

POLICY RESPONSES TO LARGE ACCIDENTS
Proceedings of an IIASA Meeting

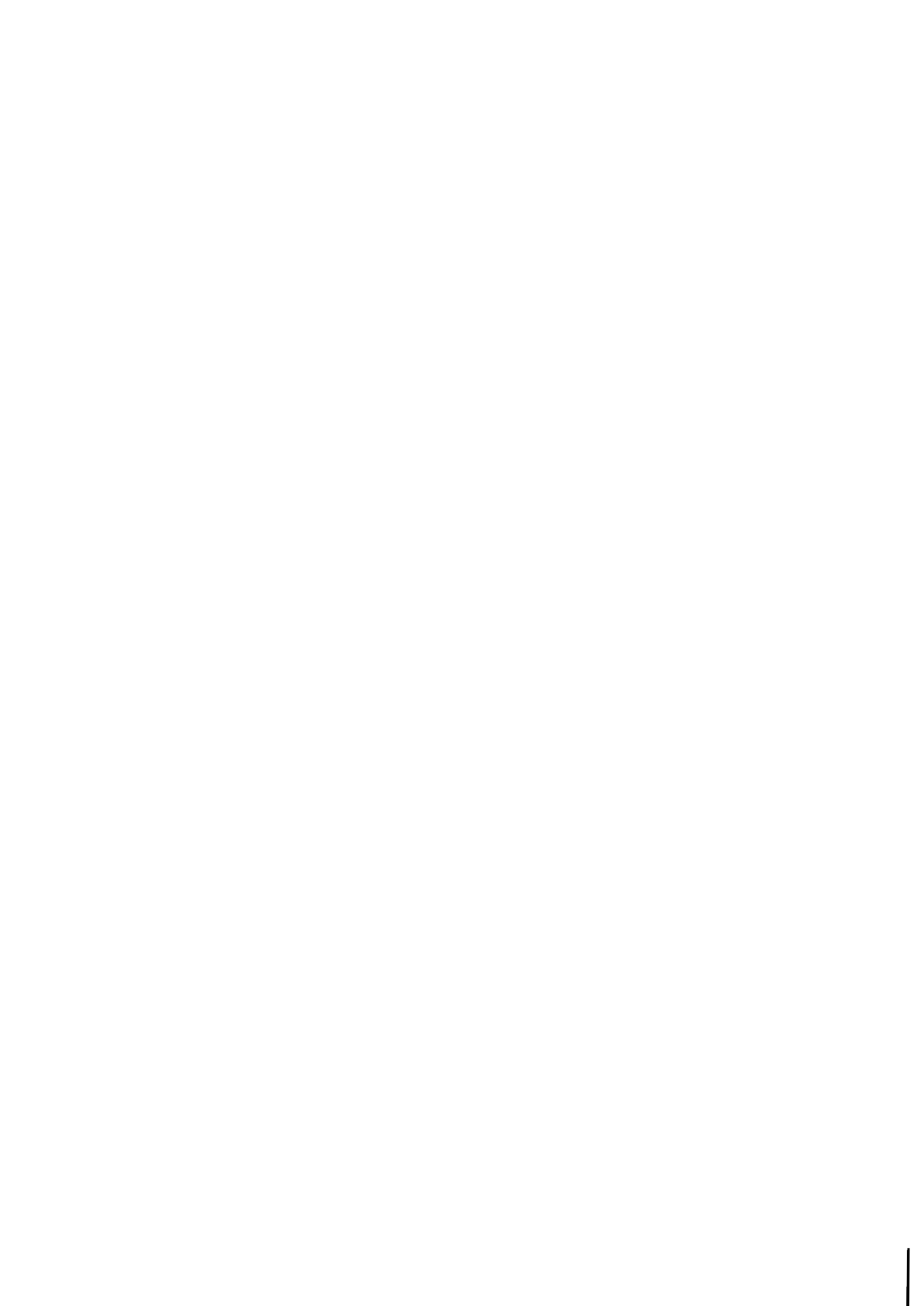
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Preface

During 1988, the IIASA Risk Task Force invited a group of experts to form a collaborating network for a study on national and international responses to the accident at Chernobyl. This study dealt with responses of society to traumatic events which are able to change social structures for an extended time period. Specific issues included were: How do authorities react, what is the role and behavior of the media system, what are the decision making structures, how do international coordination systems function. The documentation of this activity will be published by a commercial publisher.

During this work a need arose to broaden IIASA's exposure to opinions and results from experts in the field of risk research. For this reason a Conference on "Policy Responses to Large Accidents" was held at IIASA from 16-17 January, 1989. The papers presented at this conference have been compiled into this volume. They are included as delivered by the authors without additional editing.

Boris Segerstahl
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IIASA Task Force on Risk



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Policy Responses to Large Accidents
Introduction

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The phrase 'policy response' is by no means well defined or commonly used.

The whole pattern of reactions and responses to a large accident is society's policy response to the accident. A policy response is the reaction by society as a whole to an incident or accident which cannot be confined to a narrow sector or closed region, but which has a broad and often uncontrollable national or international scope. Purely technical responses to control the consequences on the site of an accident fall outside of what we mean with a policy response. Policy responses have three rational goals which in order of importance and urgency are to

- implement measures to minimize harm to the population;
- limit economic impact of accident;
- revise procedure to avoid future similar accidents and improve response mechanisms if an accident occurs.

The lasting impact of a policy response is in many cases a lasting but not necessarily big change in the way society operates and the way society and its technological systems are perceived by the public. The group of societal alternatives when the system responds to an accident is quite large. Society can

- take care of the crisis and forget it ("we cannot afford a change");
- localize responses and apply new policy only on a local level ("it cannot happen here");
- modify societal strategy through rules, regulations and legislation;
- overreact. Change strategy disregarding side effects and cost.

It is natural that society as a whole does not react to every accident. Certain characteristics are required of an accident before it can create a policy response. It is not enough that you have a great number of fatalities. Traffic can be seen as a technological system which in 1987 in Europe caused 2 million injuries and 70.000 deaths. Traffic is however part of a lifestyle and is consequently treated as a natural risk which everybody shares. Only a few spectacular accidents have created new rules and regulations. Some of the characteristics required of an accident capable of generating a policy response are:

- concentration in time and space;
- many casualties (not always necessary. Seveso didn't cause any immediate deaths);

- media attraction. An accident with no potential for dramatic reporting will not generate broad responses;
- substantial economic impact;
- ability to scare people;
- the accident has an international (or environmental) aspect.

This list is in no way complete and some of the characteristics listed will be present or absent from an accident depending on the specific circumstances. The main conclusion of the list is, however, that there is no simple way to classify accidents which create lasting changes in the way society operates.

This list gives a too simple view of reality. In a real situation like Europe after Chernobyl, there is a lot of confusion with many stakeholders and conflicting interests making consistent decisionmaking extremely difficult. To this confusion was added the problems caused by lacking information. During the first days and weeks after the accident nobody knew exactly what had happened. Predictions based on what was known were more a matter of guessing than of knowing as there was a complete lack of previous experience.

Much of what can be found out scientifically about how society responds to accidents has more to do with the dynamics of society than with the technicalities of a specific technological subsystem. The structure of a policy response is quite complex. It involves political, societal, economic and technical issues. One important aspect is the fact that responses are implemented through national and international political processes. As a consequence side issues and political ambitions and confrontations have a tendency to 'muddle the issues' until the original cause of a response has almost totally been forgotten.

Science plays a limited role in these activities. Facts are often used only when they support predetermined political positions or destroy arguments of opposing factions. It is, however, of fundamental importance that scientists pay more attention to the societal framework in which economic and technical systems operate. This knowledge is essential in all efforts to create a deeper understanding of the real deep structures and characteristics of these societal subsystems.

THE EUROPEAN COMMUNITY POLICY TO CONTROL MAJOR HAZARDS

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Abstract

The European Community has had an effective policy in place since 1984 for the control of major hazards. This policy is based on an EC Council Directive, commonly known as the Seveso Directive, which defines an information network and requires the generation and transmission of information as the basis for accident prevention and risk management. The Directive resulted from a series of major accidents which occurred in the EC in the mid-1970s, demonstrating the need for a harmonised policy for the control of potentially hazardous installations. These accidents, and their common characteristics, are reviewed in the paper and the requirements of the Directive are summarised.

The Directive has been periodically amended as experience has been gained of major accidents around the world, eg, Bhopal, Mexico City, Basel. The content of these amendments is presented and the status of the Directive's implementation is discussed.

INTRODUCTION

The European Community Directive on the Major Accident Hazards of Certain Industrial Activities, more commonly known as the Seveso Directive /1/, specifies in considerable detail the information that must be generated about major hazards in the EC. It calls for the formal identification and analysis of major accident hazards and specifies to whom this information is to be provided. The intent of the Directive is both to prevent major hazards from occurring and to minimise their effects if they should occur.

This paper outlines the political process by which directives of this type are evolved and reviews the specific accidents that created the political momentum that resulted in the Seveso Directive and shaped its content. The contents of the Directive and the status of its implementation are summarised.

COUNCIL DIRECTIVES

Council Directives of this type have two major goals: to protect workers, the public and the environment by the prevention and management of industrial hazards; and to harmonise the obligations of manufacturers in Member States in order to avoid the distortion of competition within the Community. Directives are proposed by the Commission and formally adopted by the EEC Council of Ministers, taking into account the opinions of the European Parliament and the Economic and Social Committee (ECOSOC). The European Parliament is the directly-elected representative of the people, while the ECOSOC represents all categories of economic and social life.

industrialists, professionals, workers, farmers, consumers and representatives of other public interests.

Directives set out objectives to be complied with by all Member States, and must be transposed by each Member State into national legislation; this allows various cultural traditions, institutional structures and regulatory styles to be considered (O'Riordan, 1985).

BACKGROUND OF THE SEVESO DIRECTIVE

The Seveso Directive represents "lessons learnt" from a series of accidents at Flixborough, Beek, Seveso and Manfredonia which happened within a period of 28 months in the 1974-76 time period. The most important were Flixborough and Seveso, the former an explosion of cyclohexane, the latter a release of dioxin in a runaway chemical reaction. We will summarise the main features of the two major accidents.

Flixborough

The Flixborough accident happened in June 1974, an explosion of cyclohexane which killed 28 workers and injured 36. Fifty three members of the public were recorded as "casualties" by the police while hundreds more sustained minor injuries. Almost 2000 homes and businesses suffered property damage (Lees, 1980). The accident occurred on a Saturday afternoon and it seems certain that, had it happened on a normal work day with office staff present, the on-site death toll would have been much higher. The plant is surrounded by open fields so the population density in the surrounding area is very low, otherwise public casualties would also have been greater.

The post-accident investigation revealed that the plant operator was storing 43 times the amount of flammable fluids licensed by local authorities and that cyclohexane was not among them at all. There apparently was not a disaster plan for the Flixborough plant.

Seveso

The Seveso accident took place in July 1976 when an exothermic reaction raised the temperature and pressure inside a vessel used to produce trichlorophenol (TCP, an intermediate product used in the production of bactericides and herbicides) beyond limits, causing a safety valve to vent. Dioxin (or TCDD) is normally formed in trace amounts as an unwanted by-product of this process, however, due to the high temperatures reached in the runaway reaction, it was formed in large quantities and perhaps as much as 2 kg were included in the release. Dioxin is one of the most toxic materials known and can be taken into the body by ingestion, inhalation, or skin contact. Chloracne is a well known symptom, but it can also damage liver, kidneys and the central nervous system.

An important aspect of the Seveso emergency was the lack of information about what chemicals were involved, their health effects and what emergency measures should be taken. Company officials notified local authorities, 29 hours after the accident, that herbicide vapours containing TCP had been released, although it should have been known, from a similar accident at Bolsover in 1968, that TCDD could have been formed. Consequently, local authorities didn't immediately

realise the significance of the accident /2/, and crisis management was characterised by a series of escalating measures as its severity was slowly revealed (Pocchiari, Silano and Zapponi, 1987).

No action was taken until the fifth day when children suffered skin eruptions and small animals began to die; the plant was then marked off and the consumption of locally-grown produce forbidden. On the tenth day, a laboratory belonging to the plant owner "admitted that dioxin had been found in the samples" (Pocchiari, et al, 1987) of soil and vegetation analysed, setting off a search for information about the health effects of dioxin. Eighty children were evacuated three days later. On day 17, responsibility for emergency measures was given to the regional public health minister and, in the days that followed, evacuations were continued and the zone of highest pollution extended several times.

The first complete map of dioxin concentrations was released on day 37. The accident finally involved about 1800 ha of densely populated area and a total of 220.000 people were placed under medical and epidemiological surveillance.

THE CONTENT OF THE SEVESO DIRECTIVE

The Seveso accident had in common with Flixborough the features that local authorities did not know what chemicals were involved and in what quantities, they did not know enough about the processes to understand what chemicals could be produced or released under accident conditions, and there was a lack of planning for emergencies. Also, in both cases,

changes had been made in plant or processes which compromised the safety of the facilities but were not communicated to authorities responsible for public health and safety.

With this background, the Seveso Directive is largely concerned with the generation and transmission of information as the basis for accident prevention and risk management. It obliges each Member State to generate the same information and then specifies the flow of this information, ie, who is to supply what information to whom, and when. The Directive essentially defines an information network, illustrated in Figure 1, which is managed by the Commission. The following paragraphs give the flavour of its information requirements by paraphrasing the more important points:

In Article 5, that the manufacturer shall be required to notify the competent authorities a complete safety report of the installation, including which dangerous substances are (or could be) involved, in what quantities, their properties, where the facility is located, how many people are employed, what processes are used, the sources of hazard, what arrangements have been made for safe operation, the on-site emergency plans and information necessary for the authorities to prepare off-site emergency plans;

In Article 6, that the manufacturer inform the authorities if the operation is modified in a way that changes the information above and, in Article 7, that the Member States appoint the competent authority who should receive and act on this information, that the manufacturer be informed as to the identity of this authority, that the authority ensure that an

emergency plan is drawn up for action outside the establishment and that the authority organise inspections;

Article 8 specifies that the Member States shall ensure that people liable to be affected by an accident be informed of the safety measures and how to behave in the event of an accident (in contrast to the USA, direct communication of hazard information between industry and the public is not specified, although this may happen in practice because the details of how risk information is provided are determined by the policies adopted by the Member States); Article 8 also requires that this information be made available to other Member States that could be concerned so that it can also be given to their nationals;

Article 10 requires the manufacturer to report to the competent authority any accident which occurs, how its effects are being alleviated and what is being done to prevent recurrence, while Article 11 asks that the Member States inform the Commission of any such accidents and Article 12 requires the Commission to keep a register of them so that Member States can benefit from this experience for prevention purposes;

Article 13, in contrast, limits the exchange of information to protect industrial confidentiality, requiring that officials of the Commission and the competent authorities do not divulge specifics of the information obtained under Articles 5,6,7,9,10 and 12 to third parties;

Article 18 directs the Member States and the Commission to exchange information on the experience of accident preven-

tion and consequence limitation, while Article 20 requires that the Member States inform the Commission of the national laws adopted to implement the Directive.

The Commission organises quarterly meetings of the Committee of Competent Authorities during which questions concerning the Directive and its implementation are discussed so that common approaches can be adopted. This Committee serves as a forum for the exchanges of information foreseen by the Directive and can also be convened in the case of a major accident to give advice and to offer assistance, as required, to the country in question.

AMENDMENTS TO THE SEVESO DIRECTIVE

The First Amendment

Events like Bhopal and Mexico City demonstrated that the Directive did not require major revision, however, these accidents did bring attention to the need to have more stringent requirements for some particularly dangerous substances, especially with regard to safety report notification.

Thus a first amendment of the Directive was adopted, in March 1987 /3/, to tighten the provisions for certain very dangerous chemicals, including chlorine, MIC, phosgene and sulphur trioxide. It also provided an opportunity to correct some technical inaccuracies in the Annexes so that a more balanced and effective implementation could be assured.

The Second Amendment

The Basel accident in 1986, and some other accidents involving isolated storage, demonstrated the need to strengthen the requirements of the Directive with respect to the

storage of dangerous substances not actually connected with industrial operations. The Directive was amended for the second time in November 1988 /4/ on the basis of the lessons learnt from these accidents. The aim was not only to extend the scope of the Directive to the storage of dangerous chemicals, but also to strengthen its provisions regarding information to the public. This amendment will come into force in June 1990 for new installations, with a later application date for existing plants.

Before being amended, the Directive covered only some kinds of dangerous chemical storage, the Second amendment now extends the scope to storage of dangerous substances and/or preparations at any place, installation, premises, building or area of land, isolated or within an establishment.

In order to identify what, in fact, constitutes dangerous storage, an approach based on a list of named substances and a list of categories of danger is used, together with their respective threshold quantities. The list of 28 substances enables the identification of storage where the most dangerous and widely used substances are held. The list of categories ensures that all other storage involving dangerous substances or preparations, which are classified as toxic, very toxic, explosive, oxidizing, extremely flammable or highly flammable under other relevant Community Directive are also covered.

The second amendment also added a new paragraph to Article 8.1 to require that information be communicated to the concerned parties on an active basis, through public

information media such as leaflets or information boards. It also defined a new Annex VII which specifies the content of the information to be provided to the public: for example, a simple explanation of the activity carried out at the site, the names and harmful characteristics of the substances involved, potential effects of major accidents, details of warning systems and how information would be provided during the course of an accident, how to behave should an accident occur, assurance that suitable on-site arrangements for accident management have been made, reference to off-site emergency plans, and details of how further information can be obtained within the limits of commercial confidentiality provided for in national legislation.

IMPLEMENTATION OF THE DIRECTIVE

Member States have the responsibility to implement the Directive in their own countries and, once the necessary legislation has been drawn up, it is then sent to the Commission which checks the provisions to see that they comply with the Directive. The treaty establishing the Community foresees that the Commission may bring proceedings against Member States which do not meet their obligations under Directives. The various stages of these proceedings are a letter serving notice, followed by a "reasoned opinion" by the Commission and, finally, bringing the matter before the European Court of Justice /5/.

The Commission plays a leading role in helping Member States implement the Directive in a harmonised way. The most important activity is the organisation of regular meetings of

the Committee of Competent Authorities for the Implementation of the Directive, which is chaired by the Commission. At these meetings various questions concerning the technical implementation of the Directive are discussed, providing a forum for the exchange of information, advice and experience gained from implementation in the different Member States. The Committee has also been convened to discuss the lessons to be learnt from recent industrial accidents, which led to the Amendments discussed earlier.

Some examples of the Committee's work include the formulation of guidelines to help interpret the concept of a major accident, drawing up a standardised notification form for reporting major accidents, developing a gravity scale to measure the seriousness of a major accident, and comparing in a structured way the different approaches existing in the Member States for meeting the requirements of Article 5 for safety reports.

INFORMATION EXCHANGE

The Commission organises workshops for national inspectors on the technical aspects of the implementation of the Directive. In addition, the Commission sponsored a conference, in 1987, on emergency planning and will sponsor one on particular problem of communicating with the public about major hazards in May of 1989 (see Otway, 1988). These conferences are intended to provide a forum for the exchange of information amongst the various actors involved, eg, government, industry, public groups and scientists.

The Commission has also recently established a Community

Documentation Centre on industrial risk which collects, classifies and summarises technical guidelines, safety rules, accident reports and similar materials and edits them into a form suitable for use by the actors mentioned above.

Finally, the Commission has established the MARS data bank, at the JRC-ISE Ispra, in which the accident reports supplied by the Member States under Articles 10, 11 and 12 of the Directive are stored for retrieval. The content of the information is analysed with focus on the causes of accidents in order to improve accident prevention. MARS is presently only at the disposal of the national authorities, but procedures are being developed for a wider distribution of statistical information on accidents, consistent with the secrecy obligations of Article 13.

CONCLUSION

The Directive has only been in force since July 1984 and experience continues to accumulate. The Commission will continue to monitor the implementation of the Directive and to explore ways in which it might be improved, especially with regard to deriving balanced and uniform risk criteria for the management of different hazardous activities.

NOTES

1. Council Directive of 24 June 1982 on the major-accident hazards of certain industrial activities, 82/501/EEC. Official Journal of the European Communities L230, Volume 25, 5 August 1982. The Directive does not apply to nuclear facilities, military installations, explosives factories, mining operations, or facilities for hazardous wastes which are covered by other Community regulations.

