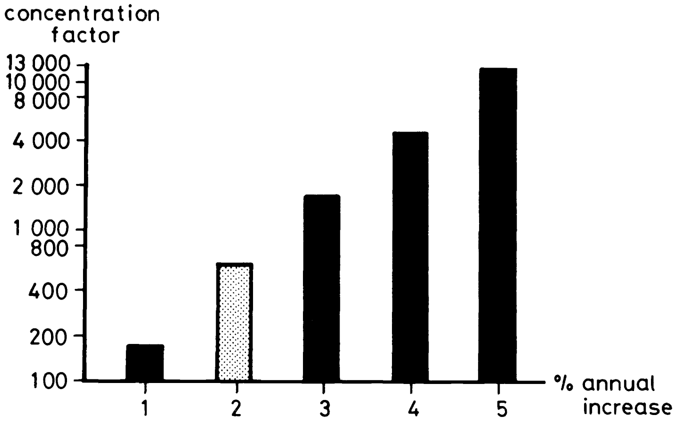
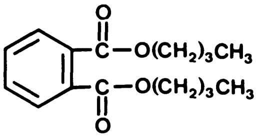


Fig. 4. Estimate of environmental concentrations of chemicals in one hundred years from now with an annual increase of production of 1 to 5 per cent.

If we attempt a prediction of global concentrations of chemicals in, say, a hundred years from now, we may use the estimate given in Fig. 4, based on an assumed annual increase of production of 2%. Substances which today perhaps occur in negligible concentrations (< 1 μg/kg) may reach global concentrations up to 1 mg/kg, and consequently prove to be of ecological significance similar to that of PCBs and DDT today.

Formula :



World Production : 230.000.-t/year

A. Use as base chemical - 0. -

B. Final use

Plasticiser in

coatings and lac varnishes	**40%**
rubber industry	**30%**
PVC-manufacture	**30%**

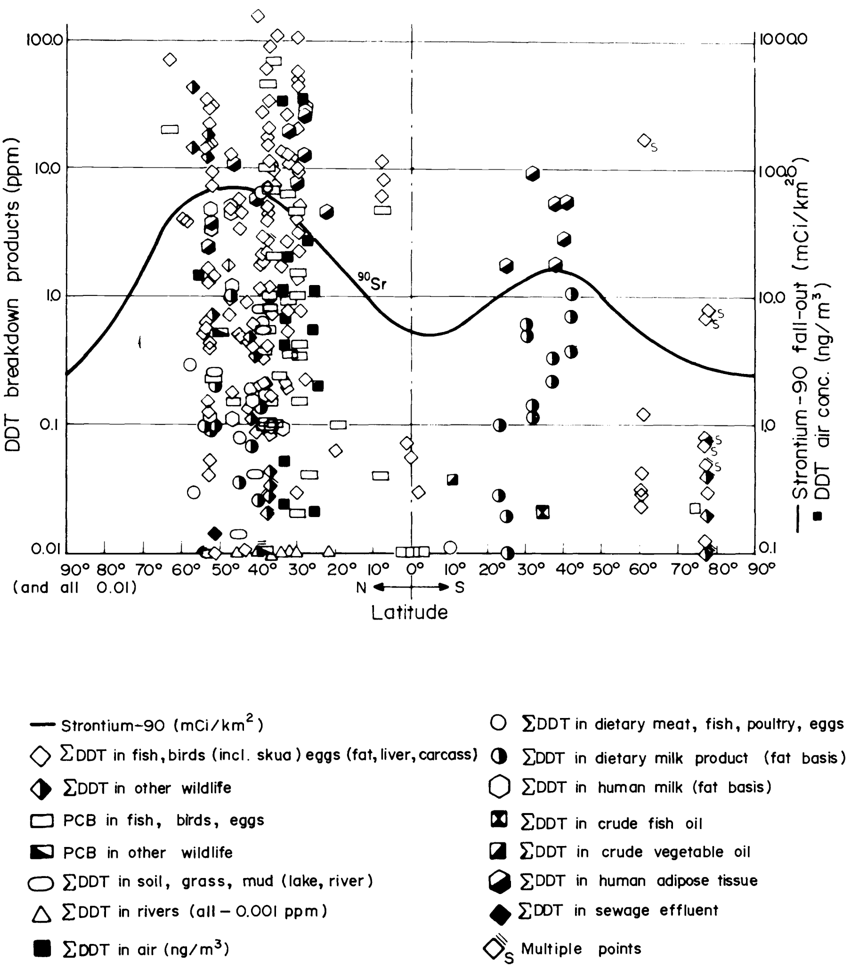
Fig. 5. Global use pattern of Di-n-butyl-phthalate

Considering this quantitative aspect only, pesticides would represent only 1% of the impact of all chemicals on environmental quality. However, they are not subject to waste treatment after fulfilling their intended use, since by far the largest portion are immediately used widespread in the environment.

