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Environmental Risk Management
- Trends in Knowledge and Technology

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Environmental Trends

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1 Introduction

Environmental risk management in industries deals with the risks resulting from the relations between all company activities and the environment, and especially with the economic implications of these risks. The important environmental aspects of today and tomorrow, i.e. the ones with greatest economic implications on society and private enterprise, may be classified as follows:

1) - The problems of the past in individual companies, especially soil and groundwater pollution from contaminated land, industrial sites, hazardous waste dumps etc.

2) - The sudden accidents or catastrophes resulting from fires, explosions etc.

3) - Problems acknowledged in the future through research, development and experience in individual companies/trades and in society as a whole.

While 1) and 2) today can be dealt with in a rather rational manner, it is generally difficult to overlook the future consequences of 3) in individual companies. Moreover, aspect 3) must be assumed to involve still more national and international duties, taxes and regulations in the future, i.e. to be increasingly a subject to political negotiations, compromises and decisions. Last but not least aspect 3) will - in my personal opinion - be by far the most expensive of the 3 categories in the coming decades, probably so expensive that the aspects 1) and 2) hardly will be considered important beyond the year 2000 for society and industry as a whole.

This implies, that risk managers should focus very keenly on the trends in environmental knowledge and technology during the 90's. This paper deals shortly with some aspects of these trends, and some tools and concepts for their assessment.

2 Trends in Environmental Science and Ecological Understanding

Environmental science and politics

Environmental legislation and regulation, nationally as well as internationally (for example the Montreal Protocol) is always initiated more or less by scientific results and developments. However, the political interpretations of the scientific results play a very important role and it is often very difficult to see the logical link between science and politics, looking back some years in the history of environment.

There are many obvious reasons for this. A rather important and interesting one is the following:

There has been a very strong trend in the last decade in public consciousness towards a more total, holistic and global view on environmental problems. This trend is largely of intuitive nature, but has lately influenced environmental politics all over the world, especially through the Brundtland Report. Environmental science has, generally speaking, not been able to cope sufficiently with this trend by developing in a more transdisciplinary direction. On the contrary, many environmental scientists are specialising still deeper into detailed problems, thus losing the broad lines of the picture. Broadly speaking, the result is that environmental science can not supply environmental policy and legislation with sufficient amounts of the right knowledge.

Environmental science too specialised?

These problems may be illustrated by the following example:

An alternative look at the greenhouse effect

The potential changes in the global climate regulating greenhouse effect resulting from CO_2-emissions from burning of fossil fuels and deforestation has attracted growing concern during the past decade. The human contribution to global CO_2-turnover is of the size of 3%, while the contribution to the