2. The Seveso decontamination was the largest in the world involving TCDD and these complicated procedures had to be devised under extreme time pressures. Most previous experi-

ence had involved much smaller quantities and contamination had been confined to the industrial sites. Examples of the decontamination problem can be seen in the 1963 Duphar accident, after which the plant was sealed for ten years, dismantled, encased in concrete and sunk in the Atlantic, and Bolsover (1963), where the plant was dismantled and a TCDD release and buried in a deep hole (Lees, 1980).

3. Council Directive 87/216/EEC of 19 March 1987, Official Journal of the European Communities, L 85/36, 28 March 1987.

4. Council Directive 88/610/EEC of 24 November 1988, Official Journal of the European Communities, L336/14, 7 December 1988.

5. See: Report on the application in the member states of directive 82/501/EEC of 24 June 1982 on the major-accident hazards of certain industrial facilities, Commission of the European Communities, COM (88) 261, Brussels, 18 May 1988.

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**Development of an Austrian Data Management System
for the Cleanup of Contaminated Areas
Caused by Chemical or Industrial Accidents**

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ABSTRACT:

Serious accidents at chemical and other industrial facilities present a large potential risk in an increasingly urbanized society. These accidents can involve the transport of extremely toxic materials over areas of many square kilometers in the form of aerosols causing severe contamination of valuable land and potentially the injury or death of many people. Because of the many uncertainties which can exist, action plans for the containment and cleanup of the accident site are not as well defined as for a smaller accident.

To support the rapid planning and coordination of the cleanup of such an accident, an Accident Site Data Management System (ASDMS) and an ASDMS Support Team is being developed by the MRRD in support of Civil Defense programmes by the State government of Styria and the Federal Government of Austria which can significantly reduce the impact of such accidents by providing timely information for planning and cleanup authorities.

The ASDM system consists of computerized aids, already developed by the MRRD for geochemical exploration programmes and land-use planning, and reapplied to emergency management planning for an ASDMS. These computerized aids can be used in the pre-accident phase at a state or national level for the maintenance of information such as geologic maps, soil maps, topographic relief, cultural features, demographic data and land-use maps which would be of significant value in preparation for a man-made or natural disaster.

The ASDMS Support Team, formed by existing staff at the MRRD, is responsible for the data management and analysis of incoming information in a zone of contamination caused by a industrial or major chemical accident. The ASDMS supports all hardware and software necessary to support an accident site cleanup. The team is composed of all personnel necessary to perform data capture and analysis of data collected at the site. The system gives State and Federal Authorities and international organizations involved in such emergencies immediate access to computing facilities which could, to a great degree, assist in the rapid planning for a major cleanup.

Preparation for a major cleanup operation proceeds in two phases: 1) preliminary planning before an accident occurs and 2) detailed planning at the time of the accident. Both of these phases involve the use of computer systems, database and statistical techniques that have been developed for geoscience data. The re-application of these systems and techniques as an ASDMS significantly enhances the existing programme of the MRRD and provide a new direction for research in the years to come.

CONCEPT AND OVERALL GOALS:

Introduction -

The Mineral Resources Research Division (MRRD) of the Joanneum Research Association has undertaken a review of the computer systems that have been developed exclusively for geological and geochemical applications to identify alternate uses for these systems. Thanks largely to the continuing contact with the International Atomic Energy Agency (IAEA), it has become apparent that the systems which were developed for geological applications are the same systems that are currently being recommended for the cleanup planning of large nuclear accidents involving hundreds of square kilometers (IAEA, in preparation). Presently the MRRD is involved with the IAEA in the preparation of a document for the overall operational planning for accident site management for nuclear facilities. The author served as chairman of a working group dealing with data management systems for this IAEA report.

Specialized Systems May Not Be an Answer -

An important principle in accident and disaster management is that systems which are in daily use tend to be the systems that can be used most effectively during an emergency because they tend to be more reliable. Existing personnel, who are already familiar with the use of such systems, can be employed as part of a larger, decentralized, system. This larger system would include components of normal civil services such as police, fire brigade, rescue and ambulance services as well as the possibility of using military to interdict and evacuate an area as required.

Horizontally Integrated Systems -

Ideally, the systems being used during the course of an emergency should be part of a larger, horizontally integrated system providing ad hoc avenues of communication between the various groups in the system such as described by Jaske (1986). One specific part of this overall planning system that the MRRD is taking part in is the implementation of an Accident Site Data Management System (ASDMS) and support team whose responsibilities are to:

- Recommend optimal sample collection techniques;
- Manage information being collected from the accident site;
- Control the quality of the data and;
- Analyze these data in order to assist in planning the most efficient cleanup of the accident site.

The ASDM system and Support Team would be used after the initial release of toxic substances has been brought under control and the accident scene has been stabilized.

Pre-Accident Planning -

Pre-accident planning is an important objective in any accident response system. Hazards and potential toxicity must be taken into account by fire and rescue workers from any accident site at the very early phase of an accident. This implies prior training not only on the part of the fire department in dealing with potentially hazardous materials but also first-aid rescue workers and police who may be put at risk and who constitute a first-line response in the community.

One major goal of pre-accident planning is to establish not only clear channels of command and control but also to inventory the potential accident sites identifying the nature of the hazards and individuals whose expertise might be required.

Pre-accident planning for the purpose of returning contaminated soils and buildings to acceptable levels requires an extensive and comprehensive evaluation of geological, geochemical and hydrological conditions as well as detailed information regarding population density and demographic data before the accident. Additionally, cleanup techniques which would be suitable for a particular type of accident must be identified. It is the objective of this type of pre-accident planning to establish priorities on the cleanup such as the protection of drinking water supplies, the identification of waste disposal sites, the establishment of guidelines for acceptable levels of a toxic substance and the overall approach philosophy to the problem of accident site management.

Computerized Aids -

The computerized aids that are available for an ASDM system are those that have been developed over the past few years by the MRRD for geological and geochemical data handling. Packages such as the extensive Geographic Information System (GIS) based on ARC/INFO, the Geochemical Package (GCP), the Laboratory Control Package (LCP) and the Geostatistics Package (GeoStat) are all directly applicable without change to an ASDMS both in the pre-accident phase as well as post-accident management and cleanup. Also, the geophysics package (MAGPAC) which performs line-levelling and calculations on airborne geophysical data is suitable for both magnetic and gamma-spectrometric data.

Multidisciplinary Staff -

In order to effectively implement an ASDM system, a trained, multidisciplinary staff must be available on short notice who can deal with large quantities of data effectively. From the ongoing work in exploration geology, the MRRD has a number of individuals who have experience and training in the field of geology, geochemistry, geography, classical statistics as well as geostatistics, sampling theory, laboratory control systems and information science.

Technical Support for Emergency Planners -

These systems are available to emergency planners as follow-up support for accidents which may require intervention in the form of large-scale cleanup. Preparation on the part of the staff of the MRRD is minimal because of the similarity of data types. The tactical planning and recommendations required to field an ASDMS Support Team with a complete computer system on short (1 week) notice is in progress for areas outside of Austria. This includes recommendations for different hardware which would be more portable as well as independent power supplies, backups and spares. Table I is the current computer configuration of the MRRD. Table II reflects some recommendations for a portable system.

Geoscience Data Analysis Techniques -

The reason that the MRRD is able to participate in depth with a project of this nature is that the same procedures that are followed for geological exploration are very similar to the procedures that should be used during the follow-up of an accident site. These are listed in Table III. Chief among the similarities are the problems associated with the measurement and statistical analysis of data arising from geochemical surveys and is especially true as it relates to the spatial (geostatistical) analysis of the data.

Information for Policy Makers -

The use of an ASDMS is a considered action following a major accident. After the accident site has been brought under control, a preliminary assessment is made to determine the

aerial extent of contamination. Based on this assessment, a decision is made either to study the impacted area in detail (ASDMS option) or perform a direct cleanup action if the extent is limited.

If the ASDMS option is selected, plans must be in place to support the system remotely or to relocate the system near the accident site. If the system is relocated, tactical support must be available to pack and transport the system; provide housing and office space for up to 20 team members; and provide technical support in the form of power supplies, telephone lines, etc. for the system itself.

These considerations must be discussed by policy makers so that the concept can be effectively included in the overall catastrophe action plan.

Benefits -

The primary benefit of the ASDMS concept would be the immediate availability of a computer system and response team which could rapidly process information from an accident site and assist in planning the appropriate clean-up action in the case of a civil emergency caused by a chemical or industrial accident. The quickness of such response could significantly reduce the direct impact of the accident by providing rapid site clean-up planning.

Timely response at a very early phase of the accident could prevent contamination of water supplies, the recovery of valuable land before deep infiltration of the contaminant, the reduction of the total quantity of toxic material entering the food cycle and significantly reduce the overall cost of the operation by minimizing the total quantity of contaminated material that would require disposal. Information gathered in a pre-accident phase would significantly decrease the time required to make decisions regarding protection of critical water supplies.

PRE-ACCIDENT PLANNING:

General -

It is important to recognize the advantages gained in pre-accident planning for the eventuality of an accident and the advantages gained at the post-accident phase. Pre-planning consists of the identification of all industrial or waste management sites that constitute a long-term threat to public health and safety, the nature of the potential accident and its possible consequences, a detailed command and control structure for each potential accident utilizing civil and, as required, military services to control the accident site as well as the establishment of cleanup criteria. Formal pre-planning for a complex cleanup operation is necessary to achieve a high degree of efficiency and speed and to mitigate the effects of the accident.

Development of GIS Information -

The information requirements for an effective ASDMS system consists of detailed geographic overlays from each site to allow for the identification of the most important factors. These include land-use, cultural features, population centers, roads systems, water supplies, watersheds, soils types, geology, surface hydrology, geohydrology and topography. The use of a GIS is essential in the preparation of this kind of detail and in order to manipulate these data along with the distribution of resulting contaminants for post-accident planning. These data permit the rapid establishment of priorities in the event of an acci-

dent. Table IV describes the information that must be available for preliminary planning after an accident; Many of these data types can be effectively included into a GIS.

The development of an extensive GIS for the purpose of pre-accident planning and post-accident management can be achieved through the same software currently running at the MRRD. Similar systems such as the Federal Emergency Management Agency (FEMA) system uses as a core for the response system a geographic underlay for the input and organization of this type of information. Proposals set forth by the International Atomic Energy Agency for the cleanup of nuclear accident sites underscore the need of an extensive GIS for accident planning.

Inventory of Industrial Sites and Hazards -

An inventory of industrial sites posing a potential hazard and a summary of the hazardous materials stored at the site is necessary to determine the response to an accident and the appropriate countermeasures. These data can be maintained on a GIS.

Transport of Hazardous Materials on Roadways -

A estimation of hazardous materials on roadways including rail should be made in order to optimize the location of tactical materials and equipment which would be used in case of an accident. These data may also be maintained on the GIS.

Second, more stringent methods should be adopted to control (not necessarily restrict) the transport of hazardous materials both internationally and within Austria. An example would be to install a computer network tracking hazardous materials and verification methods for compliance. Transport accidents involving incorrectly labelled vehicles such as the phenol accident in Karinthia (Widetschek, 1983) resulted in the injury of seven fire brigade members before the substance was correctly identified. For international transport, this point would require at each customs office a data entry terminal recording the material, route and destination.

Recommendations have been made in Austria (Widetschek, pers. comm.) for the voluntary registration of vehicles within Austria containing hazardous materials especially regarding transport through roadway tunnels, but this effort has failed.

Identification of Emergency Waste Depositories -

Emergency waste depositories should be identified or constructed to service higher risk areas. These depositories should be designed with appropriate sampling channels and monitoring systems. Relatively small accidents such as the above cited phenol accident resulted in 1,000 cu. meters of contaminated soil which had to be stored in an interim depository. Accidents such as in Góiana, Brazil (IAEA, 1988) resulted in 3,500 cu. meters of material requiring storage. In any case, virtually every minor accident involving the spillage of petroleum products on roadways requires the use of absorbants which must be properly disposed of. These emergency depositories should stock sufficient containment in the form of drums to handle roadway spills. Accidents involving extremely toxic pesticides such as in Spielfeld (Widetschek, 1979) required the disposal of absorbants use to control the spill. At the present time, no emergency waste disposal sites have been identified for Austria although provisions in the law permit authorities to confiscate sites if required.

POST-ACCIDENT RESPONSE:

Notification -

The first phase of post-accident response follows the notification of probable need. At this time, the team members are alerted and initial preparations are made for the accident follow-up. These preparations include a review of the toxicity of the material, physical properties that would influence transport and dispersion and briefings on safety and procedures.

Initial Response -

The initial response is for the ASDMS manager to meet with the Emergency Director and his team and review the accident scene itself, control and command headquarters and to make known the physical requirements for the ASDMS. The systems analysts meet with the members of the Emergency Director's staff to review specifics of the situation and to identify problem areas. Tentative recommendations regarding sampling of the contaminated area and the identification of topics of high priority (protection of domestic watersheds, etc.) are made.

Tactical Planning -

After the initial review on-site of the ASDMS manager and the systems analysts, tactical plans for the relocation (if required) of the ASDMS are made. Much depends on where the sampled material will be analyzed; either on-site or in a laboratory and the nature and size of the accident.

Plans for packing and transporting the hardware are confirmed as well as the preparation of suitable quarters, power supplies and telephone links at the remote site. Planning of this nature would be done in cooperation with military authorities.

Implementation -

The ASDMS and Support Team are relocated to the command and control center for the accident and the hardware configured. Office space and living quarters are established. The ASDMS becomes operational.

ASDMS SUPPORT TEAM:

General Considerations -

The personnel required to support the ASDMS concept are fundamental to the successful outcome of the cleanup operation. It is essential that the core group be in existence prior to the accident and familiar with the hardware and software and that the various specialists be available. The management and function of this group is the a component to a successful response system.

The ASDMS Support Team must communicate rapidly and effectively with the Emergency Director and his staff explaining not only the existing capabilities of the ASDMS but also be able to adapt quickly to changing needs and priorities during the course of the cleanup planning. The composition of the group must reflect, in depth, the working requirements with sufficient redundancy and expertise to provide a sound support team.

The ASDMS support team advises the Emergency Director and his staff on the techniques

and sampling procedures required to evaluate the distribution of the toxic substance with the help of specialists in geochemistry, geophysics or geostatistics.

Prior Existence -

This team must be in existence prior to the accident because of the difficulties in assembling an effective group of scientists on short notice. With the basic group already in existence, specialists such as biologists, chemists, health physicists, toxicologists or other scientists may be rapidly integrated into a working team.

Identification of Team Members -

Identification of individuals who would serve on an ASDMS Support Team has been dealt with in a straightforward way. In most cases, the nature of the work itself as applied to geological exploration is very similar to the tasks involved in accident site management. In general, the team consists of systems analysts, geochemists, statisticians, programmers, data entry staff and various specialists required to assist in the cleanup planning. Because many different types of accidents could occur with many different types of toxic substances, it is assumed that specialist information will become available at the time of the accident, or that the specialists will be designated prior to the accident for support in the pre-accident planning phase.

Communications -

Communication structures within the ASDMS Support Team are both vertical and horizontal. The core of the system is the group of geochemists and systems analysts who communicate horizontally to members of the Emergency Director staff to solve specific problems related to the planning of the cleanup operation. Problems regarding the allocation of various hardware components and the overall system integrity is the responsibility of the Systems Manager and his staff.

Organization and Team Structure -

The team consists of between 14 and 18 core staff into which various specialists outside the group may be incorporated. The core group is organized as follows:

- **Systems Manager**
The Systems Manager is responsible for the overall operation of the ASDM system and support team and uses the services of the systems programmer, systems engineer and database manager to establish the ASDMS at a remote site with the initial help of the other members of the support team. After operation has commenced, he maintains communications with the authorities as well as the geochemists, statistician and other systems analysts to provide them hardware support as they require.
- **Systems Programmer**
The systems programmer is responsible for the initial installation of all systems and user software and works with the systems engineer and database manager to maintain operational integrity of the systems.
- **Systems Engineer**
The systems engineer is responsible for the physical installation and integrity of all hardware and hardware links in the system during the course of the cleanup operation. With the systems programmer, he reports to the systems manager on the operational integrity of the system.
- **Database Manager**
The database manager is responsible for database security, protection and backup.

He maintains liason with the systems programmer and the statistician and especially the geochemists and systems analysts for the periodic backup of all essential data in the system.

- **Communications/Secretary**
The secretary is responsible for receiving all telephone communications and relaying them to the appropriate party and is responsible for establishing all files related to the cleanup programme including copies of all products supplied. He maintains a log of all communications and types reports as required.
- **Statistician**
The statistician is responsible for the overview of all statistical analyses being conducted and advises the geochemists/systems analysts as well as members of the Emergency Director's staff on the appropriateness of various techniques. He also works in the same way as the geochemists/systems analysts on the preparation and analysis of data.
- **Geochemists/Systems Analysts (2-3 or more)**
The geochemists/systems analysts along with the statistician are to maintain direct communications with the Emergency Director's staff and work jointly with them on the preparation and analysis of data resulting in the cleanup plan itself. They communicate principally horizontally and inform the systems manager of their needs and problems. They inform the database manager of the datasets that are being developed and that require periodic backup.
- **Programmers (2-3)**
The primary purpose of the programmers is to provide direct assistance to other experts at the accident site in the use of the computer systems. The secondary objective is to deal with specific tasks as directed by the systems manager to assist the systems programmer, database manager, statistician and geochemists in solving specific programming problems.
- **Digitizer Staff (2-3)**
The digitizer staff support the work of the geochemists and systems analysts and are responsible for the data entry of geographic data and the preparation of various maps utilizing the GIS.
- **Data Entry Staff (2-3)**
The data entry staff is responsible to the geochemists and analysts for the entry and checking of all data not in machine readable form.

The composition of the team reflects the needs for rest during the course of the accident as well as considerable overlapping of expertise to assure integrity of the implemented systems.

ASDMS COMPUTERIZED AIDS:

Background -

The MRRD began development of a series of software packages in 1983 in order to fill a series of contracts in geochemical exploration in Austria. One of the major problems

with the existing packages then available was that conventional statistics and especially conventional multivariate statistics based on normal populations were often not appropriate in the environments being analyzed. Concepts in robust statistics as applied in Exploratory Data Analysis (Tukey, 1977; Huber, 1980) were used to develop these packages. The packages extensively use graphical techniques to display the results of analyses and produce results which can be directly used by the GIS.

Activities by the MRRD have included not only geological but also geochemical and geostatistical analyses of multidisciplinary data including studies on forestry, agricultural, air pollution and ground water studies.

Hardware Graphics Support -

The software that has been developed makes extensive use of the capabilities of Tektronix hardware, especially the models 41xx and 42xx, as well as the VMS operating system on the VAX computer system. Currently, work is underway to convert these packages for use by IBM compatible microcomputers; However, the utility of these software systems as an ASDMS can only be accomplished through the use of a moderately powerful mini- or microcomputer such as the VAX series in which a multiuser and multitasking environment is required.

The software systems themselves must be used by highly trained and specialized professionals who are not only familiar with the computer and software environment, but are experienced with problems of geochemical sampling and the measurement of spatial data. This group forms the core of the ASDM system. In the following discussion of the various computerized aids, this fact should be kept in mind.

Geographic Information System (GIS) -

The GIS that has been in use by the MRRD is the ARC/INFO system developed in the USA. It currently has about 50% of the world-wide market for software systems of this type. Geographic data can be treated as thematic layers in the the GIS which may be functionally combined and analyzed in complex ways.

The GIS for use in accident site management has been documented elsewhere (Jaske, 1986). The data includes much of the basic information from pre-accident planning which has been described in previous sections. Table IV summarizes the information that the IAEA (in preparation) required for preliminary planning after a nuclear accident. A considerable amount of this information is available for pre-accident planning.

Data Base System (DBS) -

The DBS module is the basic data and file management system for the other analytical software systems such as the Geochemical Package (GCP) and the Geostatistical package (GeoStat). The main features of the DBS are an interactive data entry and editing facility and simple report generation. The intermediate or final results of all programs operating from the GCP and Geostat environment may be saved in files for use by the DBS. Normal ASCII files may be created at any point from the DBS files.