Furthermore, they have optimum conditions for geographical dispersion because of their use. Geographically resolved balance sheets of their use-patterns nevertheless would help to identify globally the areas of immediate occurrence.

In this context, it is expedient to distinguish between local and global environmental chemicals (Ref. 4). Local environmental chemicals are those which change the material environmental quality within a limited area, preferably within the area of application or release. Their occurrence is either intentional as in the case of pesticides or difficult to avoid as locally increased sulfur dioxide concentrations near power plants. All these local problems are scientifically describable and, in principle, there are technological methods for controlling such sources so that ecotoxicological effects may be avoided.

However, global environmental chemicals occur not only in the application areas but also outside of those areas; their occurrence there is not known per se. Physical and biological mechanisms possibly leading to extraregional diffusion are partly known, for instance atmospheric transport, dispersion in running water, migration of organisms, transport in food chains etc.



Residue values of 0.001 ppm plotted at 0.001 ppm, as are non detected values, also.

Fig. 6. Dispersion of chemicals

Figure 6 provides a plot of global concentrations of Sr^{90} and DDT versus latitude. The dispersion of DDT is analogous to the distribution of Sr^{90} resulting from tests with the atomic bomb, where higher concentrations have been measured in the Northern hemisphere. The left half of the figure shows the fallout of Strontium 90 and the sum of DDT plus conversion products in the Northern hemisphere; the corresponding data for the Southern hemisphere are on the right. The scale for Strontium 90 (right) is mCi/km^2, that for DDT (left) is ppm.

The full black curve represents the over-all Sr^{90} concentration in various samples, the small signs DDT concentration in individual samples, e.g. the horizontal ellipse in soil, grass, and sediments, the horizontal rhombus in fish, birds and eggs, the circle in meat, fish, and poultry, the hexagon in buttermilk, the vertical ellipse in the air (scale: ng/m^3). The rectangle and crossed-out rectangle refer to detected concentrations of PCB in fish, birds, eggs, and other wildlife animals (Ref. 5). Thus far, dispersion can be predicted from physico-chemical data of a chemical together with its persistence and data of its environmental conversion products. Reliable estimates, however, are difficult to achieve due to the complexity of reactions and transport mechanisms involved.

Persistence has been a controversial topic in pesticide evaluation for some time. It includes additional aspects when comparing total residue data of persistent with nonpersistent pesticides. This is valid since it has been generally accepted that, in addition to the parent pesticide, all its environmental conversion products also represent residues.

		1 year		2 years	
		Aldrin	Buturon	Aldrin	Buturon
Total Residues top soil layer	(% of applied)	56	42	31	33
Portion of parent compound	(%)	41	32	21	7
Portion non extractable	(%)	8	54	8	68
In leaching water	(% of applied)	1.9	0.3	2.1	1

Fig. 7. Disappearance of Aldrin and Buturon total Residues from soil under outdoor conditions

The data in Figure 7 indicates similar total residues for the two chemicals; this is due to the fact that buturon, although easily metabolized, results in a high percentage of soil-bound residues. These disappear only very slowly. This fact needs further consideration since a number of pesticides and other chemicals result in phenols and anilines which might become, by binding, long term soil contaminants. Very limited information is available on the nature of these bound residues. However, it is possible currently to predict from experience possible structures of biotic conversion products.

The structures shown in Figure 8 represent the metabolic pattern of pentachloronitrobenzene in onions. The figure includes the balance of the solvent extractable portion of the residues. These structures could be predicted and it would be possible to estimate the further, long-term conversion of the terminal products shown. However, it is necessary to determine quantities of metabolites experimentally in order to meet the quantitative requirements for assessment. In regard to the rate of metabolism and the amounts of metabolites formed, there are significant variations in different species and even sex-differences which call for specific experimental determination.