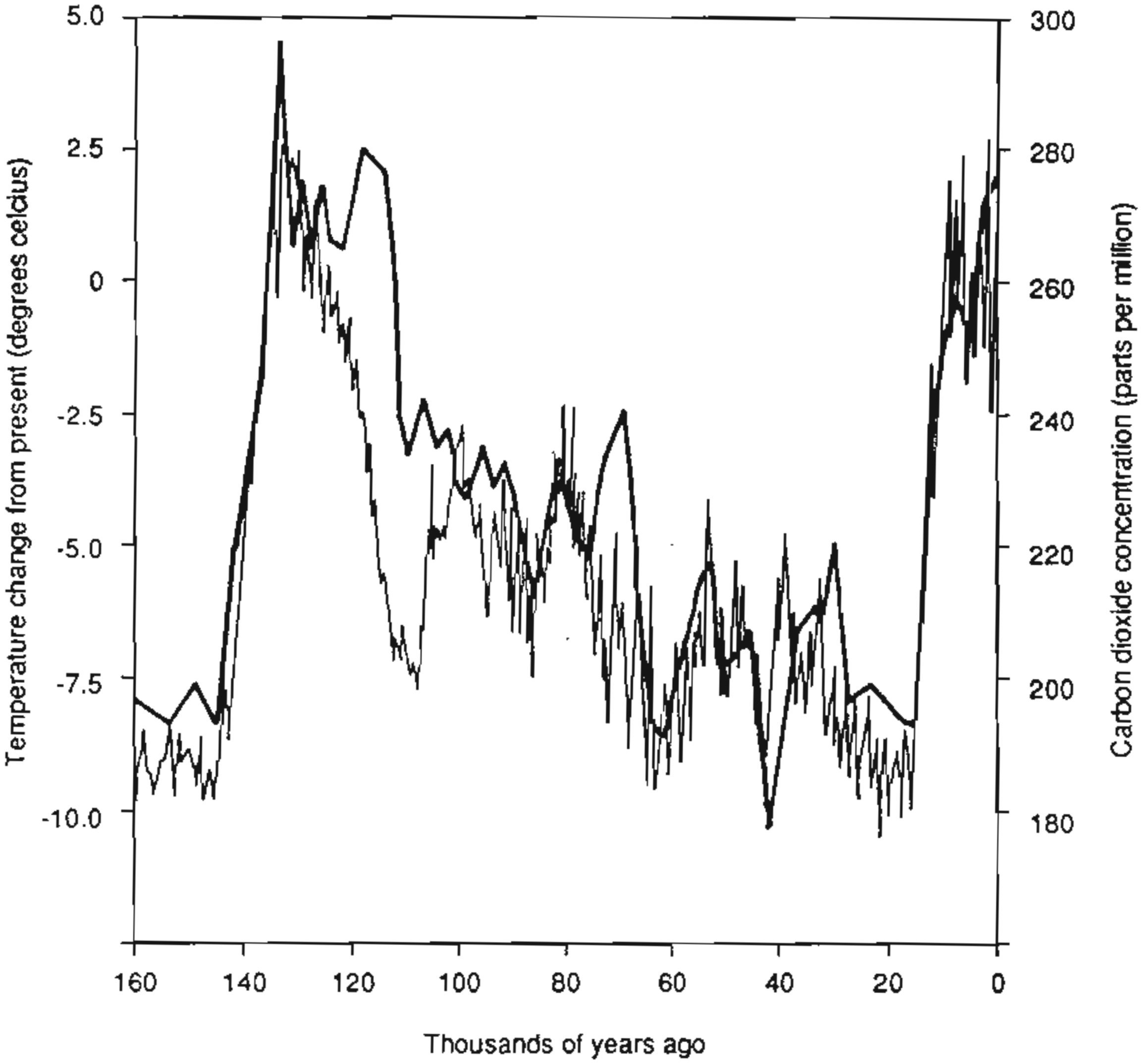

Figure 1: Temperature and atmospheric CO_2 - content over the past 160.000 years. Data from ice-core drillings in Antarctis. From Stephen H. Schneider: The Changing Climate, Scientific American, Sept. 1989, issue: Managing Planet Earth

global energy-turnover is less than 0.01%. Thus our CO_2-contribution is significant, while our energy-contribution is negligible. The CO_2-problem has lately been subject to large-scale climate-change research-programmes all over the world. The result today is a large probability of some global heating during the coming decades, followed by a rise in the sea water level. This rise has recently been estimated to less than 0.5 m in 50 years, but is somewhat disputed.

Changes of climate through 160,000 years

A broader look at the CO_2 and greenhouse-effect may be based on Figure 1, and may result in the following: Figure 1 shows values of CO_2 and temperature during the last 160.000 years on earth. The data are from measurements on ice-cores from the Antarctic. They show close correlation between CO_2 and temperature over long time-spans, and not necessarily correlation over shorter time-spans, due to other climate-regulating mechanisms. The time-span shown covers the last part of the second-last ice age and all of the last one. According to present knowledge, there has been at least 10 ice ages on earth during the last 1-2 million years, and probably in a rather periodical manner. Before this period the climate is assumed to have been stable and warm for 50-60 million years (the tertiary period). During glaciations the sea level is several hundred m's below the level today. Also in the interglacial periods considerable sea level changes have occurred, and changes of several m's are believed to have taken place during the last 2-3000 years. All for quite natural reasons.

Natural climate is a dynamic phenomenon

The climate on earth has therefore been a very dynamic phenomenon during the last 1-2 million years. We do not know why. A glacial period seems to start in a rather gradual and stepwise manner and end rather abruptly. We do not know why. Probably the global climate regulation became unstable 1-2 million years ago and still is, and probably it is oscillating as an iteration towards a new stabile condition. Based on Figure 1 you might very well think, that this new stabile condition was the glacial one, and that it might occur again a rather short time from now. But we do not know.

Transdisciplinary environmental science

Analyses and thoughts like these are generated by a few scientists today among who the most well known is James E. Lovelock with his Gaia-theory - a transdisciplinary, scientific attempt to understand global ecology or "geophysiology" as it is termed by James Lovelock.

What has all this got to do with environmental risk management? It emphasizes how little we know about global environment and ecology. The risk concerning the CO_2-greenhouse-effect problem is not related to less than one m sea level rise in 50 years. This event might very well occur for natural reasons anyway. The risk is related to the fact, that we interfere significantly with a global climate-regulating system that is already unstable for natural reasons beyond our knowledge. It goes without saying that forecasting the effects of interfering significantly with an unstable system, we do not understand, is risky business.