Geostatistical System (GeoStat) -

The GeoStat system was developed by the MRRD to analyze problems related to spatially oriented data of all types in two or three dimensions. Its chief use has been in the kriging analysis of geochemical as well as environmental data (such as forestry, pollution and agricultural studies). Besides classical variography and geostatistical modeling, the structural analysis of spatial data is facilitated by various and newly developed graphical tools.

Geostatistical analysis is essential in post-accident planning because it provides very specific tools to understand the probabilistic nature of sampled spatial variables. For instance, geostatistics may be used to determine an optimal sampling grid to achieve a pre-specified confidence or to recognize portions of a sampled area where a high variability is present. These are key issues in understanding the distribution of a contaminant.

Variography is used to investigate the spatial behavior of data and to make certain critical decisions regarding measurement reliability. Sources of variation of the data may be split in the geostatistical model into random, local and regional structures. Also, anisotropic behavior can be taken into account in, for example, wind propagated contamination. Variography may also be used to investigate the statistical behavior of the depth of penetration of a contaminant in soils. After kriging, the estimates of depth of penetration form a three-dimensional model from which the total volumes of contaminated materials may be calculated.

Certain geostatistical techniques such as probability kriging are especially suited for the estimation of cutoff concentrations of contaminants where remedial action in the form of cleanup must be accomplished.

Graphical output may be saved in "metafiles" and later combined through windowing techniques for the preparation of more detailed graphics for further interpretation. Synthetic contouring of kriged surfaces may be quickly prepared using the GCP or UNIRAS graphics packages. Alternately, a contouring package (CONTOUR) may be used in the preparation of maps.

Geophysics Package (MAGPAC) -

The geophysics package was developed for the interpretation of airborne magnetic data and the preparation of resultant maps. For use with any airborne data including gamma spectrometric, it facilitates line levelling and interactive data verification, noise reduction through Fourier transforms or moving average (spline) algorithms, and orthogonal gridding using bicubic splines. The gridded data may then be contoured using the CONTOUR program and customized using the MCAD package. The MAGPAC was used in the preparation of about 200 aeromagnetic maps for the eastern provinces of Austria.

CONTOUR program -

Utilizing the GSPP (General Surface Prediction Program) subroutine library developed by the Technical University in Graz, CONTOUR is an automatic contouring program which plots isolines and line labling. Output is directed to a "metafile" from gridded data input which in turn may be edited by the MCAD package in order to provide an interpreted result.

Geochemical Package (GCP) -

The GCP package is a generalized set of statistical and graphical routines which permit interactive evaluation of geochemical and other data bases using concepts developed in Exploratory Data Analysis. Results from the GCP may be converted for use by the GIS in the preparation of maps which include geographical data. Likewise, information contained in the GIS may be converted for use by the GCP for analysis.

The GCP also has five standalone modules which includes the Laboratory Control Package, Statistical Graphics Package, Multivariate Graphics Package, Multivariate Statistics Package and a Data Base System. These permit a great range of data analysis techniques including basic univariate statistics, multiple regression analysis, correlation analysis, factor and principle components analysis as well as correspondence analysis all utilizing graphical

techniques developed by the MRRD. Graphical output may be directed to device independent "metafiles" and saved for later processing. Windows may be created during plotting and any arrangement of graphics is possible in a single plot. All procedures in the GCP are command driven with help menus utilizing features in the VMS operating system. Although not part of the GCP system, the geostatistics package (GeoStat) makes use of the same design philosophy and may be used to process data from the GCP and to create graphics which may be combined with the other systems. These systems are described in the following sections.

Laboratory Control Package (LCP) -

The LCP was developed to assure adequate quality control for samples submitted for analysis as a result of extensive geochemical sampling during the exploration programmes by the MRRD. Utilizing robust and resistant statistics, the LCP is an extremely sensitive quality control tool utilizing duplicates and control samples to track laboratory precision and accuracy. Practical laboratory quality standards may be established much earlier as a result of the robust techniques as compared with normal statistics.

Laboratory control is essential from the earliest phases of an accident cleanup to insure that the analytical results are both accurate and precise because of the consequences of the decisions based on the results. Analysis of replicate samples can establish the effective precision of the analytical result but not the accuracy. Consideration should be given to the prior preparation on control samples to establish accuracy.

Statistical Graphics Package (SGP) -

The SGP is a part of the GCP and utilizes a graphical-statistical analysis of data using Exploratory Data Analysis and includes resistant and robust statistics. The SGP permits the following graphical and tabular data display techniques: Histogram; Density Trace; One dimensional Scattergram; Boxplot; Cumulative Density; X-Y Plot with interactive identification of sample numbers; Scattergram with interactive grouping function; Ternary Diagrams; Draftman's Display for graphical display of the correlation matrix; Streamplot to allow profiles of selected variables; Geographical display of data; Univariate statistics including robust mean and spread and outlier detection; Correlation matrix of selected variables (optionally as a robust technique); and Covariance matrix (optionally as a robust technique).

Multivariate Statistics Package (MS) -

Multivariate statistics using normal and robust techniques is a key part of the GCP. Procedures include analysis of variance, multiple regression and correlation, factor and principle components analysis, cluster analysis, canonical correlation and discriminant analysis. Most result may be displayed graphically.

Multivariate Graphics Package (MVG) -

The MVG package facilitates the graphical presentation of multivariate data in the form of multiple code symbols such as barcharts, profiles, glyphs, diamonds, stars, suns, castles, trees, boxes and Andrew's curves. The MVG is especially useful in visually discriminating various patterns of multivariate data in a single graphical presentation. Like the other parts of the GCP, it is command oriented and graphics may be combined with other "metafiles" created by the GCP and used in combination with data from the GIS.

Computer Assisted Drafting Package (MCAD) -

An MCAD package was developed as a standalone system but for which output from "metafiles" created by the GCP, LCP, GeoStat and MAGPAC may be edited to produce customized graphics. Like the other graphical packages, it uses the hardware features of

the Tektronix 41xx and 42xx graphics stations for the creation and editing of the graphics. The MCAD program is heavily used in the preparation of borders and legends for GCP and GIS graphics as well as the MAGPAC and GeoStat package.

The MCAD package may be used to customize the results of any of the graphics output from the systems currently running at the MRRD. Utilizing the capabilities of the Tektronix 41xx and 42xx graphical display stations, modifications may be made directly to contoured maps to customize the result or to any of the graphics prepared by the GeoStat, GCP and other packages. This facility provides an important capability for the analyst to quickly prepare carefully interpreted results.

UNIRAS Graphics Package and Library -

UNIRAS is a commercially available software package consisting of an easy to use and powerful program library. It features interactive modules which use the library routines and offer menu driven user services. UNIRAS is currently being used by the MRRD in problems such as contouring as well as three and four dimensional viewing of data. UNIRAS uses ASCII files converted from GCP and GeoStat DBS files.

The VAX Computing Environment -

The VAX computing environment includes several very important factors for a successful ASDMS. These are:

- **VAX Family**

The VAX computing family guarantees total compatibility of user applications from desk-top machine to large mainframes. This factor along the fact that several of the other systems for accident site management have been designed utilizing VAX hardware (e.g. FEMA) permits rapid installation of an ASDMS on any available VAX.

- **Long-Term Planning**

Because of the internal compatibility within the VAX family, it guarantees long-term planning for the development of software.

- **Rapid Upgrade**

In the event that a smaller VAX system is saturated, a larger VAX may be rapidly installed without major interruption of any of the systems.

- **32 Bit Architecture**

The VAX family of computers are fully addressable 32 bit machines.

- **Networking Facilities**

Networking facilities are fully developed including the 20 Mbaud local area Ethernet and including communications facilities with other microcomputers such as other VAX computers or IBM microcomputers. Telephone networking with other computers are supported.

- **Backup Facilities**

The VMS operating system supports convenient backup facilities for the entire system or may be customized to backup critical files automatically on a predetermined schedule such as by the hour as an incremental backup.

DISCUSSION:

Computing Capabilities -

A considerable amount of computing capability is required, both in trained manpower as well as in computing speed and storage capability for a ASDMS to operate efficiently in a multiuser environment. In addition, other applications requiring a significant amount of graphics such as the GIS will be running concurrently. Examples of other applications are processing of analytical data such as soil, water and sediment samples by statistical techniques, a laboratory control system and geostatistical processing of data. The mix is not significantly different than what is currently present at the MRRD.

Professional Requirements -

The statistician, geochemists and other systems analysts are at the heart of the ASDM system and provide the analysis of the data supplied to the support team. The analysts and programmers in the ASDMS Support Team will be required to carry-out the requests of the Emergency Director after analysis and explanation of the problem. Likewise, they will be required to explain the capabilities of the system and to provide specific support in design of the sampling campaign and the analysis of the data.

The ASDMS Support Team must have good communications skills and be able to work directly with other experts at the accident site. The systems manager will have the responsibility of selecting suitable staff and committing various pieces of hardware for the various tasks. The database manager will have the responsibility of ensuring that resulting database structures are compatible with the various applications and for ensuring the hourly backup of all information of importance on the system.

Ad Hoc User Support -

In the event of an accident scenario, there will most likely be a number of other ad hoc users requiring significant computing capability from a VAX environment. An example of this would be if software developed for the Federal Emergency Management Agency (FEMA), which also runs in a VAX environment, were installed on the existing machine configuration. As can be seen in Table I, sufficient empty ports exist to handle any additional hardware as might be required or available in an accident situation. The systems manager must decide what applications have priority in the event of hardware saturation in cooperation with the Emergency Director. In any case, they can be rapidly integrated into the ASDMS Support Team.

Hardware Considerations for a Mobile System -

Three other points of concern should be raised regarding hardware and apply if components of our system were installed in a remote location: First, certain components such as the electrostatic plotter are relatively sensitive and would require an air-conditioned environment to operate effectively. The second point is that the VAX itself should be a ruggedized version, as self-contained as possible and be able to operate in extremes of temperature, humidity and physical shock. The present VAX 8300 environment is not such a mobile piece of hardware. As proposed in Table II, a ruggedized microVAX 3600 might be one solution.

It would be a serious problem if the CPU were not able to survive transport and operation in a less than ideal environment. Finally, an independent power supply utilizing surge protectors, an alternate battery supply and a standby generator should be matched to the power requirements of the computer system and be available on short notice. Most of these requirements could be met with military and in some case fire brigade support.

CONCLUSIONS:

The development of an ASDM system and support team based on hardware, software and manpower currently being used for geological investigations is not only a desirable goal but also a very low cost alternative to having a similar system on standby solely for accident site management. The major advantages are:

- The systems have been well tested using data very similar to data resulting from an accident;
- The manpower using these systems are expert in the handling of geochemical data, statistics and geostatistics necessary for the proper analysis and handling of the accident data and;
- The ASDM system and support team are available on immediate notice.

An ASDM system will be used at some point in the future whether to reduce the impact of a major accident or to gather data in a concise way to prepare for the eventuality of an accident. Many intermediate products may be obtained from such a system during the systematic collection of geographical data. These include land-use planning maps, tactical planning maps for fire brigades and rescue units, identification of watersheds and hydrologic units as well as ecologically sensitive regions, transport corridor hazard maps and other services. The systematic development and update of information of this type will become increasingly valuable in the future.

Finally, an essential consideration for the implementation of an ASDMS is the policy maker. Without proper clarification to the policy maker of how such a system can be implemented and its purpose, function and requirements, the system cannot be included into the catastrophe action plans. This is a problem of the scientist and engineer presenting effective arguments to explain the necessity of the system and the benefits in the political arena.

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TABLE I
PRESENT HARDWARE CONFIGURATION OF MRRD

Computer:	DEC-VAX 8300, 24 MB Memory, dual processor, components for Hardware System Cluster (HSC) installed.
Hardisc:	4 x DEC RA81 (4 x 456 MB); 2 x DEC RA82 (2 x 622 MB). (Controlled by an HSC controller connected to the VAX backplane.)
Tape Drives:	DEC TU81 (25-75 ips, 1600/6250 bpi); DEC TS11 (45 ips, 1600 bpi).
Graphics Terminals:	1 x Tektronix 4115B (1280 x 1024) + 4957 Tablet; 3 x Tektronix 4207 (640 x 480) + 4957 Tablet; 2 x Tektronix 4107 (640 x 480) + 4957 Tablet; 3 x M68 Workstations (640 x 480) (Inhouse designed hardware for Tektronix 4107-4207, DEC VT125 emulation).
Text Terminals:	20 x VT220 and VT320 terminals.
Inkjet Plotters:	Tektronix 4693/colour; Tektronix 4692/colour; Tektronix 4696/colour. (These Inkjet plotters are configured with the Tektronix graphics terminals for hardcopy.)
Vector Plotters:	HP 5786B/A0/8 colours; HP 7550A/A3/8 colours.
Electrostatic Plotter:	Calcomp 5835 colour/A0 (1024 colours).
Digitizer:	GTCO Digi-Pad 5/A0; Tektronix 4958/A2. (Used in conjunction with a Tektronix graphics station.)
Personal Computers:	2 x IBM PS2/60, 1 MB memory, 70 MB harddisc; 2 x IBM PC/AT, 640 KB memory, 20 MB harddisc; 1 x IBM PC/XT, 640 KB memory, 32 MB harddisc.
Printers:	DEC LA-120 lineprinter; FACIT 24 dot matrix printer; 2 x DEC LN03R Laser printer.
Networking:	ETHERNET, 20 Mbaud; Leased line, 9600 baud, Joanneum in Graz; Leased line, 9600 baud, Leoben Mining University. (This line gives access to BITNET, ARPANET and other international networking services.)

TABLE II
ASDMS - ACCIDENT SITE DATA MANAGEMENT SYSTEM
REQUIREMENTS
PROPOSED HARDWARE

*	1	microVAX 3600 (Ruggedized, if possible)
*	32	Mbyte main memory
*	560	2 x 280 Mbyte RA70 disc storage
*	622	Mbyte RA81 disc storage
*	1	TK-70 streamer tape 296 Mbyte
*	1	TU81 plus 1600/6250 BPI tape drive
	2	Terminal Servers (DECserver) (for 32 ports)
	5	TEC 4215/4107/4115 Graphics Stations with TEC InkJet 4692/4693/4696 hardcopy and TEC 4957 digitizers.
	5	VT320 Stations
	3	Plotters: HP-7550 (A3 & A4), HP-7586 (A0) & CALCOMP 5835
	2	Digitizers: GTCO-DIGIPAD 5, TEC 4958
	2	Communications modems
	1	IBM/PS2 system (for IBM format data)
**	1	360 kbyte disc for IBM/PS2
	1	DECNET/ETHERNET capability
	2	Printers
	9	empty hard ports
**	17	empty multiplexed ports (can be used for other terminals or preferably other personal computers)
**	1	Generator/alt. battery power supply/surge protector
**		Cabling

SOFTWARE

VMS V4.7
Geographic Information System (ARC/INFO)
Data Base System (DBS)
Geostatistical System (GeoStat)
Geophysics Package (MAGPAC)
CONTOUR Program
Geochemical Package (GCP)
Laboratory Control Package (LCP)
Laboratory Control Package (LCP)
Statistical Graphics Package (SGP)
Multivariate Statistics Package (MS)
Multivariate Graphics Package (MGP)
Computer Assisted Drafting Package (MCAD)
Standard system utilities
Communications software (Kermit or DECNET/DOS)

- * = Currently proposed for a mobile demonstration system
** = Available from outside sources

TABLE III
ACCIDENT SITE DATA MANAGEMENT SYSTEM
Geological Exploration Techniques That
Can Be Applied to Accident Management

- 1) Preparation of Geographic Information System for the site; For example:
 - a) Geology
 - b) Soils
 - c) Land-use
 - d) Hydrology
 - e) Geohydrology
 - f) Cultural features
 - g) Demographic data
 - h) Topography (Digital Terrain Model)
- 2) Orientation sampling of the target
- 3) Sample preparation and submission to laboratory
- 4) Variogram to estimate zone of influence of data
- 5) Selection of geostatistical model
- 6) Optimal grid spacing based on geostatistical model and required confidence level
- 7) Detailed grid sampling of target
- 8) Sample preparation and submission to laboratory
- 9) Laboratory control systems to control accuracy & precision
- 10) Variogram to check chosen geostatistical model
- 11) Kriging to estimate concentration
- 12) Block-by-block calculation of grades - tonnages
- * 13) Decision for removal (mining)
- ** 14) Optimized removal (mining) plan of area
- *** 15) Preparation of waste disposal sites
- ** 16) Block-by-block removal (mining) control for area
- 17) Follow-up of localized high-grade areas

In parallel, other types of environmental information may also be processed in a similar way:

Statistical analysis of any type of data
Presentation of multivariate maps of the target
Contour mapping of any form of data
Geostatistical analysis of geophysical data
Correction and evaluation of airborne geophysical data
Modification of flightline spacing
Correction and evaluation of carborne geophysical data
Modification of carborne spacing

- * =In mining, an economic decision; In waste management, a safety decision.
- ** =Presently, these functions can be performed by the GIS alone.
- *** =Performed by the governmental agency

TABLE IV
Data Required To Be Contained in an ASDMS
for Preliminary Planning After an Accident
(Modified after the IAEA Report)

- Demographic data - population size and distribution;
- Layout of cities/towns including identification of areas/facilities requiring special attention or priority cleanup;
- Land classes and land use;
- Geology and geohydrology of the affected area; Soil types and permeability; Groundwater depth and direction; Topography;
- Meteorological data including airshed topographic data;
- Cleanup criteria for different zones and other relevant regulatory (radiation protection, etc.) information;
- Data on toxic materials in a facility and likely accident release sources for likely scenarios;
- Organizational aspects for managing the cleanup plan for various sub-zones as foreseen in the pre-accident planning;
- Background environmental monitoring data base for the area;
- Grid layout of area;
- Location of critical areas of river/lake systems which could be susceptible to inflow of large volumes of contaminated water from the accident or cleanup;
- Location of critical downstream drinking water supplies which could be affected;
- Actions which may have to be taken shortly after an accident, for example: the installation of in-ground hydraulic bypasses to reduce groundwater flow through the contaminated area; Diversion ditches or dams to prevent contaminated water from reaching clean water systems;
- A statistical sampling plan for different zones;
- A confirmatory monitoring plan to validate that cleanup meets the required criteria;
- Analysis of best cleanup options for each area based on assessment of soil type, land use, equipment available, etc. and the quality control programmes associated with each option;
- A list of equipment and facilities required for cleanup and the location of available items (including potential disposal sites);
- Assessment of personnel requirements for various scenarios including a list and telephone numbers of key staff members and details of the notification system;
- International contacts (as required) on all phases of the cleanup.

Policy Responses to Large Accidents:
An International Research Perspective

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Introduction

Accidents may be viewed as aberrations infrequently infecting society's technological investment or as normal events linked to a deepening technological commitment - or even as something between. Regardless of which view dominates, it is clear that technological successes have been accompanied by large accidents that are resisted, ignored or downplayed, but rarely accepted as inevitable.

Examples are numerous. Nuclear energy was pursued as a peaceful use of a new source of cheap electricity with accidents all but ignored. Manufacture of chemicals was based on rapid marketability with little thought of accidental environmental contamination and human health effects. Offshore oil and gas development has grown rapidly with accidents downplayed as one-time, abnormal events. America's space program was launched with reaching for the stars overshadowing any discourse on potential accidents.

Yet time and experience with large accidents involving each of these technological programs has led to various policy responses affecting many nations. Indeed, each of the government programs and industries surrounding these technologies have come under serious public scrutiny with national moratoria, litigation, bankruptcies, disinvestment, and greater constraints and pressures on the employment of these technologies, whether east-west or north-south.

As Wenk has noted, "One of the more tenacious paradoxes of technology we repeatedly encounter is that we have more choices but less time to choose." (1) The potential accidents from the introduction or continued use of all large technological thrusts deserve extensive scrutiny by all stakeholders, particularly those who may be gravely disadvantaged such as operators, workers and regional residents. Yet any study of

technological accidents and consequences takes an enormous amount of time, resources and expertise. Thus, careful and deliberate choice is necessary for potential researchers because of the competing demands on international research resources.