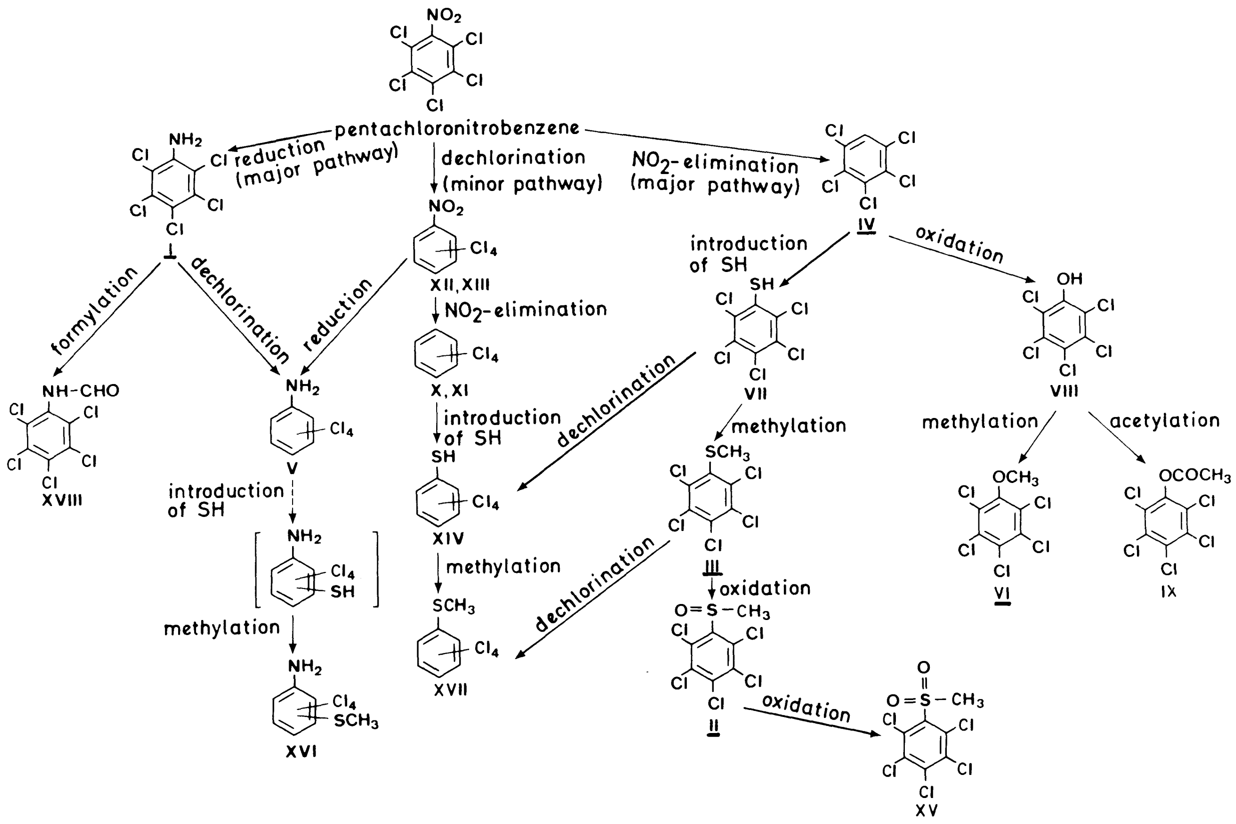
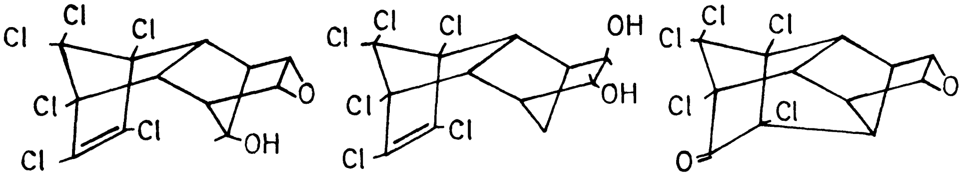


Fig. 8. Plant metabolites of quintozene

Metabolism of Dieldrin in Mammals (within 10 days after single oral application)



animal	applied dose mg/kg bodyweight	9-hydroxy-dieldrin (% of applied)	6,7-trans-dihydro-aldrin-diol (% of applied)	penta-chloro-ketone (% of applied)	dieldrin (% of applied)	total excreted (% of applied)	excretion dieldrin + conversion products (ratio feces : urine)
mice ♂	3 mg/kg	8.4	14.0	urine, trace	5.7	28.0	95 : 5
♀		10.7	14.3		2.7	27.7	
rats ♂	0.5mg/kg	8.8	2.3	urine, major	0.8	11.8	96 : 4
♀		4.6	2.4	---	2.8	9.7	
rabbits ♂	0.5mg/kg	---	1.4	---	0.3	1.7	1 : 99
♀		0.2	2.0		0.5	2.7	
monkeys ♂	0.5mg/kg	9.4	2.0	---	9.0	20.4	75 : 25
man	---	feces, major	urine, present	---			---

Fig. 9. Comparative metabolism of dieldrin-^{14}C

Figure 9 illustrates specific differences in dieldrin metabolism. It should be noted that, in general, the limit for metabolite identification is in the range of 1% of the applied dose. Thus "not detected" simply states that this compound may be present but that it is not quantitatively significant.

Predictability of abiotic conversion is similar to metabolism. Thus, initial photochemical reactions can be foreseen, but thus far reaction kinetics do not allow quantitative prediction of more complex chemicals like pesticides. This is due to the very limited information available on the interaction of pesticides with photochemically induced active atmospheric species.

UV-irradiation of dieldrin in absolutely inert solvents using wavelengths > 300 nm, that is with the sunlight of the lower troposphere, and in the presence of nitrogen oxides and of ozone respectively resulted in the compounds shown in Figure 10. These compounds are not the result of photochemical changes in dieldrin, but reaction products of dieldrin with active species which are formed upon N_2O_4- and ozone-photolysis respectively. Compounds III-VII, for example, are formed upon irradiation in perfluorinated hydrocarbons and in the presence of N_2O_4. With carbontetrachloride as solvent, compounds II-VI are formed. When a solution of dieldrin is irradiated in the presence of ozone, compound IV is the major reaction product. In a number of experiments where dieldrin was irradiated in the gaseous phase, thus far only photodieldrin could be identified as a reaction product. Of the chemicals shown in Figure 10, one is related to a metabolite. Compound VI is the precursor of pentachloroketone (VIII).