The real greenhouse-problem: Lack of knowledge

Personally, I believe that James E. Lovelock's transdisciplinary approach to global environmental science will gain momentum during the 90's, simply because it is the only way towards real understanding in the global scale. I therefore consider it probable, that a strong global initiative towards an alternative to fossil fuels will come up before the year 2000. I also believe, that the real alternative is solar energy, with nuclear fusion as a second potential. It is definitely impossible to solve the problems (if serious) by saving of energy only. Evidently, the industrialised countries will have to develop and implement this new energy source.

A new, global energy source before year 2000?

This must be financed by duties and taxes probably related to energy. If I were a risk manager in a heavy energy-consuming industry, based on fossil fuel, I would therefore seriously prepare the financing of these expenses and look eagerly for available CO_2-neutral energy alternatives.

As shown by the preceding example, the impacts of industrial production and industrial society on the environment are very complicated and comprehensive in nature. However, it also shows, that there are very different ways to consider and assess these impacts, and that some of these ways are more reasonable and operational than others.

The dynamic nature of nature

The most important message from the example is probably that nature is generally not a stabile system, but a dynamic one. Environmentalists often seem to base their work on the perception that nature has a stabile, undisturbed condition, which is the right one and should be reestablished. The perception of the dynamic nature makes things more complicated, but it also allows for more than one "correct" solution; to influence nature actively in a positive direction may be better than just minimizing the influence. (If a natural glaciation was 200 years ahead, would it not be nice to prevent it - even by burning of fossil fuels?). The environmental impacts and risks should be managed, not necessarily minimized. Only that way it will be possible to combine economic growth and environmental protection as stated in the Brundtland Report - a worthy challenge of the environmental risk manager.

3 The Challenge of Environmental Risk Management

Environmental risk management in the 90's

To predict the future and manage all relations between industrial production and nature (environmental relations) based on this prediction; given the fact that nature is not stabile, but a dynamic system with rather unknown dynamics. This is the challenge of the 90's for the environmental risk manager.

The job is difficult, and will furthermore probably be an important parameter of competition: the companies who do it best are likely to gain important advantages towards the year 2000.

Frame of reference: Best possible knowledge

Based on the above jobdescription it is evident, that the frame of reference for environmental risk management is not only present regulation and legislation but simply the best possible knowledge. The professional company in the 90's will be years ahead of present legislation in the field of environment and will - moreover - utilize this lead to actively influence the political and administrative process towards new laws and regulations.

But how to obtain best possible environmental knowledge, and what is exactly best possible knowledge for my company? The most important aspect of "best possible knowledge" is probably, that it is already available; you do not have to generate it, just to find it, understand it, and interpret it the right way. New environmental knowledge is generated at tremendous speed all over the world today; you can find what you need, if you know the right place to look.It should be noted, that the first step of best possible knowledge is a relevant and precise specification of what is not known, as this of course is a necessary condition for a realistic risk assessment.

Best possible knowledge:
To locate "the people who know"

The problem of locating the best possible knowledge may be illustrated by looking back at the history of environment for the last 20-30 years. There were certain moments when basic problems were generally, officially realised in individual countries or globally. We can all think of such moments, for example regarding contaminated sites, pollution of streams and lakes etc. Thinking carefully, we will probably also remember, that 5 or 10 years, maybe even 20 or 30 years before this official recognition of a given problem, there were people who knew. Some of them were of course vindicators or crackpots, but some were also serious, professional, hard-working people who knew and talked about it, but to deaf ears. Who were they, what kind of people were they? Think about it, and look for that kind of people today; they are the ones with the knowledge you need as a professional environmental risk manager.

Characteristics of "the people who know"

Is it possible to characterize these people on a general level? To a certain extent, yes: They have obtained deep scientific understanding in a certain field of natural science; they are highly qualified specialists. They have also managed to utilize this basic understanding in a broader, transdisciplinary manner; they have become highly qualified generalists in the fields of environment or even wider. As persons, they will normally be highly engaged and committed, but this may of course show in many ways ranging from fast-talking extrovert behaviour to silent, dignified frustration. Normally though, they will not be boring after some time of acquaintance.

The knowledge (or specified lack of knowledge) in itself is not sufficient; it must be interpreted, transformed and managed (not manipulated, that is!) for the specific use of your company. In this phase most risk managers will find that environmental risk management is largely management based on lack of knowledge. Or "management in turbulent times" as Peter F. Drucker termed it. This is important, because it means that environmental risk management (or environmental management) is just another aspect of modern management as such; innovation management in a

Innovative management and environmental management

changing world. This also implies, that companies that are successful in management of continuous innovation will also succeed in environmental risk management. Other companies will probably not, but these companies will have many other problems to cope with before environment can be given priority.