Large accidents may be seen as national or international crises demanding instantaneous responses through policy apparatuses normally given to promoting the technology involved. Compacted time horizons and high decision stress tend to restrict focus to the recovery and limiting of immediate adverse policy consequences for the organizations involved. Their goal is normalcy as soon as possible from the surprises created by a large accident. (2) Nevertheless, society has a major role to play in technological accidents, particularly those deemed large in potential international consequences. The national organizations surrounding large accidents are only one set of actors in an international technological drama. The mere existence of large accidents proves that even the technologies most imbued with a nation's dreams, as the space programs, cannot be immune from international scrutiny into their technological management. The Challenger accident revealed complex inter-organizational relations and restricted information flows that were at the core of these events and their consequences, and it would have benefitted from the research perspective of international analysts. (3)

Some Perspectives Learned from My Accident Research

My first opportunity to be involved in research on large accidents from an international systems perspective occurred in 1977 - over a decade ago. This work began with a well blowout on a North Sea platform, the first such accident there; it continued with the Three Mile Island nuclear accident, the first getting world-wide attention. (4)

This effort also was the first attempt by IIASA to study large accidents and it supplemented the earlier joint IIASA-IAEA risk studies.

What sparked my attention and subsequent commitment of international research resources was not the size of the accidents per se. Indeed, both accidents had no loss of life and minimal adverse impacts. Rather I was struck with the discontinuity between

industry and regulator statements on the impossibility of such events and the obvious existence of the accidents. As well, the national commitments to these technologies were evident in the fundamental role of these programs for the nations involved and by implication the rest of the world. Are such accidents to be ignored or downplayed in order to promote the relevant technologies? And if so, what are the roles of potential impactees - those whose lives and fortunes are at risk? What is the effect on international society from various national technological commitments with resultant accident profiles?

My research did not touch on these broader themes. Such was the first lesson learned: the extrapolation from one event to broader themes is tenuous. As much as the more basic questions were relevant, the research effort remained focused on understanding the system accident response: the actors involved, their organization, information used, communication made, and the pre-accident context. One critic of the first study labelled the work as "mere informed journalism." Nevertheless, after studying the second accident along similar lines, interesting themes began to emerge. (5) Therefore, it seems clear that studying a series of large accidents over time can lead to major hypotheses about the impact of technology and national commitment for society. I would urge that IIASA continue this work.

Another lesson learned involved the need for close ties to national reticulists to act as networkers in the nations involved. (6) My earlier North Sea work acquainted me with the person later selected to lead the national accident response in Norway. This acquaintance gave me access to key informants throughout the country. The level of access and overview was considerable and resulted in the first international conference at IIASA that involved regulators, industrialists and scientists. Later work with the TMI event did not involve a reticulist in advance; however, being from the U.S. gave me knowledge of how to find informants. In addition, my international status was of value in obtaining this access as well as my being sanctioned by the National Academy. Since IIASA has the network in place through its national committees, this arrangement is of immense value in getting access to those relevant to large accidents. Perhaps designating someone in advance in each country to act as the research reticulist would be useful.

Accidents wait for no one, including researchers. Had no surplus of funds been available, I would never have been able to accomplish the first study. The entire North Sea effort came from under-spent funds from the Bratsk-Ilimsk Territorial Production Complex study, and the TMI study emerged from surplus funds in the Energy Program. It seems that if IIASA would engage in primary research on large accidents a contingency fund to support this work is necessary. However, a more appropriate role in today's financial squeeze may be for IIASA to have standing agreements with selected researchers in each country to investigate large accidents along pre-selected lines. Then IIASA would be in a position to develop comparative studies and conferences based on in-country research.

Nevertheless, one key perspective could be lost with such an arrangement: the international questions brought to bear on a nation's institutional structure for technological decision-making. To my amazement certain fundamental questions about the accidents I studied went unasked: What if the preventive actions fail? What if the impacts exceed that planned for? What if the accident unfolds in a different manner than expected? What national features generate "blind spots" in accident assessment? What planned responses exist for international concerns? All these and similar questions are obvious, but they did not form the core of the pre-accident scenarios I studied in two countries. Therefore, I conclude that an international systems analyst has much to offer to national technological program managers and policy-workers.

My research also noted a lack of balance between accident anticipation and response. The more an accident seemed to be anticipated the less planned the response to the accident when it occurred. This imbalance suggests that an organization's capacity for response to demands is finite. Douglas and Wildqvsky also have seen this phenomenon: "The probability that any known danger will occur declines because of anticipatory measures. But the probability that if the unexpected happens it will prove catastrophic increases, because resources required for response have been used up in anticipation."

(7) Systems analysis generated the perspective to understand this concept, and international systems analysis led to seeing it as a universal problem of all technological programs.

Thus, the literature on organizations, bureaucracies and institutions becomes important to studying policy responses to large accidents.

How Large is Large?

It is clear that no society can enter the domain of zero risk or even ensure a wholly rational policy response for each large accident. Resources are too limited, time constraints too overwhelming, rewards for quick fixes too high, expertise too thin, and social attention spans too short. Equally, some attempt must be made by IIASA to set priorities among large accidents competing for scarce international research resources. Therefore, I suggest the following to spark discussion:

- o First, large accidents involving new technologies that overwhelmed the regional response being used to control the accident and its impacts. Here TMI and Chernobyl provide examples of accidents where national governments took command from responsible groups.
- o Technologies involving very high impacts both in intensity and extent of effects that may or may not go beyond national frontiers. Here chemical and genetic industries demonstrate real (Seveso, Bhopal) and potential examples.
- o Technologies involving multi-national organizational elements linked together via manufacturing contracts and franchises. Here only one national group may have the complete information on the components. Major weapon systems and certain chemicals provide examples.
- o An accident with potential impacts spilling over national borders that carry high but uncertain effects to several nations. Here chemical and nuclear plants along international rivers and borders come to mind.
- o Technologies involving major national investments of resources and prestige that are potential vehicles for international technology transfer. Here offshore oil, major weapons, nuclear power and space programs provide examples.
- o Technological innovations under considerable national pressure to perform successfully, involve a high degree of uncertainty internationally, and involve judgment calls by

many independent national organizations. Again, weapons systems and genetic manufacturing come to mind.

What may be surprising in this list of six dimensions is that cost per life saved or similar measure is not mentioned. No doubt it could be included, but I find that it is not a guide to national policy or research. (7) For example, chemical waste volume and disposal is far more potentially lethal than radioactive waste yet chemicals are discarded with lesser regulatory requirements and hence costs than radioactive wastes. Radon exposure in houses may exceed exposure to chemical wastes yet its risk has only begun to be considered and costed. Enhancing highway safety is a relatively cheap investment yet it has been subjected to decades of delay. On the other hand, only seven people died in the Challenger accident with billions spent to redesign the shuttle and an entire program put on hold for 32 months. Thus, costs do not appear to be a guide to national research investment.

What was surprising is that only transportation and infrastructure accidents are eliminated from applying the above criteria. While large accidents involving air, sea, rail and truck transport together kill and maim hundreds of lives annually and are international in scope, they involve well-known technologies that do not overwhelm regional response capabilities; they already have been transferred throughout the world; they do not carry high uncertainties in their consequences (except when carrying toxic material); they do not involve multiple international decision-makers; they are not under intense national pressure for operational perfection. Accidents in the transport sector are seen as normal events, regrettable and to be avoided but acceptable. No nation imposes moratoria on any form of transport after a major accident with large loss of life and property.

As well, large accidents involving dams, bridges and mines involve proven technologies and operating conditions. These accidents are more sporadic than transport accidents

yet share similar characteristics in their lack of straining regional response resources; their common use in each nation; their known impacts; the limited number of decision-makers; the lack of national operating pressure. Indeed, the day I flew into Wien to begin work at IIASA in 1976 was the same day the Reichsbrücke collapsed. Other than hasty inspections of other Danube bridges and hurried remarks of reassurance by the Mayor, few showed concern and traffic intensified over other bridges.

What is important about these dimensions - the potential devastation of large areas, the potential international impacts, the potential technology transfers, the multitude of independent international decision-makers, and the national push for superior performance - is their combined international consequences. In combination they carry the necessary and sufficient elements to generate accidents large enough to warrant international research response. That even national decision-makers are responding to international pressures to restrain unintended technological impacts is the testimony of the recent intermediate missile treaty to ban and destroy these missiles. Use of these new missiles would have devastated large parts of Europe, east and west, were being transferred to other nations, involved multiple national decision-makers, and involved intense national performance assumptions. The missiles fit these criteria and the international policy response was for a ban and destruction of existing hardware. This international success perhaps warrants an international research initiative in order to learn the characteristics leading to an integrated international policy response. Thus, I conclude that international research resources should be focused on actual and potential accidents that display the dimensions listed.

The Institutional Matrix Surrounding Large Accidents

Any large accident is an outcome of some breakdown in the institutional infrastructure surrounding a major technology. The organizations involved are connected in various ways to the technology and are held together by the flow of information and contractual obligations, as well as the future impact of any accident on this organizational milieu.

However, the central commonality is the system of dominating ideas about the technology that link them together. Core beliefs are essential to the success of any organization, and especially the metaorganizational form that characterizes large technological programs. Some core vision or direction is necessary for guiding the organizations toward sensing the need for the technology, developing the requisite hardware and infrastructure to fit the need, penetrating or creating a niche for it, and extending the technology deeper into the nation's institutional fabric.

This vision is linked in turn to an organizational structure that facilitates it. There must be political support for the necessary authority and resources as well as practical arrangements enabling each stage of the technological embedding process to go forward. Over time as success occurs this vision about the technology and its socio-political role become the *raison d'etre* for the organizations involved, and the technology becomes fully integrated throughout the institutional structure of the society. The original vision of the technology, its niche and its organizational structure are all necessary elements in defining and maintaining its management strategy. Matching these three elements over time is the major management concern of the organizations involved.

(9)

When a large accident occurs a change is introduced into this institutional matrix. Accidents do not accord with the original vision as they instantly expose the organizations and planning premises involved and how they behave under stress. New political and decision pressures confront the organizations' dominating ideas about the technology and themselves. The manner in which the organizations respond to these pressures is critical to their continued success. The organizations must reconcile a basic conflict in their need to balance their on-going technological thrust with a sudden need to consider unanticipated accident impacts.

To take advantage of this new open climate pressures may arise from several sources

to include: media, whistle-blowers, affected citizens, customers, suppliers, politicians, technological rivals, opposed experts, interested researchers, regulators, contractors, operators, unions, and adjacent nations. These potential impactees can be bound together into a contravailing meta-organizational form, even though no ties other than the accident bind them. Their common vision is the sharing in the accident impacts. They in turn bring pressures to bear directly on the technological institutions and the sovereign authority for change.

Such pressure forces the technological organizations to respond. In general, four types of response can be distinguished: preemptive, prescriptive, preventive, and promotive. (10)

- o The preemptive policy response refers to the attempt to continue the original thrust or direction regardless of the existence of an accident; it attempts to preempt or ignore the accident in the hope of garnering support for the "bigger picture." It is premised on avoiding change to the technological program.
- o The prescriptive policy response includes the effort to pursue the original program while simultaneously attending to accident impacts; it attempts to prescribe ad hoc, one-time limited shifts in the program without a major change. This stance is premised on minimum change to the technology after an accident.
- o The preventive policy response is designed to reduce demands on program change through working to prevent accidents; it attempts to prevent them by accepting add-on or supplementary changes to the program. This effort is premised on measured risk reduction through adopting additional technology before an accident occurs.
- o The promotive policy response is a proactive interplay between the technological program and a risk management program where accidents are viewed as integral to altering the former; it attempts to promote the total technological-risk environment. This approach is premised on changing the technology as necessary to minimize

accidents, even to the extent of eliminating the technology.

These four organizational responses are summarized in Table 1 along with accident examples for each type. While each can be separate responses to large accidents, these responses may form an evolutionary path as the organizations involved encounter stronger resistance to the accident potential of the technology. An increasing integration of the acceptance of large accidents by the organizations within the program directs them toward a new equilibrium position incorporating expected accident impacts. Such would be attempted normally through incremental decision-making which is often the norm when facing organizational uncertainty. Incrementalists argue that by thinking in small steps they can muddle through a problem without recourse to greater knowledge. (11) However, it is doubtful that incrementalism would lead to promotive policies; indeed, major incentives for promotive thinking seem necessary. As Wilson has noted, the more diversified an organization the more changes members will suggest and the fewer will be carried out. (12) Any change has spillovers that adversely affect more organizational members than those suggesting the change. In other words, the opponents will outnumber the supporters of any change, and a major technological program with a far-flung meta-organizational form will face this problem. (See Table 2.)

Thus, it seems clear that socially responsible policy responses to large accidents should begin with the institutional matrix surrounding large technologies. An adequate response is a function of not only the state of technological development but of the institutional features surrounding and directing it. This institutional capacity to obstruct or redirect socially rational policy responses to large accidents is a major research area from an international perspective.

A policy response to potential accidents cannot be deemed adequate without the participation of those whose relationship to the technology is affected. Successful policy formulation necessitates that those involved understand what is happening and why. The degree to which those potentially affected by large accidents function interrelatedly

is determined by the degree of their recognition of such interdependence, and any policy response by definition stays within the limits of recognized interdependence.

Therefore, no society can expect promotive policy responses to originate from the technological program itself. Systems thinking and international trade-offs will go unrecognized, in particular as the degree of national specialization and commitment to a technology deepens. (13) This problem will exist in spite of a latent recognition of international interdependence, especially during a time of demands for national renewal or rallying that a large accident provides. In this sense a principle of minimum dislocation may operate so that acceptance of a radical reorientation in technological management will be thwarted. Therefore, it is necessary to surmount objections and fears of those whose interests lie in an unabashed technological determinism.

To approach this institutional matrix requires a research vision that views large accidents as an integral part of the definition of technological efficiency. In this way the technological program is viewed as strengthened whenever an innovative policy response oriented to minimizing broad accident potential is attempted. Beliefs, as distinguished from knowledge, are the basis for dominating ideas, and beliefs require promotive policy thrusts to redirect them. Research that remains below the critical dimension of technological beliefs risks ignoring the catalyst that drives national responses to large accidents.

Institutional constraints generating less than promotive policy responses by technological programs include a series of intermediate decision-makers or bureaucrats, some of whom simply make poor decisions. In this way a decision is either made several times over or never explicitly made in order to preserve perceived options. Problem definition is hampered since policy-makers are unaware of how the technological program may be influenced by any one policy change. For example, a relevant control system may not be matched correctly with appropriate subsystems. This issue is particularly important

when technological and risk objectives of different nations conflict. Then different weights are attached to the different objectives and international policy responses fall short of that expected from an international systems view. However, even within one nation, different weights can be put on the same information, though all would agree to the objective involved. The Challenger accident is evidence of this phenomenon.

Constraints to Large Accident Policy Research

International applied systems analysis involves well known steps to include: problem definition, objective formulation, establishment of information needs, collection of information, generation and assessment of alternatives, and development of a decision rule. (14) When attempting to apply this format to large accidents several features emerge that constrain the use of this approach.

- o The official problem definition is slanted to both preserve the technological program and to blame those deemed responsible for an accident. As Perrow observes, "Once there is an accident, one looks for and easily finds the great causes for the great event." Any warning signal may go unnoticed by anyone and there always remain warnings "available for recall once there is an occasion." Perrow goes on to note, "One suspects it would be quite easy to convene a commission of inquiry to investigate an accident that had not taken place, and find...failures... that should have produced an accident long ago." (15) Thus, it is clear that the accident itself may be incidental to the causal factors inherent in the technological program. It is then quite simple to overlook more basic policy weaknesses through concentration on the accident itself as well as on certain weaknesses supported by an information base. As well, whistleblowers and the media may point blame elsewhere.
- o The objectives formulated for the technological program reflect the disparate goals that form the inherent conflict in any meta-organizational form, even without a

large accident. However, a major accident can cause organizations to reinterpret their relationships with one another to fit their new assumed needs. For example, new political pressures may emerge that color their interpretation of existing information, or one of the organizations may become more willing to risk than others. Any accident may hide mismatches between goals as the organizations attempt a more solid facade before a public investigation of an accident. In this case a premature end may come to the investigation with the more basic organizational factors remaining masked.

- o Information more readily available for analysis may not match the underlying accident causes. Certainly, a quantitative analysis rarely will be possible. Accident information about major national technological programs may be bound in secrecy whether from reasons of national security, proprietary or fear of political reprisal. Politicians and top civil servants connected to the program will not look kindly on the questions of an international analyst and will remain unavailable. Indeed, one great difficulty is the temporary commissions of inquiry that are created to investigate accidents: they exist for a short time and then disappear. The only long-term organization with the requisite knowledge and information of the accident and post-accident risk is the technological program itself--precisely the organization which has the least incentive to share its information with the analyst. Its overwhelming objective is to return to normalcy as soon as possible and put the accident behind it. Questions from outsiders are greeted with at best a rosy future of technological lessons learned. Fundamental questions such as the implicit consensus of beliefs surrounding the technology are not open for examination. The analyst only can learn best in the brief period of the accident responses when all organizations involved and their dominating ideas are exposed to the outside.
- o The generation and assessment of alternative accident approaches is hindered through

lack of knowing significant information concerning the technology and its niche in the nations involved. Therefore, the analyst is prone to concentrate on other issues with a better information base. As noted above, no continuing accident investigation and risk management organization exists for allowing access to any ongoing accident policy research and the degree of appropriateness of various alternatives.

- o It is a paradox that the only permanent organization with responsibility for accident management policy is local or regional government, even though it has the least knowledge and resources available to respond. Local government is supposed to protect local citizens and property, yet it too suffers from lack of information about technological programs located within its jurisdiction as well as a lack of resources from central government. (16) (While in the U.S. a recent law has begun to document on-site hazardous materials no information is required about the technological program itself.) Indeed, one could expect wrong impressions being given to local governments to reduce anxiety of residents. Thus, even though risk is never eliminated, the institutions with greatest responsibility for accident impacts are under-prepared. The more they act in this way the greater the surprise--and perhaps probability--of large accidents. Thus, severe constraints operate to reduce good information to international systems analysts. The consequences of this restricted information mean that the analyst is freer to concentrate on the inferred core beliefs and policies of the institutions involved and to sketch out the meta-organizational form. From this endeavor the set of incentives and disincentives can be developed and a counter-vailing policy suggested. Nevertheless, how to approach these constraints remains important in order to maintain credibility of analytical results and to ensure effective use of the international mantle.

An International Research Response

An international research perspective can begin to open the door to the above constraints. This effort involves two important tasks.

- o Framing the large accident problem from a trans-disciplinary, multi-national basis breaks through lesser dimensioned efforts that "prejudge the problem and prejudice the answer." (17) International applied systems analysis can include in its research program whatever bounds seem rational from its enhanced perspective. Systems generalists and substantive experts generate differing voices which can be integrated to focus on broader issues of institutional import. This more comprehensive yet integrated international approach can lead to the promotive thinking so necessary to reduce the international risk embedded within the institutional matrix of national technological programs.
- o Use of national reticulists enables international analysts to interface with the multi-layered organizations supporting and opposing national technological programs or otherwise related to large accidents. Such networking is necessary to gain access to all groups relevant to an international perspective on national technological management, even though some national core groups may deny this relevance. Choice of reticulists is important because of the need to go beyond the superficial, conventional wisdom frequenting politically connected inner circles committed to the prevailing national view of technological management. As well, connection to neutral national authorities such as academy of science is important for gaining access to information a core organization would not willingly provide. The reticulist should be as prestigious and neutral as possible toward the technological program. The selection of reticulists by international organizations can endow them with supplementary credentials to help accomplish the kind of access desired, especially if the relationship endures over time.

Both of these advantages are unique to the international research perspective. Focus on the international dimension integral to all major national technological programs is enlightening even for the nation supporting the technology or experiencing the accident. Both the U.S and the U.S.S.R. nuclear accidents generated international fears, confusion, and uncertainty of policy response by potential impactee nations. National technologies that produce such international crises affect international bonding and trust.

The mere absence of a large accident is insufficient to generate integrated international technological and risk management. Indeed, the absence of an accident is no reason to continue any technological program unabated. National technological management should promote international unity, and international applied systems analysis can go far in promoting this dimension.

In order to approach this goal international systems analysis should embrace certain features:

- o Long-term projects are necessary because of the time required to establish the research network among and within the nations included in the project. As well, the institutional complexity of each must be studied before an accident occurs in order to grasp which organizations are relevant, what the questions are, and how to elicit the necessary information.
- o International comparisons of various institutional matrices are important to establish how policy responses are formed, how the range of acceptable policy is forged, and how dissent is integrated into policy responses. In particular, the structure of national research supporting the technological programs should be compared to determine how the technological problem is defined, what resources are available, and what information networks and forums exist.
- o International technology and risk policy attributes can be developed and tested in

a "second round" of research effort. In this round policy-makers should be included and used to assess alternative policy responses included from an earlier international research perspective.