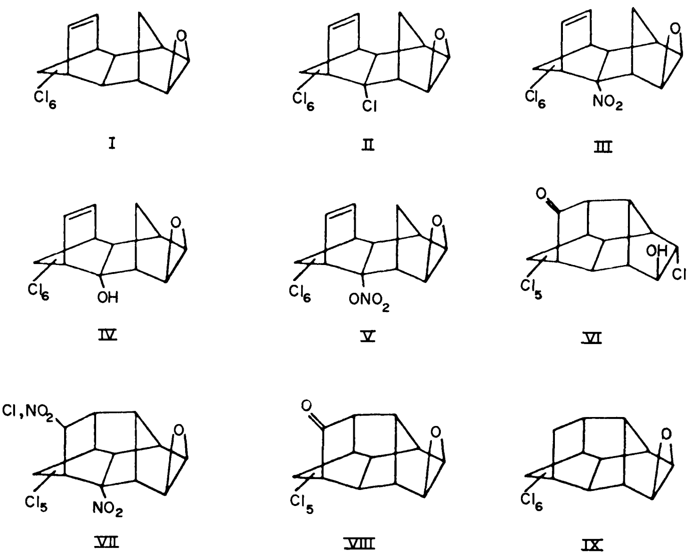


Fig. 10. Dieldrin conversion with active species

Energies and energy-fluxes principally available for reactions of chemicals are much higher in the atmosphere than in the enzymatic process of the biosphere. Consequently, the study of the behaviour of chemicals in the atmosphere should be a major topic in ecotoxicological investigations (Ref. 6).

During the past two years, it was found that a number of chemicals which show persistence against enzymatic attack can be completely mineralized by tropospheric sunlight. This indicates that the atmosphere may be the final sink for persistent chemicals. It can be anticipated that chemicals, not otherwise broken down, reach the atmosphere by evaporation. This has been shown in open air experiments for several pesticides. Mineralization in the troposphere does not include detectable risks and, therefore, represents elimination of ecotoxicological long term problems for the respective chemicals.

Systematic approaches for action

The chemical and physical factors considered thus far can, in principle, be evaluated exactly. The biological aspects are much more difficult to assess reliably. Considering man as the center of the ecosystem, the assessment of the effects of noxious agents in the environment includes direct and indirect interferences with human health and welfare. Direct action may be regarded as the consequence of the intake of the chemical by man. Indirect interferences may result from effects of the chemical on ecosystem components. For several years there have been many distinct efforts, especially by biologically and analytically oriented disciplines, to investigate and identify such possible indirect impact on human health and welfare. The following are examples:

a) studies of the influence of chemicals - especially pesticides - on the populations of wildlife species,

b) the indicator organism concept,

c) monitoring of changes of concentration of chemicals in media or organisms of the environment and correlation to population dynamics.

During the last few years, scientists have developed an approach on an international level (within SCOPE or, administrative, within the OECD), which was named ecotoxicology and includes the principles of ecological chemistry and biological criteria. The term ecotoxicology has been defined by a SCOPE group as follows:

> In contrast to classical toxicology which deals with the toxic effects of chemicals on individual organisms, ecotoxicology is a discipline which studies the impact of toxic agents on ecosystems. It involves the estimation of doses and their related effects, of any activity which may contaminate the environment. The subject matter includes:
>
> 1) the sources, occurrence and environmental behaviour of pollutants;
> 2) the fate of the pollutant in the physical environment and in biological systems;
> 3) the dose to receptors from the time of release of the agent until it and its effects disappear;
> 4) the total of the significant effects on populations of all living receptors ranging from man to micro-organisms.

These four points are identical in content to the six parameters discussed earlier. Thus, these are the basic questions for ecotoxicological evaluation of chemicals. Ecotoxicology utilizes the results, data and estimations of classical toxicology and incorporates these into studies of ecosystems. Thus far, there are no suitable testing systems to combine and evaluate the information expected from an investigation of these parameters.

Various approaches to develop an effective screening system are conceivable and must be considered. Three such approaches which cover various aspects of the problem will be discussed.

The OECD has proposed a scheme for the assessment of environmental chemicals which takes into account the above mentioned parameters. Specifically, it is suggested that a screening of chemicals already on the market comprise:

a) the determination of world wide production figures for all industrial chemicals and the establishment of priorities by taking their utilization patterns into particular consideration;
b) the investigation of their dispersal in the environment, their possible accumulation in various host media, and the fate of their conversion/decomposition products.

It is assumed that chemicals thus identified are likely to constitute potential hazards. Therefore they, before all others, should be subjected to further examination.