4 Tools for Environmental Risk Management

4.1 Terms and tasks

Today there are many tools for managing the environmental risks in companies. On management level, however, it is important to focus upon conceptual tools, that create a general view over environmental problems and risks, and form a basis for priority ranking of these issues. This leaves us with terms like "environmental impact assessment" (EIA), "environmental audit" (EA), and "product life-cycle assessment (PLA). However, these concepts cover a wide range of varieties for different purposes, and further: There are many different opinions as to how these concepts should be designed and used. Thus, there are today no generally accepted international standards, although guidelines, manuals etc. have been worked out by international development banks (for instance the World Bank) and government bodies in some countries or communities (for instance DGXI in the EEC and EPA in the USA).

Lack of accepted standards

Basic demands for relevant tools

It is not difficult, however, to describe what a useful environmental risk management tool should be able to accomplish. Basically it has two tasks:

1) To register and describe all environmental relations of the given activity (company, production or product), i.e. all relations between this activity and environment. This task has the form of an inventory, and must comprise not only today's well-known relations, but also tomorrow's, based on projections of the development of the company/production/product, society and nature. The list will be a long-list for further elaboration.

2) To evaluate, structuralize and priority rank all the environmental relations in the long-list inventory of task 1). The result should be a short-list of major environmental relations, with assessments of their individual environmental impacts and mutual dependence. Finally, a broad outline of possible company actions towards the issues of the short-list should be given.

Company environmental strategy

Afterwards, a strategy for environmental risk management (task 3) shall be shaped by integrating the result of task 2) in overall company strategy. This process will probably result in a priority ranking of environmental relations and actions different from the one in task 2). This is natural, as in task 2) only environmental impacts were considered, while in task 3) overall company considerations have been made. While task 2) is on the level of risk management/environmental management, task 3) is on top-management level, and is not dealt with by the environmental risk management tool. My personal experience has shown, that it is extremely important to be very conscious indeed about the difference of the roles of environmental management and top management in this process.

In the following, some important aspects about the tasks 1) and 2) are described.

4.2 Environmental relations inventory - task 1)

It is vitally important to define exactly the activity for which the inventory shall be carried out. It may be a production plant, a production unit, a product line, an industrial complex etc. etc. A very important problem here often is to decide for a production plant approach (PPA) or a product life-cycle approach (PLA). In the last case, environmental relations of all sub-suppliers, sub-sub-suppliers etc. plus customers, consumers and re-users/waste handlers are incorporated. In my personal opinion there is no doubt, that the production plant approach is too narrow for the challenges of the 90's. On the other hand the ultimate product life-cycle approach may be too complex to handle for many companies. The optimum solution will normally be a balanced version of PLA with most emphasis on the PPA-part of it.

Production plant approach or product lifecycle approach?

What is an "environmental relation"

Also, a clear definition of the term "environmental relation" is needed. The concept may be limited to "ecological relations", i.e. relations to nature, flora, fauna etc. or it may include relations to human health and well-being, i.e. noise, local air pollution, occupational health and safety etc. In my opinion both ecological impacts and human health aspects should be included as the two types of relations have many things in common, in fact they are often two effects of the same cause, and should be treated coherently.

Practical inventory problems: Top-down or bottom-up?

To carry out the long-list inventory successfully involves many practical problems. It is of vital importance, that no significant relations are missed in this work. Therefore a combined top-down and bottom-up approach will be necessary. The top-down approach should be based on a comprehensive and suitable logistics framework with a checklist to secure that all important environmental relations of today and tomorrow are considered. The bottom-up approach shall activate the involvement and interest of all company employees to secure that no serious environmental relations in daily work and routines are left unconsidered (especially occupational health and safety will be covered up this way). When both approaches are used simultaneously and carefully in a coordinated manner, important uncovered relations will be very improbable.

Examples of inventory concepts

The logistics framework and the checklist for such inventories will normally be drawn up on the basis of some kind of total input-output balance of the activity (production plant etc.) in question. Simple examples of such concepts are shown on figures 2 and 3 for a production plant.

4.3 Environmental relation priorities, task 2)

Which is worst - apples or pears?