- o Joint international-national communication and planning would seem important as a key adjunct to this research perspective. Establishing communication links could carry international researchers into a more proactive stance beyond mere publication; however, advocacy of linking international technological and risk profiles should prove acceptable over time. Even if such advocacy only is limited to the concept of feedback loops to ensure accidents are seen as integral to the technology a step forward is assured.

What policy responses are necessary for large accidents depends upon what the problem is. Technological programs do not simply appear; they are conceived, promoted, and sustained by an institutional matrix committed to national prosperity. Large accidents involve the unthinkable and challenge this precept. International applied systems analysis is a means to begin thinking about the acceptance process associated with large accidents to redefine the technological program with potential international accident impacts as part of its definition. Then international research can begin to influence national policy toward the international loss associated with large accidents. In helping to create this future we all are stakeholders.

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Table 1. Organizational Responses to Large Accidents: A Typology

	PREEMPTIVE	PRESCRIPTIVE	PREVENTIVE	PROMOTIVE
Objective:	Continue Program; Avoid Change	Continue Program; Least Change	Supplement Program; Practical Change	Shift Program; Total Change
Strategy:	Emphasize Benefits; Ignore Concern	Acknowledge Concern; Symbolic, One-Shot Changes	Retain Technology Minimize Costs	Systems View; Technology Trade-offs
Accident Response:	Tolerate	Buffer	Restrict	Minimize
Example:	Chernobyl?	Bhopal	Challenger	CFC → HCFC
Risk Response:	Accept	Prioritize	Test	Transcend

Table 2. Organizational Factors Affecting Accident Response

<u>Simpler Response</u>	<u>Difficult Response</u>
Narrow scope, little variety of functions	Broad scope, great variety of functions
Stable environmental conditions	Changing environmental conditions
Clearly defined functions	Vaguely defined functions
Relatively simple functions	Highly complex functions
Indivisible functions	Separable functions
Consensus about functions	Conflict, diversity of opinion about functions
Operation in one place or several similar places	Operation in many places with varying environments
Trust in science, statistics	Trust in democratic process, self-management
Appeal to authority, expertise	Appeal to responsibility, peer groups
Use of rules	Use of education

LARGE ACCIDENTS AND RISK LEVELS

Petter Wulff
FOA

1. What is a large accident?

An accident can be large in a number of ways. Largeness may refer to geographical extent like in a country-wide power failure. It may refer to accident duration like in a severe oil blow-out. Largeness may further refer to the number of persons injured in an accident - a thing of primary importance to the medical sector. Very often largeness refers to the number of dead.

Beside all of these physical dimensions of large accidents there is another dimension of possible interest. That is the extent of mass media coverage given to the accidents.

If we look at a well-defined category of accidents like railway accidents (in Sweden) there seems to be a correlation between largeness as measured in number of deaths and the extent of mass media coverage (fig 1). Coverage is here measured as percentage of front page space in newspapers. This measure I will call (degree of) spectacularity. 1)

Private car accidents are more timid guests on the front pages seldom reaching above 10-20% in spectacularity. The correlation between largeness in number of deaths (above an "every day" level of about three dead) and spectacularity is distinctly different from in the railway case (fig 2).

Accidents with small aircraft fall somewhere in between railway and car accidents while the very few fatal accidents with large

aircraft (scheduled and charter traffic) tend to have spectacularity values about as high as the single highest value for railroad accidents (fig 3).

Two conclusions can be tentatively drawn from the examples given. Firstly, different accident categories have different spectacularity weight, so to speak. Secondly, within an accident category there is a rough proportionality between number of deaths above an "every day" level and spectacularity.

The importance of the spectacularity measure is indicated by the fact that the mass media image of an accident is the "reality" upon which the general public must base its reactions and opinions. This "reality" may also be something that decision makers are basing decisions on concerning safety regulations and safety spendings.

It may therefore be a not too far-fetched hypothesis that spectacular accidents influence risk levels.

2. Large scale influence

Three pieces of evidence are put forward in favour of the above mentioned hypothesis as applied on a large scale.

Let us compare first different transportation alternatives. Here car accidents dominate the picture in the annual statistics on fatalities. In the average fatal car accident only one person gets killed. The number of fatalities per year for small aircraft accidents is almost two orders of magnitude less than for cars, while the number of persons killed per accident is a little higher than for cars.

The more spectacular railroad accidents in the form of collisions between trains or derailments show a still lower annual risk level. Finally large aircraft accidents with the largest average death toll and spectacularity per accident show the lowest annual risk level (fig 4).

That is: The higher the death toll and spectacularity per accident the lower the risk level per year.

The second piece of evidence concerns the long term perspective. Since the 1920s the number of fatalities in all accidents in Sweden has increased faster than the population. The number of large accident fatalities (with 5 deaths or more), on the other

hand, seems to have increased slower than the population or not at all (fig 5).

The last piece of evidence concerns safety spendings relating to large aircraft. There are rescue forces at all Swedish airports with large aircraft traffic. It has been calculated that the majority of rescue forces (at 28 of the 34 airports) will be called into action to extinguish a fire in a large aircraft about once every 800 years or so. 2) That does not seem to be the most efficient way of using qualified personnel and equipment.

One possible explanation of the facts and figures given is that the mass media focus attention in such a way that safety measures tend to be concentrated on activities with large accident profiles.

3. A model

The observations made can be fitted into a more general model of interaction between accidents and risks. The model is depicted in fig 6. Let us follow the model's main interaction cycle.

A large accident occurs and becomes spectacular through the mass media. Decision makers of the system concerned are then expected to take on responsibility for what has happened. They come under pressure to do something to restore the confidence of the general public and/or the mass media in the system.

One way of restoring confidence is by promoting extra safety controls; another way is by providing extra means for safety spending. Such actions, if successful, help to bring down risk levels. It may then be long before a new large accident starts the wheel of interaction over again.

Other paths of interaction exist and are indicated in the model. The people operating a system may become more alert and attentive after a large (and spectacular) accident. It is also conceivable that post accident investigations lead to recommendations reducing risk levels.

In Sweden after the Chernobyl accident and the assassination of prime minister Palme the need of action from the highest political quarters is recognized, as the following quotation indicates:

"In those large accidents or other forms of major crises that may take place the government will probably find it necessary to act

both on factual grounds and with regard to public opinion ..." 3)

The mention of an opinion motive for action can be seen a recognition of the pressure exerted through the mass media on decision makers after a major accident.

This pressure may sometimes lead to unwarranted action. This is well illustrated by what happened after the Three Mile Island accident, when nuclear plants worldwide were shut down and restarted more frequently for safety checks, although these phases of operations are by far the riskiest operational stages.
4)

4. Influence of a single accident

Let us now test the model presented by choosing a specific accident to see if there are indications of interactive behaviour.

The example chosen is the most spectacular of the railroad accidents. It happened at a place called Sya (a three hour railroad journey south of Stockholm) in 1975. There a car hit a train and caused a derailment leading to the death of 14 persons. The mass media did respond with heavy front page coverage (about 80%).

In the following fiscal year there was an increase in safety spendings for road-railroad crossings. This seems to be linked to the Sya accident. After that spendings declined again maybe a little more slowly than before (fig 7).

The risk level for train collisions and derailments increases after Sya. A risk level increase is also observed for car accidents at railroad crossings as compared to car accidents in general. Whether these changes could be the result of hasty and/or unwarranted action due to the Sya accident is not quite clear.

With this let us leave the Sya accident for a summing up.

I have tried to point out a few cases where large accidents seem to have influenced safety measures and risk levels.

I have also tried to argue for a view of large accidents not just as random events but as parts of a system of interaction. The problem of the workings of such a system (if it exists) is a matter I propose as a research endeavour. It would be nice if the problem merited some consideration.

Notes and references:

- 1) Spectacularity measurements have been made on the two swedish newspapers with nation-wide distribution: "Svenska Dagbladet" and "Dagens Nyheter". Spectacularity values presented are the mean values of spectacularity for these two newspapers.

Some large accidents may have been on the front page for more than one day. But spectacularity values are based only on the day of largest media coverage (Normally the day after the accident).

To be precise "front page" is equal to first page with news (Around 1970 and earlier pages 1 and 2 of Svenska Dagbladet were devoted to advertisements and formal announcements).

- 2) The Swedish Civil Aviation Administration, report 1985:03/CL, Flygplatsernas Brand- och räddningstjänst (in swedish)
- 3) Defence department report DsFö 1987:01, Samhällets Åtgärder mot allvarliga olyckor - ledning och samordning (in swedish)
- 4) The example is taken from Kasperson et al, The Social Amplification of Risk: A Conceptual Framework, Risk Analysis Vol 8, No. 2, 1988

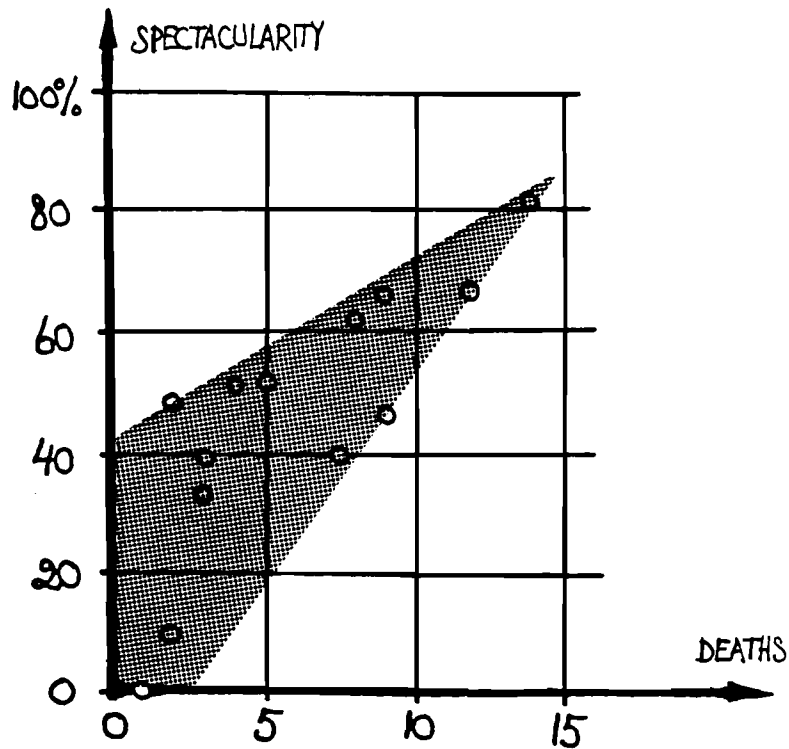


Fig 1. Spectacularity of swedish railroad accidents.

Accidents during the twenty year period 1968-87. For accidents with 4 deaths or less only some examples have been included. Two accidents occurring the same day (1978-08-10) are not included because of difficulty in apportioning spectacularity between them. 13 accidents.

The number of deaths is given as the number known and reported by the newspapers at the time. This number may differ somewhat from actual and final death toll.

(Based on statistics from the State Railways)

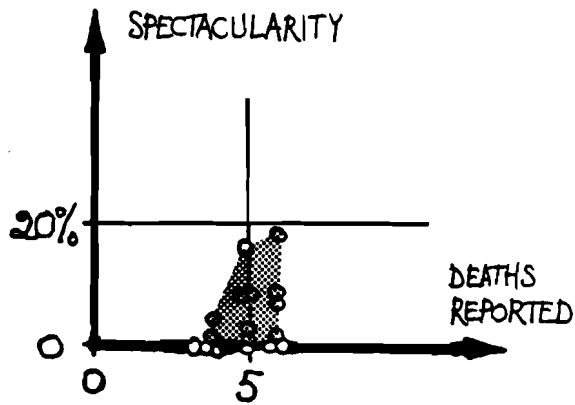


Fig 2. Spectacularity of swedish car accidents (except level crossing accidents car-railroad)

Accidents during the ten year period 1977-86. Car accidents with four deaths are included only for a two year period (1985-86). 17 accidents.

(Based on statistics from the National Road Safety Office)

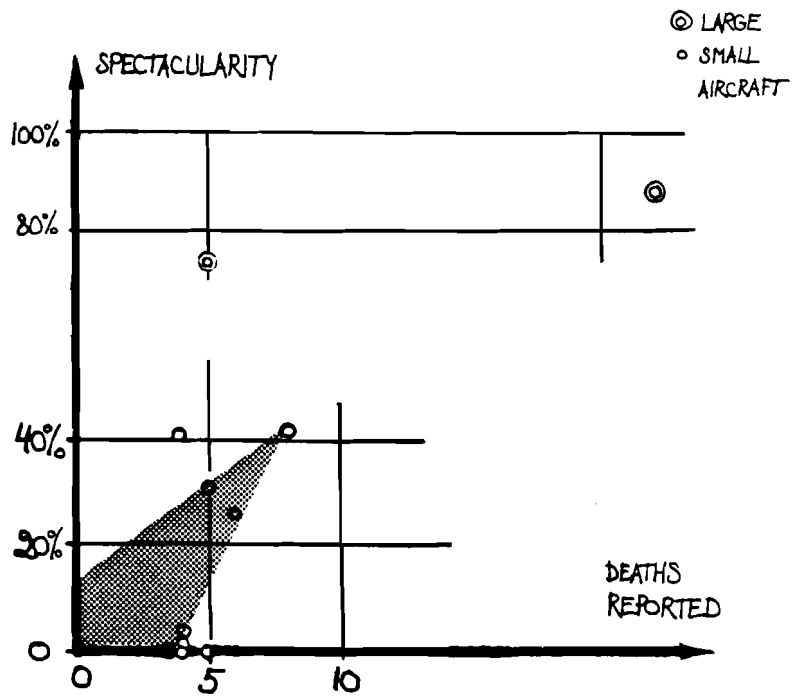


Fig 3. Spectacularity for accidents with large and small aircraft.

Accidents during the twenty year period 1968-87 (with five deaths or more) and the ten year period 1978-87 (with four deaths). Instructional flights and helicopter not included. 2 large aircraft and 8 small aircraft accidents.

(Based on statistics from the Civil Aviation Administration and lists of accidents in FOA report C 10241-M2, February 1984, ISSN 0281-0247)

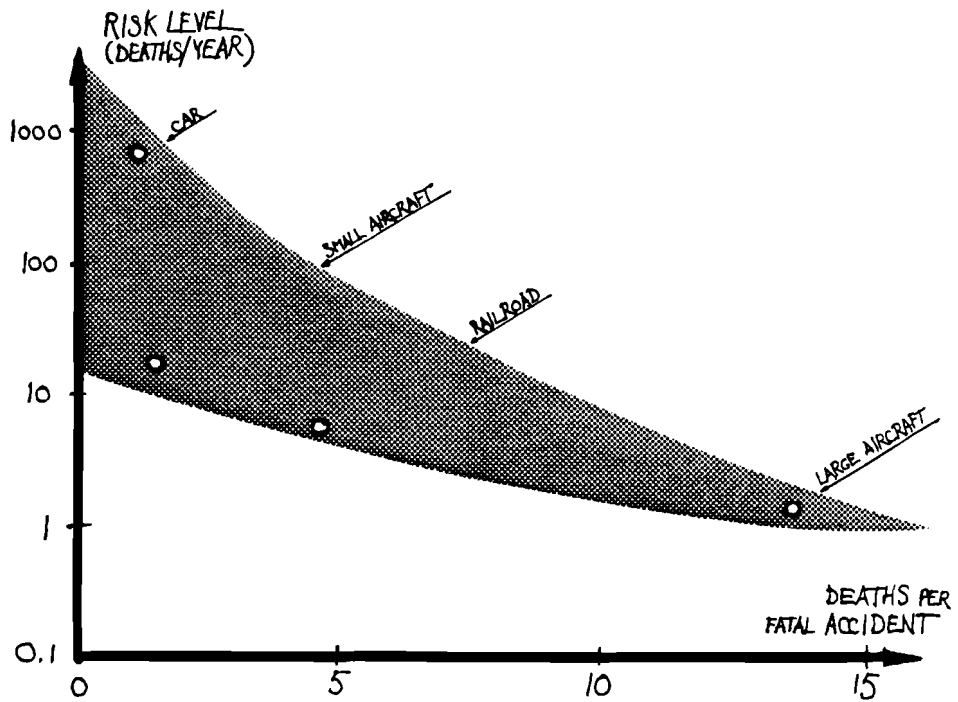


Fig 4. Risk level seems to be a function of accident size in number of deaths.
(Based on swedish official statistics within the last twenty years)

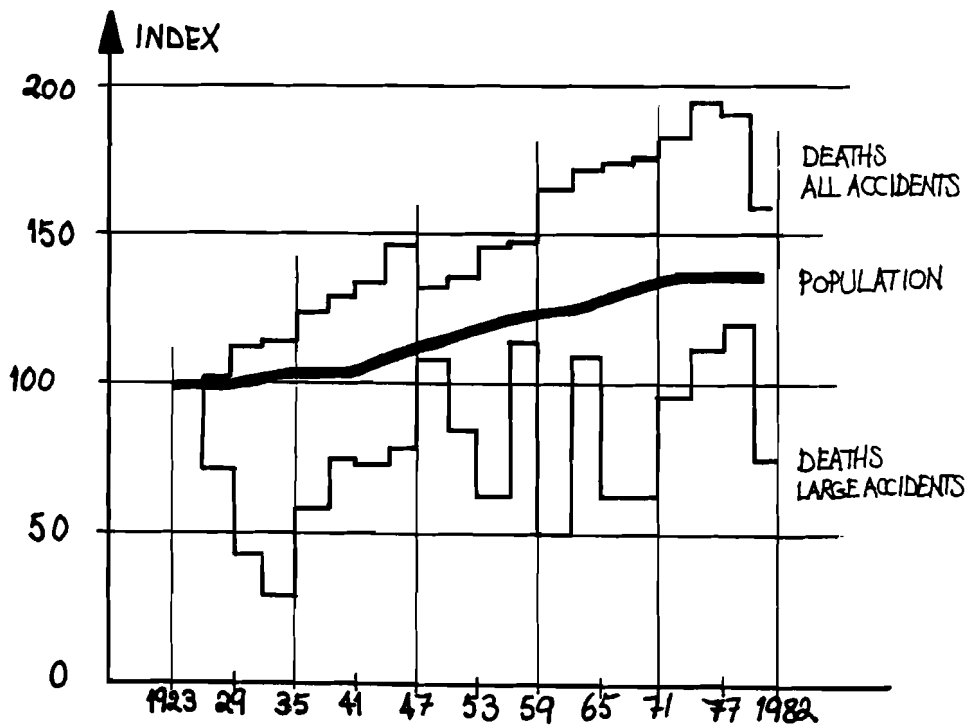


Fig 5. The risk level for large accidents (with five or more deaths) has not increased like the risk level for all accidents.