Over and above these efforts, a pre-market screening of all new chemicals in regard to their potential for toxic and ecotoxic effects must become mandatory in an internationally harmonized manner. The intensity of such screening should depend on the quantities presumably put into the market.

Several ad hoc working groups are engaged in drafting lists of chemicals according to the above mentioned criteria. For instance, a delegation of the FRG has presented a survey of 120 industrial chemicals produced worldwide in excess of 50,000 tons/year. The use patterns of 50 of them have also been provided.

Such efforts will provide a type of priority listing for further investigation of environmental and ecotoxicological effects. The task of establishing standardized testing methods of general applicability as well as evaluation criteria for environmental impact is still under scientific discussion.

Ecotoxicological Profile Analysis

Ideally, chemicals selected by the above criteria should be tested under simulated environmental conditions. In fact, laboratory model ecosystems have been successfully developed by R.L. Metcalf and others and are utilized for evaluating the chemical and biological behaviour of radio-labelled micropollutants. Complete model ecosystems may, however, be too complex and experiments too time-consuming to allow an easy interpretation and a quick screening of chemicals with regard to their chemical/biological behaviour. An evaluation scheme requiring a minimum of experimental effort by limiting the number of variables is proposed. A determination of single factors, e.g. biodegradation, or degradation via combustion and irradiation etc. is also likely to provide a means for prediction of environmental stress, as long as such factors pertain to the relevant parameters and the behaviour in the set of tests is assessed as a whole (Ref. 7).

In this scheme, individual environmental conditions are simulated and controlled but no attempt is made to simulate complete ecosystems. A series of tests is being designed to supply information regarding the behaviour of chemical substances under various conditions.

These tests comprise (Fig. 11):

a) simulated technological processes (aerobic degradation with activated sludge, aerobic degradation in garbage pits, incineration of waste)

b) simulated biological processes (excretion, biodegradation/metabolism, retention/bioaccumulation)

c) complete degradation under simulated atmospheric conditions

d) simulated transport processes (evaporation from soil and water, solubility, distribution in standardized water/soil systems and water/organic solvent systems, seepage in standardized soils).

By choosing suitable standard reference compounds the test-substances can be classified with respect to their environmental behaviour relative to the standard. Obviously, the most important criterion for the selection of standard compounds is their environmental behaviour. A substance will be considered suitable if it is still environmentally acceptable; that means, relatively widespread, medium degradable, and ecotoxicologically acceptable. Among the widely used organo-chlorine compounds, dichloro- or trichloro-biphenyl seem to satisfy the above conditions. For instance, dichloro-biphenyl is easily degraded and non-accumulating, while tetrachloro-biphenyl is much less degradable and already accumulates in organisms.

In all these experiments, the standard as well as the test-substances are ^{14}C-labelled. Con-

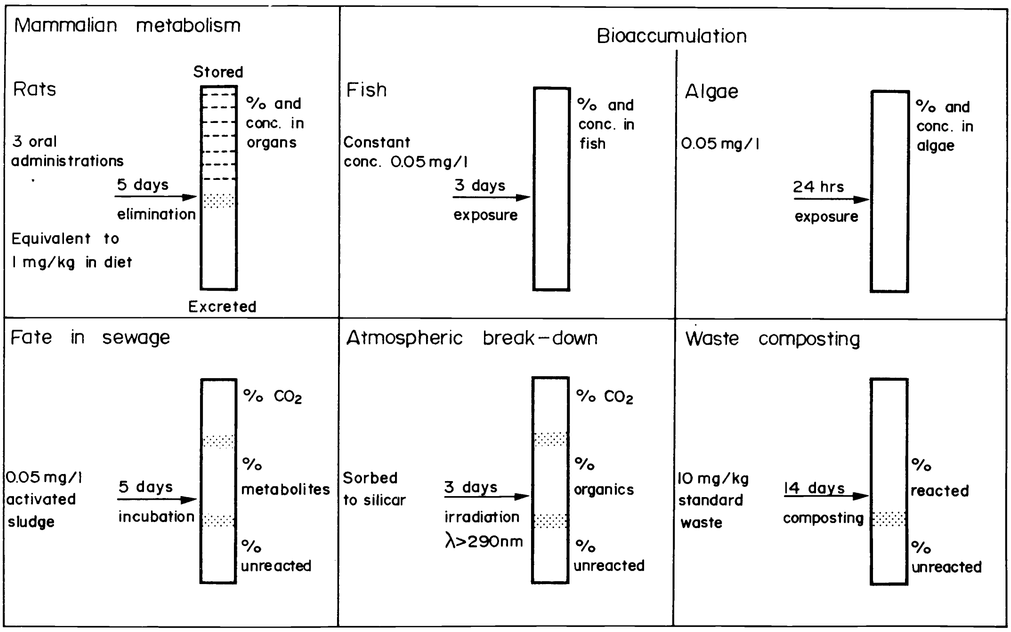


Fig. 11. Outline of ecotoxicological profile analysis

centrations of applied substances will be in the range of potential occurrence, that is ppb up to a few ppm. Depending on the test, the data measured are radiolabelled CO_2, the parent compound and/or the sum of conversion products. Ratios of the amount of radioactivity released/ excreted vs. the amount of radioactivity retained are determined.