In this task a very basic problem in environmental risk management exists, the problem of giving priorities, i.e. comparing environmental relations of different nature. Which is worst, the environmental impact of X tonnes of heavy metals in a fjord or Y tonnes of NO_x in the air over a city? It is important to realize, that such a comparison can not be made in a scientific way today, and maybe never. It is also important to realize, that priorities have to be given. Therefore the tools for priority ranking of

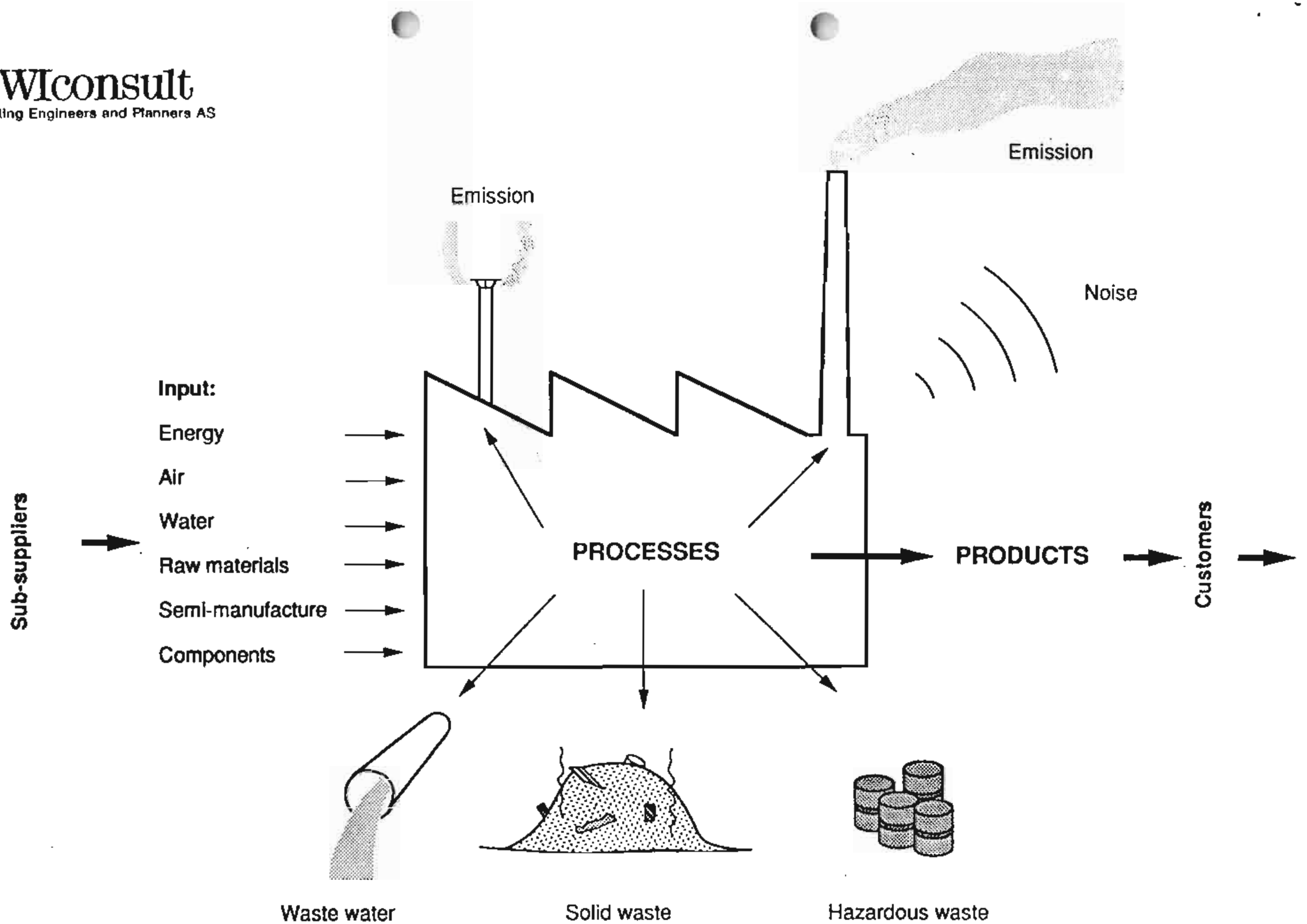

Figure 2: Simple sketch of input-output balance fundamentals for production plant

Figure 3: Checklist for environmental relations in production plant (short version)

General information:

- Location, name, address, municipality, district, country - topographical map 1:10,000
- Production pr. year and employees by number and qualifications
- Key points in plant history, previous use of plant site
- General view of process flow (diagram) and corresponding map sketch
- Previous experiences with and measures towards relations to environment, occupational health and risks (environmental relations)
- Legislation, regulations etc. related to production and environmental relations
- Own procedures, instructions and guidelines concerning environmental relations, contingency plans
- Future plans concerning production and measures towards environmental relations
- Plant surroundings - natural conditions: Climate, drainage, surface water runoff, soil conditions, water works, important conservation sites
- Plant surroundings - relations to society: Living areas, institutions, neighbouring productions and trades