From: FOA report A 10004-M2, February 1984. ISSN 0281-0204, Stora olyckor. Räddningstjänsten i centrum (in Swedish)

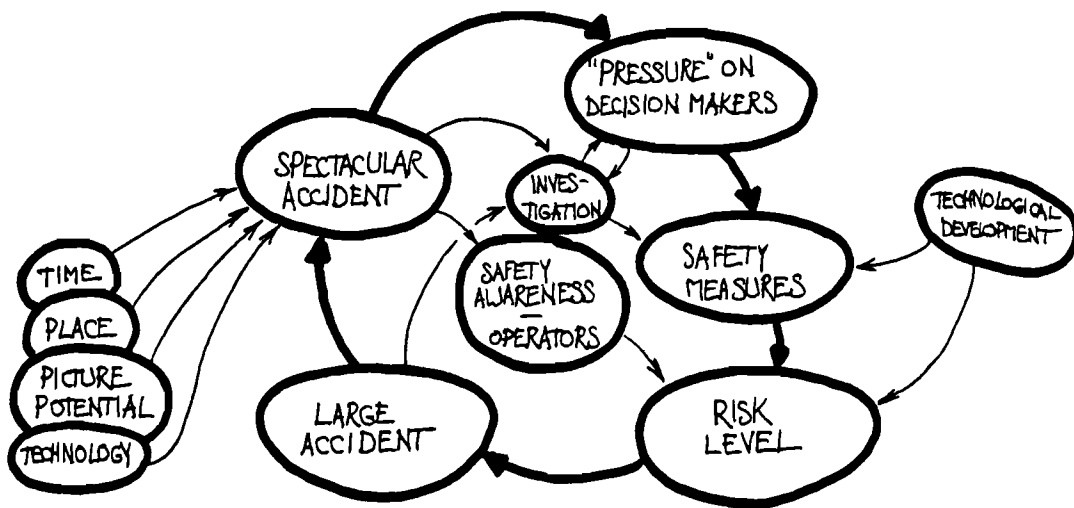


Fig 6. A wheel of interaction

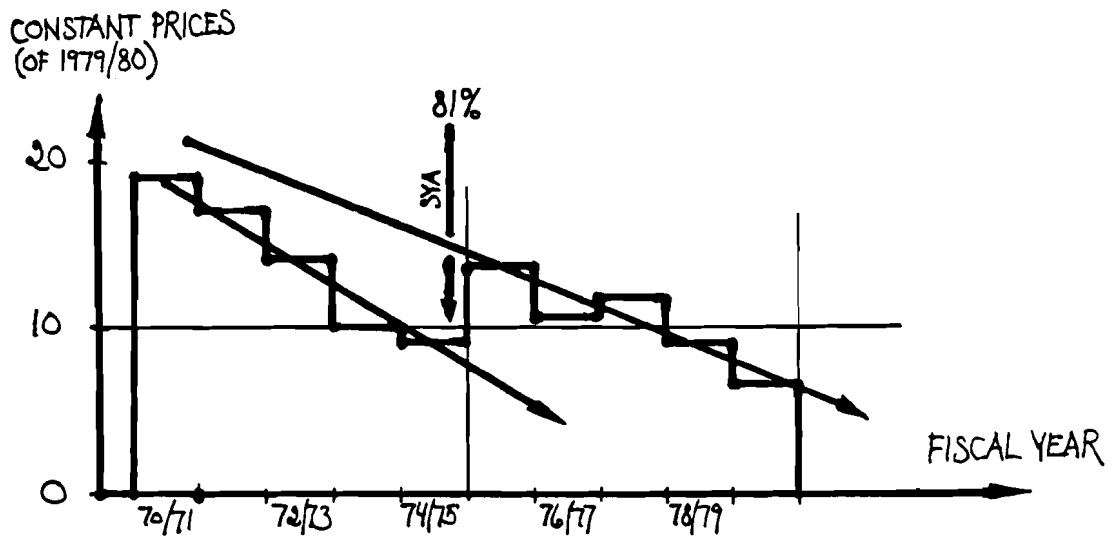


Fig 7. Safety spendings for level crossings increased after the Sya accident.
(Based on annual safety report from the State Railways)

A SYSTEMS APPROACH TO THE MANAGEMENT OF LARGE ACCIDENTS

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1. Risk management as an objective demand of contemporary
technological change

The man-made technosphere or "second nature" man lives in proved to be dangerously fragile. Effects of its disraptures are felt not only nationally but also internationally and even global-ly. Of growing concern are issues related to accidents in industry especially in its chemical and energy sectors, as well as in transportation and agriculture. The soviet academician V.A. Legasov stressed: "A salient trend of our times is that while the probability of an individual hazardous event (an air crash, railway or ship accident, a dam failure or an accident at a chemical factory or nuclear facility) diminishes the scale of its consequences, if it occurs, increases as a rule rather markedly". It can be argued that this feature is manifested at both global and national levels and observed in the Soviet Union.

Despite its relatively small number large accidents result in appriciable economic and environmental damages as well as irreparable human losses. In a number of cases the effects of accidents spill over one nation boundaries.

Large accidents are thouroughly investigated nationally and studied internationally. As a result governmental decisions are taken and even international resolutions or conventions are sometimes adopted that have repercussions on economic development. There is a growing understanding that harmful consequences of accidents can and must be reduced while their risks can not be

brought down to zero.

A number of facts contribute to greater risks of accidents and scope of their consequences. Among them are: a) growing spatial urban-industrial concentrations; b) a sharp increase in the complexity of technical systems, tightly packed with energy, chemically and biologically active components; c) a conspicuous quantitative spread of such systems; d) their declining reliability due to aging; e) growing human incapability to adapt to new complicated technologies; f) an increasing complexity of control and monitoring for such systems that cannot ensure timely technological changeover.

The above selected trends can be traced in most countries and naturally contribute to technological risks as well as effects of accidents including transboundary pollution and possible mutagenic implications for future generations. In addition, the indicated trends result in greater expenses for risk management activities. All that adds to external or public costs of manufacturing and maintenance of industrial products.

Retrofitting "traditional" industrial facilities with environmental controls has reduced pollution but entailed substantial expenses and has not mitigated risks of accidental emissions of pollutants due to failures in pollution abatement equipment or in industrial facilities.

It is against this background that the following sections of the paper discuss economic and social damages incurred by large accidents in the Soviet Union over the recent years as well as the establishment a state risk management policy to anticipate and prevent industrial accidents as well as control its impacts. Operational activities of relevant government services in accident

management are left outside the scope of this paper.

2. Large accidents and their harmful effects

A number of recent sorrowful developments have reminded us that technological change that contributes to the productivity growth, improves labour and living conditions, enhances material well-being and intellectual capacity of the society also brings many dangers connected in particular with complex engineering systems. One can cite many examples of such events. Among them are accidents at nuclear power stations (NPP) in the US and Europe, at Chernobyl in the USSR, at chemical plants of Bhopal, India, and Basel, Switzerland, the explosion of the "Challenger" spacecraft in the USA, several large railway accidents at Arzamas and Sverdlovsk, Kamenskaya station and Bologoye in the Soviet Union, the loss of soviet passenger sea-faring ships "Admiral Makhimov" and "Lermontov" that led to many human deaths.

The above and other accidents that took place in various locations on the globe and resulted from different causes have one thing in common. They prove the point that the saturation of production and services sectors with modern technologies without complementary adequate measures to ensure its safe functioning and maintenance leads to a sharp rise of the "price tag" for a technical failure or a human error. But even the availability of the best equipment with multiple redundancy and other safety devices does not guarantee a 100 percent reliability of its performance.

There is the evidence that even with growing reliability of technological systems the real number of accidents keeps rising. The accidents at NPPs can serve as a characteristic example.

During three last decades in the USSR there were registered

relatively insignificant incidents at NPPs which did not lead to any serious consequences. The Chernobyl accident due to its paramount economic and ecological negative impacts became a national disaster. Melting of the reactor, the following crash (blast) and radiation outlay were accompanied by the nearly immediate death of 30 persons, hospitalization of over 200 and evacuation of 115 thousand of people from the nearby region. The total direct material damage has been estimated to be over 8 billion of roubles or 0,7 percent of GNP.

In recent years railway accidents has become not so a rare event. Despite the decrease in real number of serious accidents and victims per transportation unit (or mileage) as well as material costs and losses in the same terms, the risk of various types of technological accidents and damages related to carrying of hazardous materials -toxic, explosives, etc., increases. As the direct result of only two railway accidents occurred while transporting explosives at Arzamas and Sverdlovsk stations in 1988 nearly 100 persons perished and about 300 were hospitalized (some of them were badly injured). Material losses of solely Arzamas accident exceeded 100 million roubles. Even more grave losses were suffered as a result of large railway accidents took place at Kamenskaya (1987) and Bologoye (1988) stations resulted in more than 130 deaths, not taking into account the wounded persons. Several hundreds persons perished as a result of shipwreck of "Admiral Nakhimov" liner.

The damages contributed by large accidents are not limited by dead bodies and heavy material losses. Substantive socio-ecological impacts are also of great importance, in particular those produced by chemical and nuclear power installations. As an effect of Chernobyl NPP accident a large territory embracing 11 regions

(oblasts) of the Soviet Union where now 17 million people live, including 2,5 million children up to five years old, has been radioactively polluted to some or other degree. According to some estimates, a territory with the radius of more than 2000 km covering nearly 20 countries has been affected by radionuclides.

Potential carcinogenic consequences of the accident being discussed arise particular concern because cancer mechanism has not been adequately researched. According to academician L. A. Ilyin, theoretically possible growth of cancer cases among the population of the USSR, in particular of its european part, induced by Chernobyl accident may reach only hundredths of percent related to average figure of cancer occurrence in the next 50 years. Similar data have been cited by professor R. Geil from California university. According to his calculations, next 50 years would bring 15 thousand deaths (or 0,025% of all cancer-related deaths) additionally due to Chernobyl accident. He believes also that a number of negative teratogenic as well as mutagenic effects for the same period would be less than 700 and 1900 cases respectively. These figures correlate well with L.A. Ilyin calculations supposing that the probability of mutagenic effects constitutes only one third of potential cancer cases.

In general context of carcinogenic, mutagenic and teratogenic repercussions of contemporary socio-economic development the cited data concerning losses related to Chernobyl accident (considered by forsasts' authors as maxima) are, no doubt, far from being considerable. Nevertheless, following humanitarian background it should not be forgotten that even a single case of human death is a tragedy not saying about 15 thousand cases. It should be also noted that Chernobyl accident caused psychological impacts, in particular

an increase of radiophobia. These facts were stressed at scientific conference "Medical aspects of the Chernobyl accident" took place in Kiev last year and at IAEA and INPC congress (Sidney, 1988

3. Risk and emergency management

Various grave consequences of large-scale accidents for the population and economy promote the necessity of working out and rapid realization of cluster of measures aimed at mitigation of technological hazards, preparation, reaction and liquidation of their repercussions. This kind of measures can be conditionally divided into two groups: preventive and operational.

One of them, preventive actions, have been developed and introduced into practice primarily by ministries and departments of those industries which possess technological systems presenting potential risk for humans and environment (NPPs, chemical plants, NLS terminals, gas-oil pipelines, dams, etc.). These actions are also performed by civil defense units, local authorities as well as by relevant departments of trade unions.

The decrease of safety of the objectives discussed manifests the drawbacks and errors in management process and requires its reorganization. These issues are going to be analysed in the following sections of this paper and NPPs and railways will serve as cases.

3.1 Nuclear power

After Chernobyl accident soviet government promoted several regulations oriented towards liquidation of all negative consequences as well as to reform in this sphere of energy production to make it less risky. In 1986 the new Department of nuclear power industry was established and accepted full responsibility for performing technological policy in the industry, including setting up

NPPs and their deployment over national territory. Earlier these functions were performed by the Energy department of the USSR. The new initiative displays once more the specific role nuclear power plays in fulfilling the needs of Soviet economy in energy supply. As to the formulation of technological policy in nuclear power industry this issue remains the prerogative of the USSR State committee for nuclear power as well as supervision over NPPs. Secure exploitation is in the hands of State nuclear power plants control service (Gosatomenergonadzor) organized from the State energy control service (Gosenergonadzor).

The new organizational structure promoted a number of immediate measures which can be subdivided into two main clusters. One of them is aimed to cushion repercussions and maintain full control over the situation resulted from Chernobyl accident till the moment when all rehabilitation measures in the suffered region would be finished. We reckon it may take plenty of time. To reach the point the Department of nuclear power industry established special production complex "Kombinat" to coordinate activities related to deactivation and procurement works at this place. As to quantitative characteristics of these works by the mid-1988 21 million m² of machines and apparatus surface was deactivated, 500 thousand m³ of radioactive soil was burned, more than 1 million m³ of soil was used for dams erection protecting rivers Dniepr and Pripjat. More than 600 villages were deactivated and this procedure is practically completed in possible scale in the town of Pripjat which is being prepared now for conservation. Clearing Chernobyl is task performed nowadays although the most "dirty" districts of the city have been already deactivated. Radioactive debris together with soil have been collected and stored.

Measures to abate radioactive dust are taken in the zone which would remain uninhabitable for many years.

System of thorough radioactive control of surface and underground waters and wells located inside 30-km zone and adjacent areas is developed and introduced into practice. The whole territory of the zone and vicinities as well as food products at the markets are subjected to systematic radioactive monitoring.

Another cluster of measures elaborated and realised by relevant organizations at the head of soviet nuclear power industry is oriented towards restructuring of R & D and technological policies in this field. The process goes on several directions reflecting the desire to introduce systems approach to secure management of NPPs.

Rethinking of the previous schemes of NPP personnel training is among pivotal steps being taken now. Involving additional knowledge basis in the training process and more strict re-examination of personnel capabilities can serve as a good example of these measures. It is especially important in the view that malfunctioning of Chernobyl NPP operators serve as a trigger of a blast. By the way, it is typical not only for this particular accident or our country alone. According to some estimates, 45% of NPP accidents, 60% of aircrashes as well as 80% of accidents at sea are the result of human errors, mainly made by operators though they are not the unique persons to be blamed.

More rigid monitoring and control of NPP functioning is another measure taken as a policy response to Chernobyl accident. Recent comprehensive analysis of NPP at Rovno performed by IAEA experts can serve as an illustration of these activities. After Chernobyl accident all experiments not included in the protocol of tests have been forbidden. As far as scheduled reactors tests

dealing with power changing or fission termination are concerned now it should be performed only in the presence of chief engineer of the plant and inspector from USSR Gosatomenergondzor, who should stand directly near NPP control panel. Additional stationary rods have been erected in all functioning reactors in order to prevent possible chain of errors similar to those made by Chernobyl NPP operators.

One more direction of changes in R & D and technological policy in nuclear power industry concerns reactors design in particular their reliability as well as control systems. As it is known, drawbacks of RBMK-1000 along with those in protection systems contributed to Chernobyl large accident. Therefore decisions were made concerning the perspectives of RBMK-1000 exploitation. In July 1986 the soviet government adopted a special regulation prescribing development of high-reliable, automated control systems designated for NPP technological processes manipulation. It serves as an impulse to start the work which have recently resulted in increase of speed of protection system performance as well as automated regime control of RBMK. These systems are multiply redundant. Before the accident it took 18 seconds to put control rods into the active zone of reactor, now it takes 12 seconds and the system permitting to lay down this figure to 2 seconds is being tested. In a few years coming these protection systems will be installed on all NPPs served by RBMK-type reactors.

Nevertheless, taking into account better technological, economic and safety characteristics of LWRs USSR State committee for nuclear power and Department of nuclear power industry have come to a decision to base future development of this branch of industry on that perfect type of reactors and not to construct more

RBMK- type plants. Besides, expert systems are planned to be introduced in NPP control and protection schemes.

Among policy responses to large accident at Chernobyl new theoretical and practical approaches concerning deployment of NPPs based on the premisis of safety distance between them and large human settlements, low seismity zones, etc. should be stressed as a pivotal step promoting less risky future. These approaches to identify appropriate places for new NPPs costruction diminishing the risk of population exposure to potential radiological threats are realised by two methods. One of them presumes closing of NPPs under construction in case their safety criteria are inadequate. This has been done in spite of relatively large investments already made. Ceasing of NPP erection in Krasnodar and third power block of Ignalinskaya NPP in Lithuania which have already absorbed 14 million and 260 million roubles respectively; of nuclear heat plant being costructed only 37 km from Byelorussian capital Minsk can serve as vivid examples of this particular method. Another kind of methods suppose to revise the scheme of future NPPs' deployment in accordance with safety criteria.

Establishing of vast and comprehensive medical control of the population living in the effected zone along with research of psycological consequences of large accidents similar to that of Chernobyl are one of the policy responses which can hardly be overestimated. Besides continuing of medical observation of the affected persons a number of new R & D and curative institutions have been organized in Ukraine and Byelorussia. In the latter a bank of biomedical data relating to 155 000 persons was set up, radiological load on local population have been studied and their health forecast has been performed. Analysis covering Mogilev and

Gomel areas of Byelorussia as well as Kiev area of Ukraine and Bryansk area of Russia discovers rather strong correlation between cancer increase rates in these regions, e.g. for the former case from 239 per 10^5 inhabitants in 1985 to 267,8 in 1987, and average national (all-union) figures. This supports an important idea that for the early postcrisis phase more or less pronounced trend of increasing carcinogenic cases is not typical, though such a conclusion in respect to distant repercussions should be considered as lacking ground.

The last but not the least area of policy responses to Chernobyl accident manifests itself in the increasing role of public, participating in discussion of NPPs development and deployment issues. This trend is considerably coherent with improvement in the field of risk communication, supply more detailed data on Chernobyl accident and its consequences as well as current radiological situation inside 30-km zone to lay people though we can not say that this information is exhaustive. Along with this line goes the trend of growing attention to the public opinion from the side of republican and federal governments. Refusal to continue construction of NPPs in Byelorussia and Lithuania as well as Ukraine, mentioned earlier, serve as a good example of this trend. It can be also added that shortcomings in NPPs deployment were heavily criticized by the public representatives at XIX All-Union Party conference last summer. The central government decisions denouncing a number of water-economy related as well as mineral resources development projects should also be included in the assets of increasing public activities. We consider all these facts are the result of augmenting power of glasnost and democratisation policy in the Soviet Union.

3.2 Railway transport

Hard consequences of large railway accidents mentioned in the first section of the paper reflect serious drawbacks in risk and emergency management performed in this field of economy. The accidents taken place in 1987-1988 witness that measures undertaken previously lacked systems approach and did not touch the organization scheme of transportation as a whole.

Recently, in October last year, the Safety transportation board was formed. It is considered as an independent structural control division of the USSR Railway department responsible for realising measures directed to accidents' risk minimization, analysing of safety control situation as well as developing main rules administrative and technical actions just to eliminate the causes of accidents. These and other steps should be performed through checking up trains, rails, etc., auditing of safety control work in "linear" and other subdivisions of Railway department, supervision over the diffusion of technological innovations and so on.

Administration over personnel training and upgrading along with coordination of voluntary safety control activities done by "public" inspectors are considered by officials of the Railway department as one of the main responsibilities of the new board. Investigation of the 1987-1988 large accidents disclosed that the errors made by train drivers, rails inspectors, station duty personnel serve as an immediate, direct reason of the crashes.

Organizational shifts in the USSR Railway department itself oriented towards more safe carrying of bulk and passengers are not the only measures taken to lower technological risk linked in particular with hazardous loads moved by railways. Other notable cha-

nges are as follows:

1) introducing of the new preparation order (scheme) of transportation hazardous loads. In particular, current standards of production and carrying of explosives do not prescribe moisturing as well as flegmatization of this kind of load in advance in order not to react to shocks and burning. Now a decision concerning introduction of more strict and safe federal standards is under way.

2) designing special kinds (types) of trains. After large accident took place in Arzamas the USSR Railway department together with other organizations developed a set of more drastic requirements to vans carrying hazardous loads, including use of automatic devices cushioning strong shocks caused by vans transmissions as well as enforcement of their shieldings, etc.

3) planning special routes for carrying hazardous loads in order to pass away from large cities, railway complexes like Sverdlovsk, the largest bulk loading station in Europe. This work is being done now by a substantial team of specialists from the USSR Railway department and relevant institutions.

Another set of policy responses, besides preventive ones, oriented towards diminishing of possible scales of losses is connected with actions taken during accidents per se as well as at the preparation stage. To perform this job regularly emergency commissions have been recently organized. They function at republican and regional (oblasts, kraya) council of ministers as well as soviet executive committees at local level. In case of emergency they give assistance to those suffered, organize evacuation and rescue operations, nutrition, recreation of refugees, etc. Besides, they pay compensations for burial of victims, perform losses assessments and so forth. They are also responsible for supervision and coor-

dination of actions screening people from technological and natural hazards in a specific region of the country. One of these emergency commissions functioning in the region of Arzamas organized the work of 6 thousand persons involved in liquidation of consequences of the large accident occurred there in autumn 1988. Thanks to its activities the city of Arzamas (Gorky region) returned to its everyday life soonest.

4. Policy responses: some problems of implementing

A combination of actions aimed for mitigating technological risk and prevention of emergencies, more rapid and effective liquidation of large accidents consequences as illustrated by cases of nuclear energy industry and, to less extent, of carrying hazardous loads by railways discussed earlier, display an intention to introduce new management approaches to promote safe and sound economic development. These approaches are distinguished by more deep and comprehensive understanding of the problem as a whole: beginning from accidents' causes and terminating with their consequences.

However to our mind, policy responses taken as a reaction on large accidents occurred recently in industry and transport should not be considered fully adequate to requirements produced by systems approach to technological risk management.