In a model activated sludge test, the chemical (conc. 1 mg/kg) was incubated with 1 g of dried activated sludge obtained from artificial sewage which was kept constant in respect to the concentration of organic carbon, nitrogen and phosphate. The incubation period was 2-3 days. A determination of $^{14}CO_2$ released and of total radioactivity in the water provides

% in sludge	28	3	67	95	79	6	4	54	2	80
-metabolized	24	2	39	11	11	0	0	0	0	0
% in water	22	96	15	3	4	85	97	48	88	3
% evaporation	37	< 1	7	< 1	1	< 1	0	1	2	3
- CO_2	17									
Chemical	Para-chloroaniline	2,6-Dichlorobenzamide	Pentachloronitrobenzene	2,5,4'-Trichlorobiphenyl	Aldrin	Monolinuron	2,4,6-Trichlorophenol	Pentachlorophenol	Sencor	Hexachlorobenzene

Fig. 12. Balance of conversion by activated sludge

information regarding the degree of decomposition. The ratio of unchanged test substance vs. total conversion products (determined by TLC) determines the degree of persistence of the compound tested.

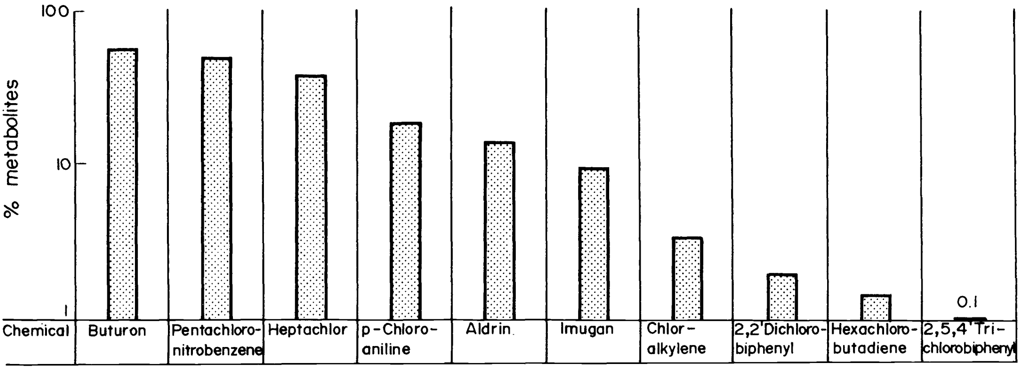


Fig. 13. Conversion ratio (% metabolites) upon simulated waste composting for 21- 28 days

To simulate waste composting, which represents attack of terrestrial microbes, the substance was subjected to aerobic degradation in the presence of artificial waste of constant composition. The incubator was thermally insulated. The test period was approx. 3 weeks. Quantities measured and information obtained (persistence, degradability) were the same as in the previous test.

Photochemical mineralization was observed in adsorbed and/or solid phase in a well standardized and controlled apparatus (Ref. 6). Wavelengths above 290 nm were used to simulate tropospheric conditions. To enhance the speed of reaction, oxygen atmosphere was used so that the time needed for performing the test was only 3 days. In this test only $^{14}CO_2$ produced was measured.