Input-output balance:

Input:

- Energy consumption in Joule/year, sources: Electricity, oil, gas, coal, district heating, biofuels etc.
- Water consumption in m^3/year, use in processes
- Raw materials, mineral or biological, types and amounts pr. year
- Semimanufacture, mineral or biological, types and amounts pr. year
- Sub-suppliers of relevance

Output:

- Products, types and amounts pr. year
- Materials in products, types and amounts pr. year
- Specifications and quality demands for products
- Emissions to air, types and amounts pr. year, purification measures
- Emissions in waste water, types and amounts pr. year, purification measures
- Solid waste, types and amounts pr. year, treatment
- Hazardous waste, types and amounts pr. year, treatment/disposal
- Other bi-products, types and amounts pr. year, treatment/disposal
- Noise and vibrations from the plant, description, measurements

Occupational health and safety:

- Storing and handling of chemicals and hazardous substances on the plant premises, and utilization of these agents in plant processes
- Other occupational health and safety conditions of relevance

Risks:

- Reports on risk conditions on the plant
- Identification of processes/locations on plant premises with significant risk conditions

environmental relations must include room for risk assessments and personal judgements to be operational.

Exact priority ranking is impossible

This means, that it can not be exact and detailed, and that it must be used in an open and transparent manner so that the preconditions and the considerations used may be reviewed and judged or argued by the involved bodies or persons.

The tools for priority ranking normally have the form of scoring systems, where each relation is assigned a score; the bigger the score, the worse the relation. The levels of scores should be very limited to preserve the general view, and because complex and detailed scoring systems are not relevant for this type of problems.

4.4 The role of environmental consultants

The "ideal" consultant

There are today many consultants operating in the field described above, both on the national and international level. The ideal consultant in this field, both as a person and as a company, has extensive experience in both environment, risk assessment and management. They are not seen very frequently around. Basically, there are presently two types of consulting firms in environmental risk management as described in this paper:

The "real" consultants today

- The consultant with scientific/technical background, who is trying to integrate the management aspects into his work. Examples can be research institutions and consulting engineers. It is extremely important, that the technical/scientific background is multi- and transdisciplinary.

- The management consultant who could also be accountant or lawyer, trying to integrate the technical/scientific aspects into his work.

There are of course advantages and disadvantages in both types, which should be evaluated carefully, when consultants are chosen.

The role of consultant will depend very much on his qualifications, but also on the conditions in the company in question:

Company conditions are important for choice of consultant

A company, that has successfully implemented innovative management and/or quality management, and wants to integrate environmental risk management, will not have serious problems. If the company has extensive environmental knowledge, it might profit from a high-level transdisciplinary consultant as a sparring-partner for the management, or it might not need a consultant at all. If extensive environmental knowledge is not at hand, a consultant will be of great advantage, and his background should be focused on transdisciplinary environmental knowledge and less on management.

A company, that has not yet implemented innovative management and wants to introduce environmental risk management, will be in trouble. It will be very difficult to accomplish these two difficult tasks at the same time with almost any consulting assistance. In this situation, start with introduction of innovative management in the core functions of the company using management consultants. At the same time deal with the environmental problems on the technical level with the help of a professional technical consultant. Postpone the introduction of environmental risk management on management level until innovation management has been introduced.

4.5 Examples of tool concept: Product lifecycle assessment

An overall scheme for an environmental relation inventory (task 1) in product lifecycle assessment is shown on figure 4. The matrix in the middle represents the product lifecycle, divided in seven phases each separated by transport: Raw materials, semi-manufacture, sub-components, products, distribution, consumption, and waste treatment. The other way the matrix represents the types of environmental relations: Ecological impacts and human health impacts. Both categories have continuous components and accidental components, the last represented by the word "risks" in the diagram. The input-output balance of the system is represented by the arrows from and to "mother earth", representing raw materials/energy and waste/emissions respectively.