Taking NPPs as an example government officials in Byelorussia and Ukraine express their unanimous opinion that a holistic state program for liquidation of Chernobyl accident consequences should be elaborated. This program should take into account both deactivation activities and promotion of socio-economic growth of the areas adjacent to 30-km zone which suffered badly from the accident

Besides, fixed dates to perform the job as well as execution personnel, allocations' volumes should also be designated in the program. Unfortunately, there is no such a program up to now and efforts undertaken by "Kombinat" in the direction being analysed are obviously inadequate and not always effective.

There should not be missed as well that suspending of NPP erection in Krasnodar and to continue works at Ignalinskaya NPP (third block) along with other restrictions lead to lowering overall capacity of power plants by 28 million kWt. As was stated by minister of nuclear power industry N.F.Lukonin at press-conference held on 23 December 1988, this loss can be compensated only by constructing heat power plants. The last as well known are ecologically less sound, in radiological respect in particular. Extensive type of economic growth have yet being followed nowadays orients towards increase of power consumption and does not permit solving energy supply problem at all scope. Thus a shift to energy conservation strategy is of great importance not only from energy supply point of view but in risk aspect as well.

As far as railway transport is concerned it also lacks action program for the safety board mentioned earlier. In part it can be explained by a short time of the board's functioning. But from the other side setting up this relatively independent organization in the USSR Railway department only half a year ago can not be considered timely because the need for it was urgent many years ago.

To our mind not sufficient attention has been paid to ergonomic aspects of safety. However, as illustrated by cases of Chernobyl and railways' large accidents a bulk of operators errors are connected with shortcomings in human-machine interface including ignorance or not adequate attention paid to peculiarities of human

psychology and physiology in the process of development and deployment of devices. According to vice-president of the USSR Academy of sciences K.V.Frolov, only 8% of Soviet technology corresponds to modern requirements on safety and ergonomics. No less actual are the problems dealing with control and measuring devices needed badly for early screening and assessment of technology, technological processes management, etc., as well as those concerning modern equipment for civil defence units which should support activities performed by local emergency commissions.

The last but not the least is the issue connected with development and reliability of communications systems' functioning which provide multichannel and timely information flows to different users including public. Nowadays information systems at the disposal of relevant services do not satisfy the requirements for non-stop working and development of all levels of management as well as public.

The problem of risk communication is also of great value, especially in terms of correct interpretation of available data. For example, not so rarely different means and channels of communication provide contradictory information causing tension both among managers and communities which could be observed in particular during postcrisis phase of Sverdlovsk large railway accident.

Systems approach to management of sophisticated technological units somewhat risky to human health suppose organization of control covering the whole life-cycle of these units: starting from units projects design till termination of their functioning. This kind of approach facilitates overcoming the difficulties mentioned above though of course does not eliminate them completely. Technological and environmental impact assessments of the projects per-

formed by independent (from the ministries or departments) experts along with early discussion by concerned public would make the decision-making process easier. Believe that international experience including that accumulated in IIASA will be paramount in the process of our perestroika in this particular sphere of management. Therefore the usage of this experience can be considered as an important policy response on large accidents oriented towards lowering of technological risk in the future.

Conclusion

The experience gained in the Soviet Union and abroad shows that the analysis of the major accidents took place recently and the practice of liquidation of their consequences have considerably stimulated the development of theoretical and applied research for risk management and design the safety measures for technical (engineering) installations as well as more effective practical steps primarily organizational ones in this field. Concrete economic and managerial aspects at the state-level have been already considered in the earlier sections of this paper. It should be added here that in the USSR Academy of Sciences a Scientific council for risk analysis and assessment and safety control has been created. Its activity takes place within Systems analysis committee. Mass deployment of potentially hazardous techniques in the industries and the rise of antropogenic overloading on the ecosystems lead to specific "irregularities" in the process of socio-economic development. At the local or sometimes at the regional levels they are created by technological and engineering hazards, at the global level this can result in irreverse changes in the biosphere dealing with possible effects of global warming of the climate,

depletion of ozone layer, etc. To manage socio-economic activities successfully it becomes imperative to get more knowledge about conditions of the functioning of technological, man-machine and ecological systems, their bifurcation points and so forth. Taking this new knowledge into consideration to formulate the trade-offs in the development process we can approach to more balanced type of human society.

Believe that in the risk management field the following important positive tendencies should be mentioned:

- the improvement of the risk analysis and assessment methodology especially relating to hazard-prone industries;
- the development of technologies with intrinsic safety capacities, the ability to exclude or mitigate crisis situations preventing self-destructive processes (it should rather be considered as a temporary solution as far as optimal schemes of hazard industries deployment are concerned);
- optimization of a decision-making process under conditions of uncertainty and insufficient information;
- education of the population from the point of view of risk perception;
- creating the systems of control and monitoring for screening dynamics of technological and ecological systems to ascertain the limits of their sustainable functioning;
- assessment of risk factors and possible social costs;
- diversification of the economy structure, deconcentration and lowering the level of energy- and chemical saturation of the respect industries and units;
- taking into account the results of risk assessment as well as en-

- vironmental impact statements performed for industrial installations and projects;
- development of the national and creation of the international legislation systems for technological risk analysis and assessment;
 - the creation of international mechanisms of risk assessment, monitoring and storing the data, early warning of accidents, the center of urgent ecological assistance (INTERHELP);
 - active public participation in discussions of major industrial projects potentially hazardous to population or environment. Participation of communities representatives in environmental impact assessment for local industrial projects.

These and other measures should promote the balanced and sustainable development of socio-ecological as well as techno-economic systems that especially important from the point of view of new common values and targets of comprehensive economic growth.

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CRITERIA AND INDICES OF NPP SAFETY ANALYSIS

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1. INTRODUCTION

A new approach to ensuring nuclear safety has begun forming since the early eighties. The approach based on the probabilistic safety analysis, the principles of acceptable risk, the optimization of safety measures, etc. has forced a complex of adequate quantitative methods of assessment, safety analysis and risk management to be developed. Particular attention is paid to large accidents. It is caused both two large accidents happened (Three Mile Island and Chernobyl) and specific metodological problems arising in development of methods of quantitative safety analysis and risk management.

The present-day safety measures ensure a very low probability of severe NPP accidents. As a result we should consider them as a case of an insufficient statistics. Even in the case of availability of an exact adequate probabilistic description of considered events there is non-compliance between some real results of its appearance and probabilistic characteristics of them, such as the mathematical expectation. These problems of PSA level 3 in case of low probability/high consequence accidents are well-known in literature. They complicate the development of the system of criteria and indices of safety analysis. Besides there are national features in approaches to its development and applications.

Developing of this system on national and international levels especially in frame of PSA, has been paid much attention in the eighties. It is appropriate to mention here IAEA and IIASA activity in this area (see [1,2]). A review of this IAEA activity was made in [3].

In the paper our suggestions on the system of criteria and indices for safety analysis are presented. They have been obtained on the basis of investigations on safety analysis and risk management issues in I.V. Kurchatov Institute of atomic energy (Moscow). This system pertains to level 3 if the PSA terminology is used.

2. GENERALIZED INDICES

The current procedures of the **risk analysis and regulation** raise a question about the measurement of detriment to human health due to the factor under study. For this purpose the natural indices characteristic of the detriment are required. The difficulties of their introduction and justification result from a number of factors. Among them are:

- dependence of harmful effect on age and sex;
- delay between the harmful factor action and its manifestation;
- variability of detriment: death or diseases of different type and severity;
- competition between the effect of harmful factors under study and natural causes.

The natural indices in their original definition should take into account all these factors. As to the application, the averaging

could be made for some factors depending on the field of application. As a result the explicit dependence on these factors could disappear.

Basing on the experience gained in our investigations of the problems of radiation risk analysis (see, for example, [4]) and in the works of other authors the following two natural indices are proposed for the use:

- generalized individual life-long risk R.
- generalized detriment to health G.

The term "generalized" is connected, above all, with the attempt to describe a variety of detriments by a single index.

Generalized individual life-long risk R.

Let an individual at the age "a" be exposed to an individual whole-body dose D. Then the generalized risk R, i.e. the probability of life or health loss due to a curable or incurable carcinogenic effect, equals to

$$R = \int_0^{\infty} \Phi(t, a) [\tilde{h}^{(mt)}(t, D) + k(t, a) \tilde{h}^{(mb)}(t, D)] dt$$

Here t is the time from the moment of exposure, $\tilde{h}^{(mt)}(t, D)$ ($\tilde{h}^{(mb)}(t, D)$) is the density of net-probability of death (disease) from the carcinogenic action of ionizing radiation.

For the functions $\tilde{h}(t, D)$ it is proposed to use the normal distribution

$$\tilde{h}(t, D) = f(D) \tilde{h}_a(t), \tag{2}$$

$$\tilde{h}_a(t) = \exp\{-\frac{1}{2}[(t - t_0)/\epsilon]^2\} / \sqrt{2\pi} \epsilon, \tag{3}$$

where t_0 and ϵ are the distribution parameters; $f(D)$ is the probability of the malignant regeneration of tissue (the superscripts (mt), or (mb) are omitted).

The distribution as given by Eqs. (2) and (3) obtained on the basis of the present-day ideas (see [6] and references therein) about the multistage development of malignant tumor and the general principles of the theoretical-probabilistic description of such a process [4].

Among other quantities in Eq. (1) $\Phi(t, a)$ there is the probability of survival of a person of the age a to the age (t+a):

$$\Phi(t, a) = H(t+a) / H(a)$$

H(t) is the probability of survival to the age t from the moment of birth under normal conditions. The function H(t) is calculated from demographic data. It depends on sex, socio-economic conditions of living, etc. K is the weighting factor comparing the risk of death and disease. Equation (1) is given in a somewhat simplified form relative to the factor k. Generally speaking, all possible considered diseases should be divided into several categories, each category being characterized by its own weighting factor. The quantification of $\{k_i\}$ is a subject of expert judgement.

The risk increment per unit time during the action of a harmful factor will be called a risk intensity:

$$\dot{R} = \Delta R / \Delta t . \quad (4)$$

The average annual risk intensity ($\Delta t=1$ year) is used, as a rule, in the assessment and standardization of individual risk. It should be noted that Δt in Eq.(4) is the period of the harmful factor action, but not the time of response to it. The latter can be considerably prolonged to disagree with Δt .

In assessing R its dependence on sex, age, etc. could be taken into account in a different way (on an average, a maximum or else) depending on the application area of this index.

Standardization is one of the basic areas of R application. In this case it is necessary to estimate the maximum value of R in a group of persons under consideration (personnel of dangerous industries or population).

Generalized detriment to health G.

This index is required to compare various sources of potential harm by degree of impact on health of people (personnel and/or population). Such a comparison, for example, is made between different power plants, industries and between natural and anthropogenic sources of harm.

The same index is needed to estimate the efficiency of environmental protection and safety improvement measures.

It is proposed to use mathematical expectation of the life-span reduction due to the action of the considered harmful factor as a measure of harm to health. A generalized, or reduced, man-year serves as a unit of measurement, a man-day being a smaller unit. The time lost due to disease is converted to the lifespan reduction by multiplying it by the corresponding conversion factor α . The system of such factor $\{\alpha_i\}$ for different diseases should be established by the expert judgement. In the general case the factors $\{k_i\}$ introduced in the above section to ensure the equivalence of risks do not coincide with $\{\alpha_i\}$, but there is a relationship between them. The quantity G equals to

$$G = \sum_{i=1}^N g_i \quad (5)$$

or

$$G = \sum_k N_k \bar{g}_k \quad (5)$$

Here the summing is made over each individual from the considered group of people (Eq.(5)) or over the subgroups k of N_k individuals. g_i is the individual health detriment, i.e. the expectation of the survival time reduction for the i-th individual (\bar{g}_k is the average value for the k-th subgroup). The individual detriment to a person of the age a from a short-term exposure to a harmful factor is equal to

$$g(a) = \int_0^T \varphi(t, a) \bar{H}(t) dt, \quad (6)$$

where

$$\bar{H}(t) = \int_0^t [h^{(mt)}(\tau, a) + \bar{h}^{(mb)}(\tau, a) Y(t-\tau)] d\tau \quad (7)$$

Here $Y(t-\tau)$ is a survivor function for a person with the disease diagnosed in the time moment τ . Other functions and variables were defined above.

For some applications the quantity $g(a)$ should be calculated taking into account the discounting function.

The expressions similar to Eqs. (6) and (7) were obtained also for the indices estimating the genetic effects. However, they are not given here because of their greater complexity and some awkwardness.

3. ON THE CONCEPT OF WEIGHTED DOSES

The concept of the effective dose equivalent D_e was introduced to allow for the different sensitivities of human organs and tissues to radiation [5]. Initially it was intended for using in the standardization of radiation exposure. However, later the quantity D_e became widely used to assess and compare the effect of or the risks from different sources of ionizing radiation. For this purpose it is used in the UNSCEAR materials (see, for example, [6]). In this case, as a rule, it is pointed out that a careful attitude is needed to the quantitative assessments on the basis of D_e due to a considerable uncertainty in the coefficients of risk, underestimation of curable forms of cancer and genetic effects in each generation, sex-age specificity of human organism, etc.

To avoid the shortcomings of D_e the various concepts of "weighted doses" are proposed in some works: the genetically (or leukaemically) significant dose equivalent, etc. (see review [7]).

This work proposes to introduce two different effective (or, in other words, weighted) doses on the basis of the two introduced indices. There are $D_e^{(s)}$ and $D_e^{(a)}$ intended for using in the standardization and assessment of risk respectively.

The general definition of the weighted dose is

$$D_e = \sum_i \omega_i D_i \quad (8)$$

Here ω_i are the weighting factors; i is the human body organ or tissue; D_i is the dose equivalent to organ or tissue i . The weighted doses $D_e^{(s)}$ and $D_e^{(a)}$ are defined by the sets of factors $\{\omega_i^{(s)}\}$ and $\{\omega_i^{(a)}\}$ respectively

$$\omega_i^{(s)} = R_i / \sum_i R_i; \quad \omega_i^{(a)} = G_i / \sum_i G_i \quad (9)$$

R and G are the above-defined generalized indices of risk and detriment respectively. To calculate $\omega_i^{(s)}$ the maximum values of R_i (in their sex-age variation) are taken, and the averaged (over population) values of G_i are used for $\omega_i^{(a)}$.

Table I gives the calculated values of $\{\omega_i^{(a)}\}$ and $\{\omega_i^{(b)}\}$ and compares them with $\{\omega_i\}$ for the current concept of effective dose. The corresponding values of R_i and G_i are also presented in the Table.

4. CBA PARAMETERS AND INDICES

4.1. The concept of socio-economic damage.

Until recently there existed serious difficulties in the quantitative or even qualitative estimation of the economical damage Y due to harmful effects on the health of population. Some of the difficulties hold so far.

A great number of works including those by Soviet authors are devoted to the problem of determination of Y (see, for example, the Proceedings of the International Symposium [8]). This work presents the results of investigations performed in I.V.Kurchatov Institute of Atomic Energy.

The quantity Y is proportional to the damage G :

$$Y = \alpha \cdot G, \quad (10)$$

where α is the price of the damage. The value $G_0 = 2$ man.day is taken as the damage unit. In so doing, α becomes simultaneously the price of 1 man-rem. (0.01 man.Sv), if the ICRP recommendation on the linear dose-response relationship with no threshold is accepted.

Conceptual definition of α

The quantity α consists of two components:

$$\alpha = \alpha_0 + \alpha_s, \quad (11)$$

where α_0 and α_s are the objective and subjective prices of damage respectively.

The component α_0 characterizes a direct damage to the society due to the death or the contraction of disease of an individual as a producer of material goods and the expenses for indemnity, medical treatment, etc.

The component α_s reflects the subjective attitude of an individual to risk. It is a measure of equivalence between variations in safety and quality of human life (within the definite limits, see [9]). Otherwise α_s could be named a social component of the price of damage. Accordingly, the quantity Y could be defined as a socio-economic damage.

It is inadmissible to relate α with "the cost of life". The strict limits set on the level of individual risk practically exclude the use of the latter term in CBA (in more detail see, for example, [9,10]).

Quantification of α

The mean value of α_0 falls in the range Ebl. 5-10.
The value of α_s is estimated as follows:

TABLE I

Coefficients of weighted doses D_E^* , $D_E^{(s)}$, $D_E^{(a)}$

Tissue	for D_E^*		for $D_E^{(s)}$ **)		for $D_E^{(a)}$ **)		ω_i
	R_1 $10^{-2}Sv^{-1}$	ω_i	R_1 $10^{-2}Sv^{-1}$	ω_i	G_1 days/ 10^2Sv	ω_i	
Gonads	0.4 ***	0.25	0.6	1.8	0.2	0.6	0.17
Breast	0.25 ***	0.15	0.6	0.6	0.3	0.3	0.16
Red bone marrow	0.2	0.12	0.2	0.2	0.2	0.2	0.17
Lung	0.2	0.12	0.2	0.2	0.2	0.2	0.13
Thyroid	0.05	0.03	0.05	0.05	0.03	0.03	0.02
Bone surface	0.05	0.03	0.05	0.05	0.05	0.05	0.04
Remainder	0.5	0.30	0.5	0.5	0.4	0.4	0.31
Whole body	1.65	1	2.2	3.4	1.4	1.8	1

*) Concepts of weighted dose ICRP [5]

***) Left column of values take into account genetic effects only of the first two generations, right column - all generations.

This implies that

$$\alpha = \alpha_0 + \alpha_s = \alpha_s = \text{Rbl. } 100-400 \quad (12')$$

Thus, the value of Y is determined mainly by the component α_s . A further narrowing of the uncertainty range (12') for α is hardly possible.

The cost of damage α_s belongs to those quantities that, in principle, cannot be evaluated to a high accuracy. A substantial uncertainty in α_s is due to its nature; it reflects the subjective opinion of an individual about the risk-benefit relationship (or in other words about the safety-quality of life relationship). This opinion is characterized by a considerable uncertainty.

The uncertainty in α_s is its property, but not its demerit, and should just be taken into account in the standardization of the α value.

It is appropriate to mention here that some other quantities of a socio-economic nature have similar uncertainties. For example, such is the case in the standardization of the discount rate E . Nevertheless, the specific value of E is established as a standard one in the interests of the efficient control of the economy.

The differential optimum cost criterion is often used in the optimization of radiation protection

$$\gamma = \alpha \quad (13)$$

where $\gamma = -dX/dG$ is the cost of detriment reduction.

According to the data available for different industrial and non-industrial human activities in a developed country the value of γ falls within the range

$$\gamma = \text{Rbp. } 2-2 \cdot 10^4 \text{ per unit detriment } G_s \quad (14)$$

For optimal safety measures γ should be the same for all industrial and non-industrial human activities and equal to the standardized value of α in accordance with the condition in Eq.(13). The wide spread of γ values is the evidence of a significant departure from the optimum in current safety decision-making.

To lay a practical basis for making optimal decisions on safety it is necessary, firstly, to establish government regulations for the α value. The choice of the optimum safety measure should then be governed by the condition in Eq.(13).

The opinion of the authors with regard to the standardization of the α value under uncertainty conditions (12') amounts to the following.

First, the choice of any α value from the range (12') for regulatory purposes would not contradict the human perception of risk-benefit relationship. Second, it is important to note that because of a large gap in uncertainties of α and γ values (see (12') and (14)) the choice of a standard α value would enable to get closer to optimum safety decisions.

The standardized value of α must be the same over the whole range of the acceptable values of R .

It is proposed the following value for α :

$$\alpha = \text{Rbl.200} \quad (15)$$

Could this value prove to be excessive from the angle of the scantiness of resources the society spends on the quality of life and safety?

At present the technogenic risk in the developed society is characterized, on an average, by the value $R_T \approx 10^{-3} \text{ year}^{-1}$. This corresponds to a loss of about $G_T = 10$ man-day per one person.

If the whole value of R_T or G_T is supposed to be compensated, the social expenses for this would amount to $Y_s^{\text{max}} \approx \text{Rbl.1000}$ per man-year or $\approx \text{Rbl.80}$ per man-month. This is an upper limit for Y_s . The value Y_s^{max} amounts to 5-15% of the average per capita income in the contemporary developed society. Really, Y_s will be lower, as a part of R_T is compensated on another basis (for example, risk due to using up-to-date transport).

This allows one to conclude that the proposed standard (15) does not prove to be excessive.