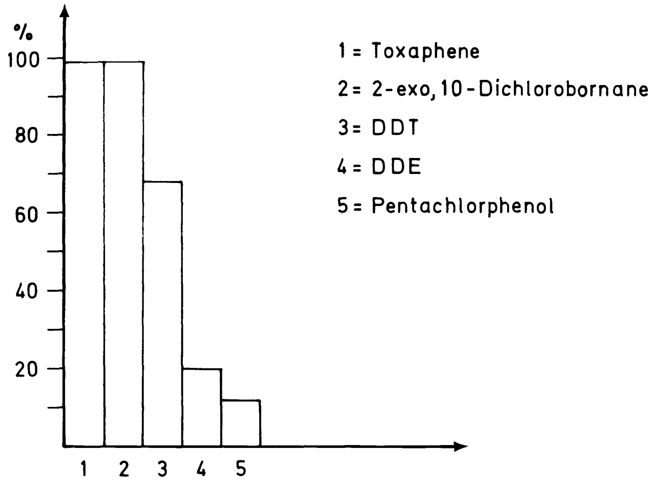


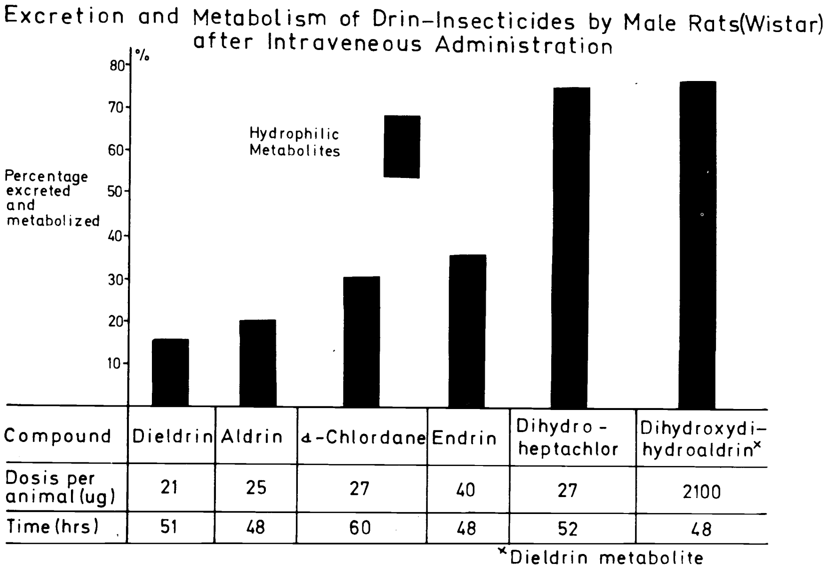
Fig. 14. Photomineralization of Chlorinated Hydrocarbons Adsorbed on Silica Gel with Wavelength $\lambda > 290$ nm (7 days)

A combustion test was designed to investigate the thermo-stability (persistence) of the test substance. The substance was incinerated together with artificial waste (see Fig. 15) at a temperature of 800°C. Radioactive CO_2 and organic substances in the exhaust and the residue were determined.

Chemical	% $14\text{-}CO_2$	% 14-C organic fragments	% 14-C in soot	Balance for 14-C
2,5,4'-Trichlorobiphenyl	92	n.d.	1	93
Chlorobiphenyl mixture	81	8	2	91
Aldrin	76	6	4	86
Kepone	86	6	2	94
Monolinuron	95	n.d.	-	95
p-Chloroaniline	98	n.d.	-	98
2,4,6-Trichlorophenol	68	13	7	88
Hexachlorobenzene	80	4	3	87
Quintozene	78	4	3	85

Fig. 15. Waste Incineration Test
Concentration of chemical about 10 kg/g;
Combustion temp. 800°C;
Percentages based on applied ^{14}C.

Another series of three tests were intended to provide information about the biological behaviour of the test substance in animals and plants.

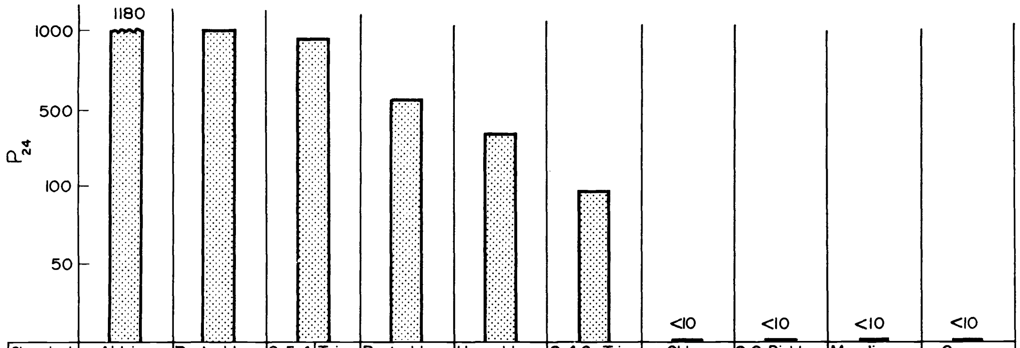


Compound	Dieldrin	Aldrin	α-Chlordane	Endrin	Dihydro-heptachlor	Dihydroxydi-hydroaldrin*
Dosis per animal (ug)	21	25	27	40	27	2100
Time (hrs)	51	48	60	48	52	48