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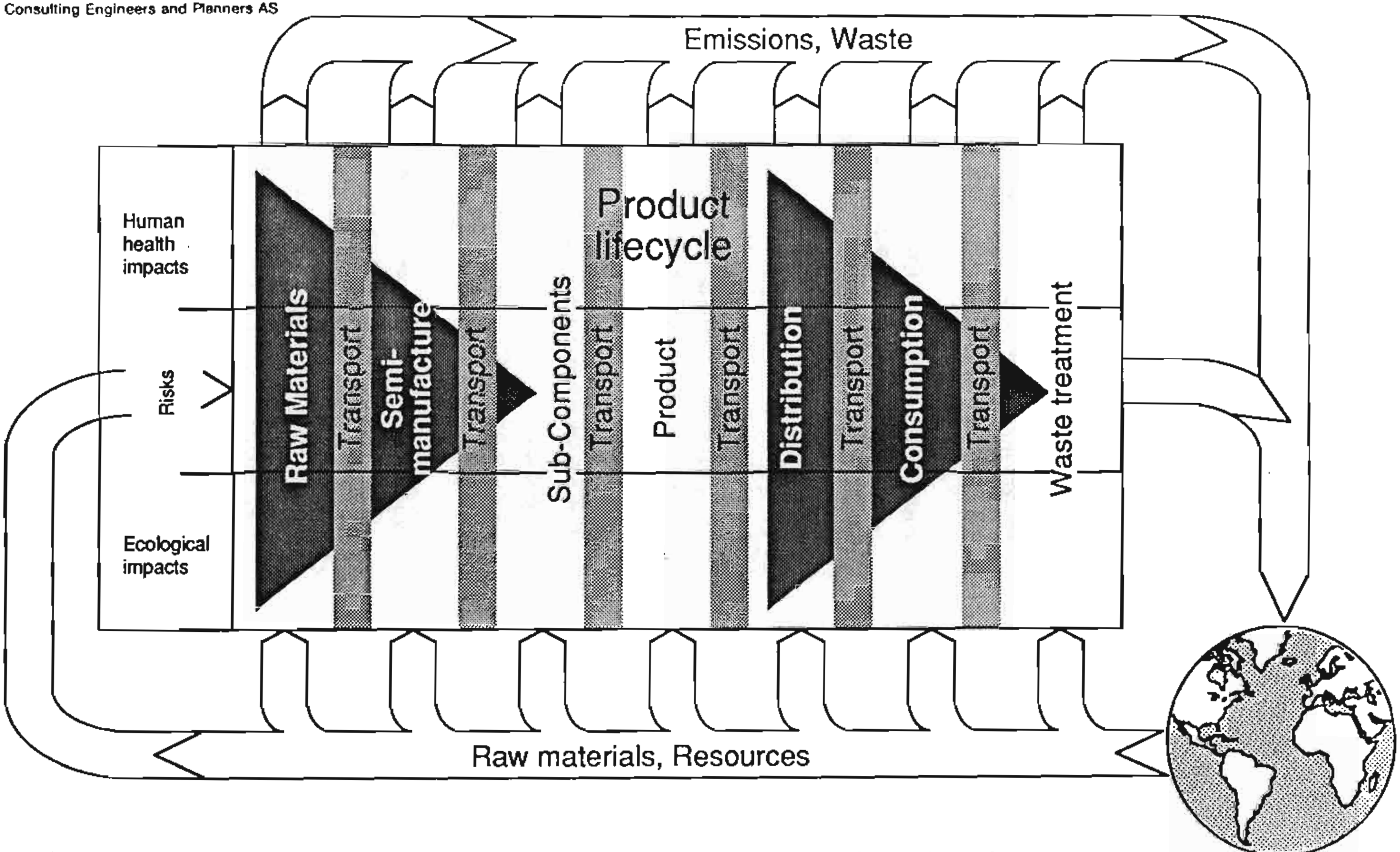

Figure 4: Product lifecycle assessment, scheme for environmental relations inventory

The product lifecycle thus represents a network of activities, linked together by the product line. Many of the activities are production plants of various kinds, but all kinds of trade are included in a product lifecycle.

Input-output balances for each activity in the lifecycle have to be set up to identify all relevant environmental relations in the lifecycle. A simple fundamental sketch of such a balance for a production plant is shown on figure 2 and a corresponding short version of a checklist on figure 3. A much longer and more detailed checklist may be applied for a detailed environmental audit in a production plant.

Definition of "environmental relations"

A very important aspect is a clear definition of "environmental relations". We have in COWIconsult chosen this definition: An environmental relation is an effect of the product lifecycle with a certain impact on the environment, i.e. the total biosphere including human beings.

We divide environmental relations in 2 main categories as mentioned: Ecological impacts and (direct) human health impacts. Ecological impacts are subdivided into resource utilization (including energy), emissions/waste and risks (i.e. connected with accidents/catastrophes).

6 basic categories of environmental relations

Human health impacts are subdivided in emissions, occupational health/safety and risks (again accidents/catastrophes). We thus end up with 6 basic categories of environmental relations. Any environmental relation must be defined, so that it is placed in only one of these categories.

It is important to notice that resource utilization is only relevant as an environmental relation when the resource is water or a biological resource, utilized in a non-sustainable manner. Utilization of mineral resources (e.g. metals or fossil energy) has no environmental impact in itself; the environmental impacts here are related to emissions and are accounted for as such.

Priority ranking of the inventory long-list (task 2):

Assessment parameters and scoring system

For the priority ranking of the environmental relations a simple scoring system is used by COWIconsult. Each of the 6 environmental relation categories are assigned 3 assessment parameters, each of which may have the score 1, 2 or 3. The total assessment score for each relation is obtained by

ENVIRONMENTAL RELATIONS

Impact	Category	Assessment parameters	Scores 1	Scores 2	Scores 3	Assessment score
Human health impact	Occupational Health / safety	Amount:	Trace	Small	Large	A x D x E
		Dispersion in working environment	Very good protection	Protection	No protection	
		Effect on health	No effect	Irritation, illness	Reproduction risks Cancer risks	
	Emissions	Amount:	Trace	Small	Large	A x D x E
		Dispersion scale	Local	Regional	Global	
		Effect on health	No effect	Irritation, illness	Reproduction risks Cancer risks	
	Risks	Amount x probability	As for "Amount" under health impact, other parameters unchanged			A x D x E
Ecological impact	Risks	Amount x probability	As for "Amount intensity" under ecological impact, other parameters unchanged			A/I x D x E
	Waste / emissions	Amount:	Trace	Small	Large	A x D x E
		Dispersion scale:	Local	Regional	Global	
		Effect:	Natural / low toxic	High toxic / biodegradeable	Persistent	
	Resource utilization	Intensity:	Low	Medium	High	I x A x E
		Area of influence:	Local	Regional	Global	
		Effect:	Insignificant, reversible	Significant, reversible	Irreversible	

Figure 5: Basis categories of environmental relations and parameters and scoring system for their assessment

multiplying the scores for the 3 assessment parameters with each other. Thus the total assessment score for each relation may obtain values 1, 2, 3, 4, 6, 8, 9, 12, 18 and 27, i.e. 10 classes of total score. It is extremely important to emphasize, that this is not an exact system at all, but merely a logical framework for the assessment process. The framework is shown as a diagram on figure 5, where also the assessment parameters and the classes for scores 1, 2 and 3 for each parameter are briefly defined.

Concept background and utilization

The concept is a rather simple mix of well-proven environmental classifications and knowledge, risk assessment systems and decision-support systems. It should therefore be treated carefully, and transformed and adjusted to each specific case. Reasons should be given clearly and briefly for any scores assigned, and total assessment scores should not only be classified by one number (12), but by the individual multiplication (2 x 3 x 2 or 2 x 2 x 3 etc.). Our experience with the system has shown it to be durable as a basic framework, and possible to transform into operational tools in specific cases.

5 Summary and conclusions

It has been reasoned, that by far the most expensive environmental risks in the next decade will be the ones related to the developments in environmental knowledge/environmental politics and the resulting taxes, duties and regulations.

The trends in these developments have been discussed and exemplified through an alternative look at the greenhouse effect. The general conclusion is, that environment/nature is not a stabile system to be conserved, but a dynamic system to be managed. This makes environmental risk management more complicated but also gives a broader potential for sustainable solutions.

Environmental risk management must therefore not only use present legislation as its frame of reference, but has to strive for the best possible knowledge. Ways to obtain best possible knowledge have been discussed; it is possible, but demands new ways of thinking. Future environmental risk management is regarded as just another aspect of modern innovative management in general.

Tools and concepts for environmental risk management have been treated. Specific tasks and demands for operational concepts have been set up. The two main tasks are:

- Inventory: To produce a long-list of all relations between a given industrial activity and environment.

- Priority ranking: To elaborate the long-list into a short-list of significant environmental relations including priority ranking.

These two main tasks have been described in detail, and important problems discussed.

Consultancy in the field of environmental risk management demands comprehensive experience in environment, risk assessment and management, which is today a scarce combination. Choice of consultant involves not only consultant qualifications, but also client company conditions are of utmost importance.

A concept for product lifecycle assessment has been briefly presented including inventory framework and priority ranking system.

Conclusively the very complicated challenge to environmental risk management through the 90's can be met in a professional way today. The demands are, however, extensive and strong tradition for strategic, innovative management and experience in optimum utilization of professional consulting services are important preconditions of success. Implemented successfully, environmental risk management may be a key parameter of competition through the next decades.

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