*Dieldrin metabolite

Fig. 16. Comparative excretion and metabolism in rats

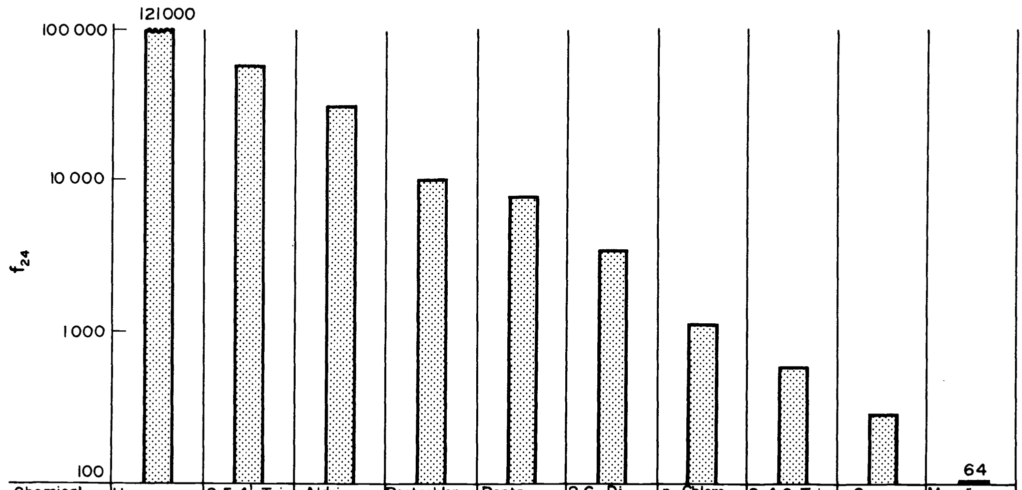
Three rats were fed with the test substance (~ 1 mg/kg body weight) in single applications on three consecutive days. The radioactivity in urine and feces, as well as the ratio of parent compound vs. conversion/degradation products (TLC) in excretion products, was determined. After one week the test was terminated and the animals were sacrificed to allow determination of radioactive substances in tissues and blood. The test allowed an investigation of the degree to which the substance was metabolized by the organism as well as the degree of retention.



Chemical	Aldrin	Pentachloro-nitrobenzene	2,5,4'Tri-chloro-biphenyl	Pentachloro-phenol	Hexachloro-benzene	2,4,6-Tri-chloro-phenol	p-Chloro-aniline	2,6-Dichloro-benzamide	Monolinuron	Sencor
Average exposure ng/ml	2	2	36	42	40	30	52	50	45	54
Balance	93	56	95	73	64	64	100	100	100	100

Fig. 17. Bioconcentration in fish, exposure for 3 days, concentration factor calculated for 24 hrs.

The same parameters, but under conditions of constant exposure, were determined in an aquarium test with fish "orfe". The pH of the water was 7-8, the temperature 15°C. The test was continued for 2 weeks during which period the concentration of the substance under investigation in water was kept constant. Information on bioaccumulation/concentration factors was obtained.



Chemical	Hexa-chloro-benzene	2,5,4'-Tri chloro-biphenyl	Aldrin	Pentachloro-nitrobenzene	Penta-chloro-phenol	2,6-Di chloro-benzamide	p-Chloro-aniline	2,4,6-Tri-chloro-phenol	Sencor	Monolinuron
Initial conc. in water (ng/ml)	51	50	36	49	46	45	50	49	51	50

Fig. 18. Fate in chlorella suspension, amount of algae 0.1-0.2 g/liter, bioconcentration calculated for 24 hrs (f_{24})

The degree to which the substance may be utilized (metabolized) and/or retained by algae was investigated using Chlorella in a ventilated sterile system containing a standardized nutrient solution, resembling the water of only slightly polluted rivers. The chemical was applied only once and a period of one week was allowed for the cells to utilize it. Emitted $^{14}CO_2$ was measured throughout the test period; the concentration of the parent compound in water and the amount retained by Chlorella as well as amounts of conversion products in water and cells were determined.

This system of tests, together with a number of experiments to study the physical-chemical properties related to transport processes under actual environmental conditions (e.g. evaporation, solubility, partition coefficients), is assumed to cover the parameters necessary for screening the environmental/ecotoxicological impact of chemicals. That is, the persistence, degradability under various conditions, bioaccumulation and dispersion tendency (the latter being deduced from the combined results of tests of the former) can be evaluated. While in each test only individual elements or factors of ecosystems are investigated, the results are expected to be predictive for the total system. With a standard of known environmental behaviour, a relative scale for the impact of large numbers of chemicals may be obtained.

Environmental Specimen Bank

There is an additional interesting approach to an evaluation of possible hazards of chemicals which focuses on man rather than ecosystems. It is known as "environmental specimen bank" or "tissue bank", still in the planning stage. The aim here is to collect and store a multitude of environmental samples - from air to human tissue - known or suspected of accumulating pollutants, which will provide references for further and future assessments. The samples are selected according to a key carefully developed in respect to accumulation capacity, exposure history, reproducibility, accessibility, storability, statistical value of sample, ease of preparation and analysis, etc.

Conclusion

In conclusion it should be emphasized that the potential for global changes of the material chemical environmental quality has arisen only recently, when industry reached a respective world-production scale. Thus far chemistry and technology have supplied materials with excellent performance in regard to their use pattern. Recently the behaviour of materials in the environment are included in the development of new products or substitutes for unwanted products.

The ecotoxicological behaviour of xenobiotica is one urgent factor which must be considered in any assessment of chemicals in the environment. It is understandable that biota and their enzyme systems do not have a sufficient capacity to eliminate xenobiotica; however, the energy, which is in excess when compared with organic materials in the atmosphere, is non-specific and therefore also able to mineralize xenobiotica. Furthermore, high energy light (UV) can be used technologically to enhance degradation of chemicals, e.g. in accidental situations as happened recently in Seveso. UV and diffuse daylight irradiation may become important tools to decontaminate the environment of organic persistent materials.

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