Allowance for time factor

The damage Y distributed in time should be summed taking into account a temporal weighting factor - a discounting function:

$$F(t) = e^{-\epsilon \cdot t} \approx (1 + \epsilon)^{-t}, \quad (16)$$

where t is the time; ϵ is the discount rate standardized for the current economic calculations (see also [9]).

4.2. On restrictions of risk from severe accidents

The present-day safety measures ensure a very low probability of severe NPP accidents (with considerable radioactive releases).

The high consequences of the accidents and their low probability pose a number of problems for both the risk analysis (in particular, for damage assessment) and the risk management as a whole.

For a long time the following questions have been a subject for consideration by experts:

1. What rigorous limitations on accident consequences should be added other than the limitation on individual risk?
2. What CBA index of expected damage due to accidents should be used under conditions when the variance can exceed the expectation of damage?

The solution of these questions is given much attention to on both national and international levels including the IAEA activity.

There are no unambiguous answers to these questions. They depend strongly on national economic structure features etc.

Our view on solving the above questions resolves itself in brief into the following.

It is impossible to find a correct answer to these questions from the standpoint of considering a single NPP. It is necessary to take into consideration the industry as a whole and, moreover, all potentially dangerous industries.

In addition to other non-economic strict limitations a rigorous restriction should be imposed on the maximum damage from an accident at a NPP and other industrial facilities (in our opinion this limit for NPP should equal to Rbl. 3-5 billion; for comparison the damage due to the TMI accident amounted to ~~US\$~~ 2 billion, the Chernobyl-Rbl. 8 billion). A state system of insurance against damage due to accidents should be set up at potentially dangerous plants. The size of an obligatory insurance premium should be estimated from the expectation of damage $\langle Y \rangle$ despite its large variance

For example, the annual payment \dot{Y}_{ins} for the accidents of a given type with a frequency ω and a damage Y should amount to

$$\dot{Y}_{ins} = \langle \dot{Y} \rangle = \omega Y$$

or the total payment Y_{ins} in the moment of setting NPP into operation

$$Y_{ins} = \omega Y / E$$

where E is the discount rate.

In addition to Y_{lim} a minimum value of complementary cumulative distribution function W_{min} (W_{min}) is suggested to be established (so called "de minimus" level). It determines lower limit for accidents which are taken into account. Accidents with $W < W_{min}$ are considered as incredible. It is proper to call them "hypotetical accidents". The value W_{min} is established from the condition

$$N \cdot W_{min} \ll 1,$$

where N is the total sum of reactor-years, cumulated by a reactor generation of considered type (see Figure).

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COMPLEMENTARY CUMULATIVE
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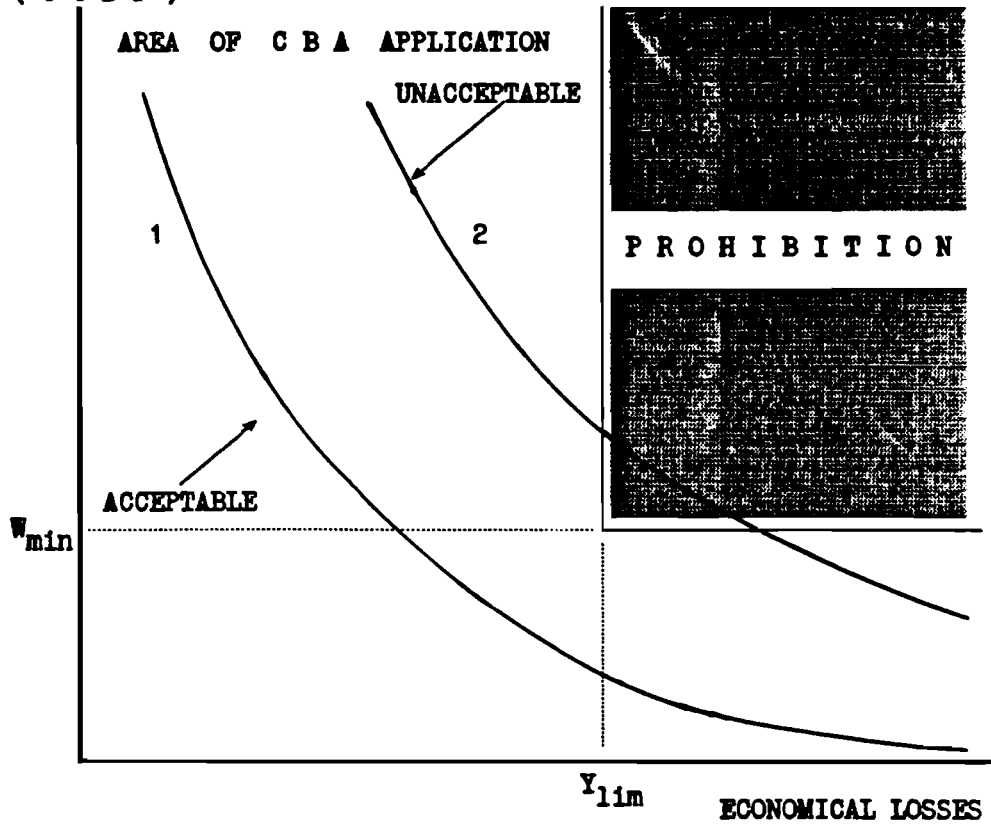


Figure. Criteria for decision making in risk management with consideration of severe accidents (Y is economical losses, W is CCDF, i.e. expected frequency of accidents with $Y' \geq Y$). Curves 1 and 2 correspond to two different decisions on NPP safety system.

**Large Accident and Demands to Safer
NPP of New Generation**

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Abstract

Large accidents at Tree Mile Island and Chernobyl became a landmark in world nuclear power (NP) development and produce stricter demands to nuclear power plants (NPP). As a result the safety and social acceptability of NP became of absolute priority among other problems. In the paper quantitative criteria of safety derived from estimation of social risk and economic-ecological damage due to large accidents like TMI and Chernobyl are formulated. Concepts of high safety reactor and asymptotic high safety reactor are introduced. It is stated that latter could hardly be created in the framework of traditional ways of safety improvement.

1. Introduction

In the history of NP development two stages may be definitely outlined. NPP large accidents took place at Tree Mile Island and Chernobyl became a landmark which divided these stages.

The first one can be characterized by rather high NP growth and too optimistic attitude to safety. It is correct, that NP could overcome ecological problems caused by organic fuel combustion. This is a decisive advantage of NP, but in some way it hypnotized wide NP development supporters. Somehow or other high hypothetical accidents were not paid much attention. But TMI and Chernobyl showed their reality. So NPP large accidents resulting in reactor disruption and possible radioactivity release to the environment became synonyms of public acceptability of nuclear power.

Now NP has entered the second stage of its development and ought to obtain the same public support, it had earlier. This time

safety and social acceptability of NP are of absolute priority among other problems. It means that concept of safer reactor of new generation should be worked out.

Safety of any energy capacious technology can't be absolute, this is a technical "nature" of safety. Improvement of safety means permanent movement and apportionment of technically reachable intermediate goals. The experience gained at TMI and Chernobyl accidents may serve as "experimental data" for this purpose.

2. Estimation of NPP large accidents social damage.

Social damage is connected with global character of large accidents, great uncertainty in real economic damage, possible loss of human values which couldn't be estimated from the economic point of view and public unacceptability of radioactive releases to the environment. To formulate social criterion of NPP safety it is necessary to take into account that even a few large accidents with radioactive release to the environment could completely blow confidence to NP and put a question of its elimination. So social criterion consists of demand, that during forecasted period of NP development (approximately 50 years) no large accident with radioactive release to the environment occurs within confidence limits of probability.

This demand correlates with psychological barrier of human unacceptability dangerous events repetition and some smoothing it after change of generation. Quantitative estimations of P_s - probability of large accident with radioactive release to the environment are obtained on the base of this criterion [1].

$[P_s] = (\text{year})^{-1}$. The following assumptions were used:

- since such accidents may have international consequences the assesment is determined by expected NP scale in the world;
- in the middle of the next century the specific energy consumption will be about 5 kW per capita; total world population will be 8 billions; nuclear power will be about 30% of total.

The expression for P_s is of the form:

$$P_s \leq \min \left\{ \sqrt{nP_s} + nP_s \leq 1 ; \frac{1}{2}(nP_s)^2 \leq \delta \right\} \quad (1)$$

where $n \cong 3 \cdot 10^5$ reactor-years worked out and δ - "psychologically" acceptable probability of of large accidents up to 2050 yr. Fig. 1 presents m - the mathematical expectation of such accidents for various values of P and uncertainties within the limits of one dispersion - σ . It is seen that first condition in (1) is satisfied by $P < 10^{-6}$. It was assumed that all NPP were characterized by the same value of P . But if construction of new NPP with $P=10^{-6}$ begins at 2000 yr. or later, and old ones have $P=10^{-4}$ or 10^{-5} , then this condition is not satisfied (see Fig.2). This means that it wouldn't be sufficient to introduce only safer reactors. It is necessary to replace old NPP's or to improve their safety drastically ($10^{-4} \rightarrow 10^{-6}$). Second condition in (1) means that two and more large accidents are excluded with propability - δ . For $\delta=0,5\%$ one can obtain from (1), that social criterion leads to

$$P_s \leq 10^{-7} \quad (2)$$

3. Estimation of economic-ecological damage due to NPP large accident.

Economic-ecological damage is connected with that of reactor, reactor building or NPP itself, impossibility of land use around NPP and so on. Damage may result in full loss of repairability of NPP, even when all radioactivity (r/a) is localized inside it.

Economic-ecological criterion consists of demand that economic losses from large accidents will not exceed a certain part of income from energy production. The latter is comparable with γ - economic growth and equal to some percent. It follows from this criterion

$$\beta \cdot C \cdot M \leq \gamma \cdot \zeta \cdot n, \quad (3)$$

here C - damage due to a large accident; β - factor of income excess compare to damage; ζ - specific discounted cost of energy

production; M - expected quantity of large excidents. To estimate the latter we use a conservative approach and put it equal to $m+\sigma$. Taking into account that main part of ζ is connected with k -capital cost, we put for simplicity $\zeta = \lambda \cdot k$, λ - discount rate. The equation(3) takes the form

$$\sqrt{n P_e} + n P_e \leq \frac{\gamma \lambda \cdot k}{\beta \cdot C} \cdot n \quad (4)$$

where P_e - permissable probability of NPP large accident derived from economic-ecological criterion.

From (1) and (4) it follows that functions $P_s(n)$ and $P_e(n)$ are quite different. The function P_s decreases monotonously when n grows. That means safety demands becomes stricter upon time. The function P_e increases with n and is asymptotic to $\frac{\gamma \lambda \cdot k}{\beta \cdot C}$. It has a simple physical meaning. Social criterion demands limits of expected quantity of accidents no matter how large n is. So $P_s \propto n^{-1}$, when n is large enough. Economic-ecological criterion demands only that damage will be small compare to income. For large n both values are proportional to n and therefore $P_e \rightarrow \text{const.}$

To estimate P_s quantitatively the following two types of large accidents are taken as "reference" ones.

Type A. Large accident following core disruption and r/a release to the environment. Chernobyl could be a model for such accident. For this case we have $C \cong 10 \cdot k$.

Type B. Large accident following core melt and r/a localized inside containment. TMI is a model for this type and we have $C \cong k$.

Taking for other parameters $\gamma=0.1$; $\beta=10$; $\lambda=0.1 \cdot \text{yr}^{-1}$ we obtain the solutions $P_e^{(A)}$ and $P_e^{(B)}$ shown at Fig. 3 for both types of accidents.

4. Safety demands to nuclear reactors of new generation.

The necessity to satisfy both criteria leads to the conditions:

$$P^{(A)} \leq \min (P_s , P_e^{(A)}) \quad (5)$$

$$P^{(B)} \leq P_e^{(B)}$$

Fig. 3 shows that for large enough period of time one can

take as necessitive the following values:

$$\begin{aligned} P^{(A)} &\leq 10^{-7} \text{ (react. yr.)}^{-1} \\ P^{(B)} &\leq 10^{-5} \text{ (react. yr.)}^{-1} \end{aligned} \quad (6)$$

and as a sufficient

$$P^{(B)} = P^{(A)} \leq 10^{-7} \text{ (react. yr.)}^{-1} \quad (7)$$

It must be definitely said that modern reactors do not satisfy these demands. Therefore the conditions (6) and (7) may serve as bearings in development of nuclear reactors of new generation. Following this way it is possible to distinguish two steps. The NPP of the first step have $P^{(B)} = 10^{-5}$ for core disruption and external facilities to localize r/a release inside the containment down to $P^{(A)} = 10^{-7}$. We call such reactors as high safety reactors.

The NPP of the second step have $P^{(B)} = 10^{-7}$ for core disruption. We call such reactors as asymptotic high safety reactors.

It is naturally that working out of high safety reactors will go in the framework of traditional approaches with maximum use of reactor technology developed. So safety improvement is realized as a rule by additional active engineering facilities. Though some inherent and passive safety may also be used. This extensive way obviously results in more expensive NPP and one can't exclude that NPP advantage before traditional PP will be used up. (For European part of USSR this cost advantage for modern NPP is about 20-40% [1]). In this case the transition to asymptotic high safety reactors is accompanied by very strict cost demand. To characterize it let us introduce α - the effectiveness of cost investment in safety defined by

$$\alpha = (\Delta P/P) / (\Delta k/k), \quad (8)$$

where ΔP - reduction of P value, which costs Δk ; P and k are the corresponding basic values. It was shown in [1], that this factor satisfies the non-equation

$$\alpha \geq (\lambda/P) \cdot (k/C) \quad (9)$$

For type B accidents and reactors with $P^{(B)} = 10^{-5}$ we have $\alpha \geq 10^4$. It means that transition from reactors with $P^{(B)} = 10^{-5}$ to

ones with $P^{(B)}=10^{-7}$ must practically leave the capital cost of NPP the same.

There is no real hope to fulfil it by using only additional active safety facilities. The proper way is to use simple physical (but not complex engineering) principals of fission phenomenon; that of natural convection of coolant; perhaps quasi-continuous fuel reprocessing and so on.

In any case the safety demands obtained from TMI and Chernobyl experience are challenge to world nuclear society. The future of nuclear power depends on its solution.

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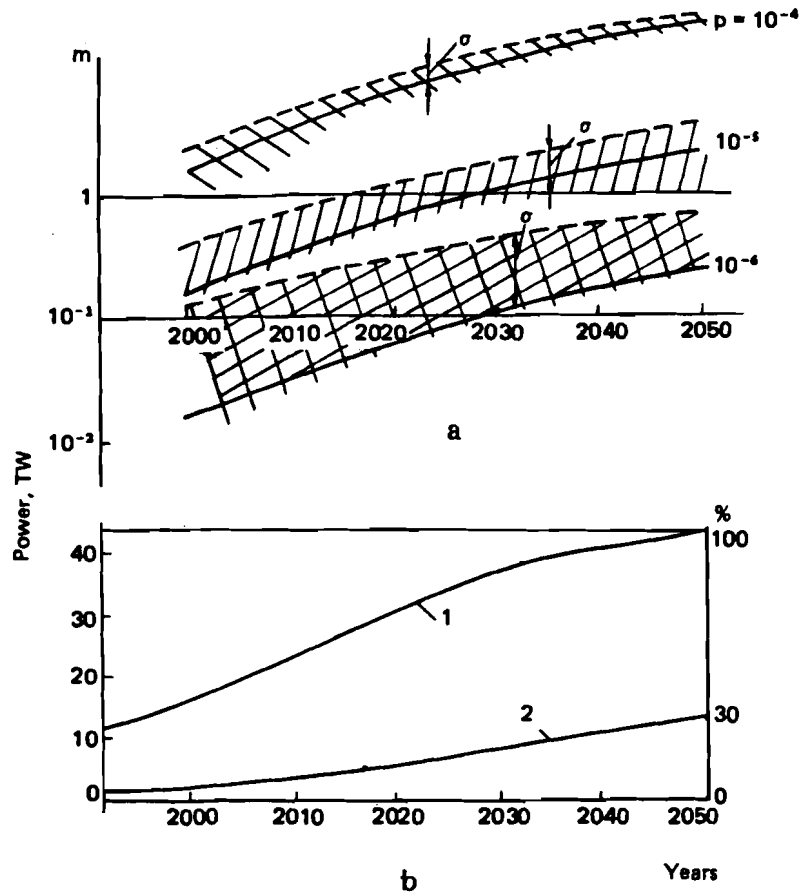


Fig. 1. Mathematical expectation (m) and dispersion (σ) of the number of accidents (a) and energy prognoses (b): 1 — total energy production; 2 — nuclear energy

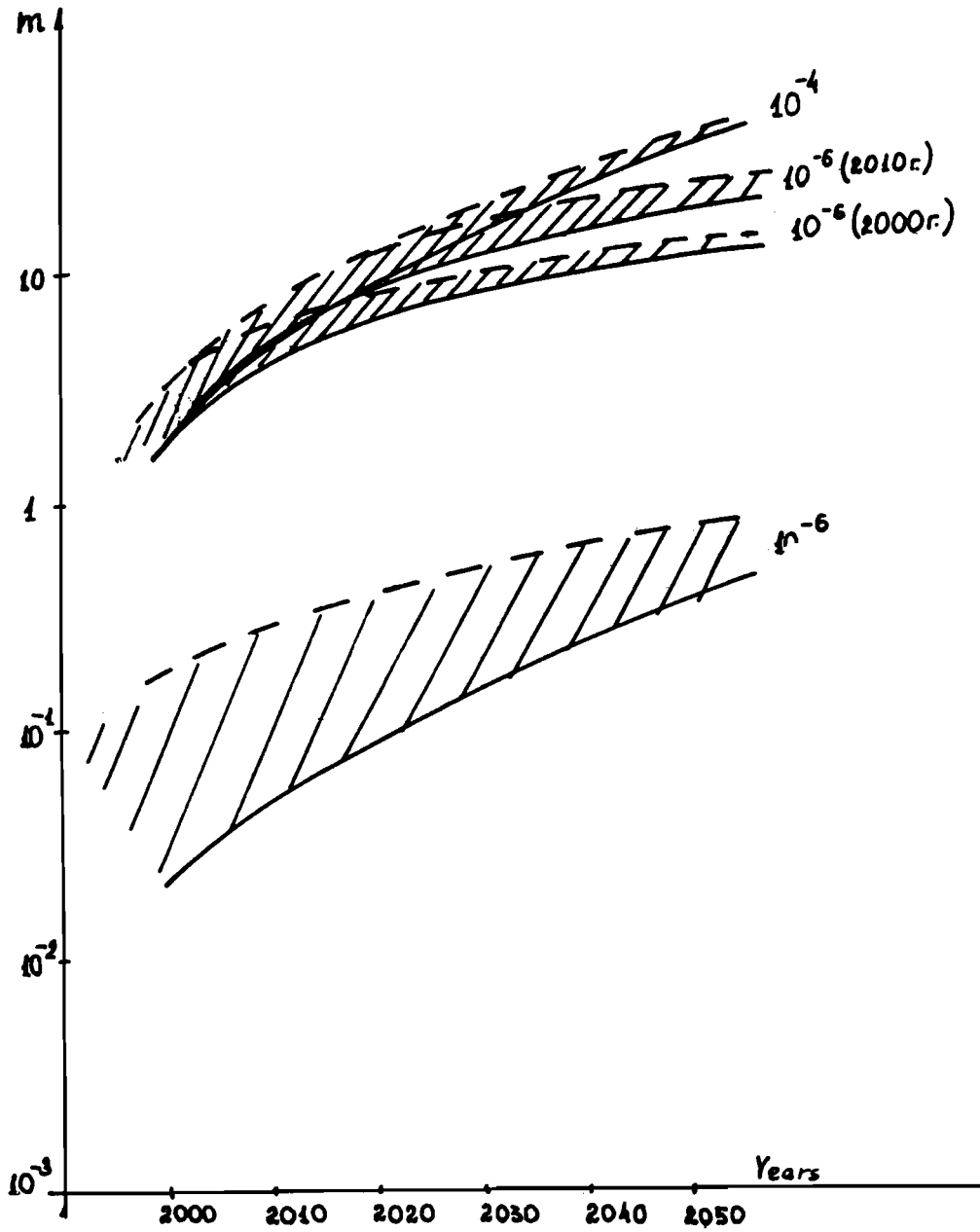


Fig 2

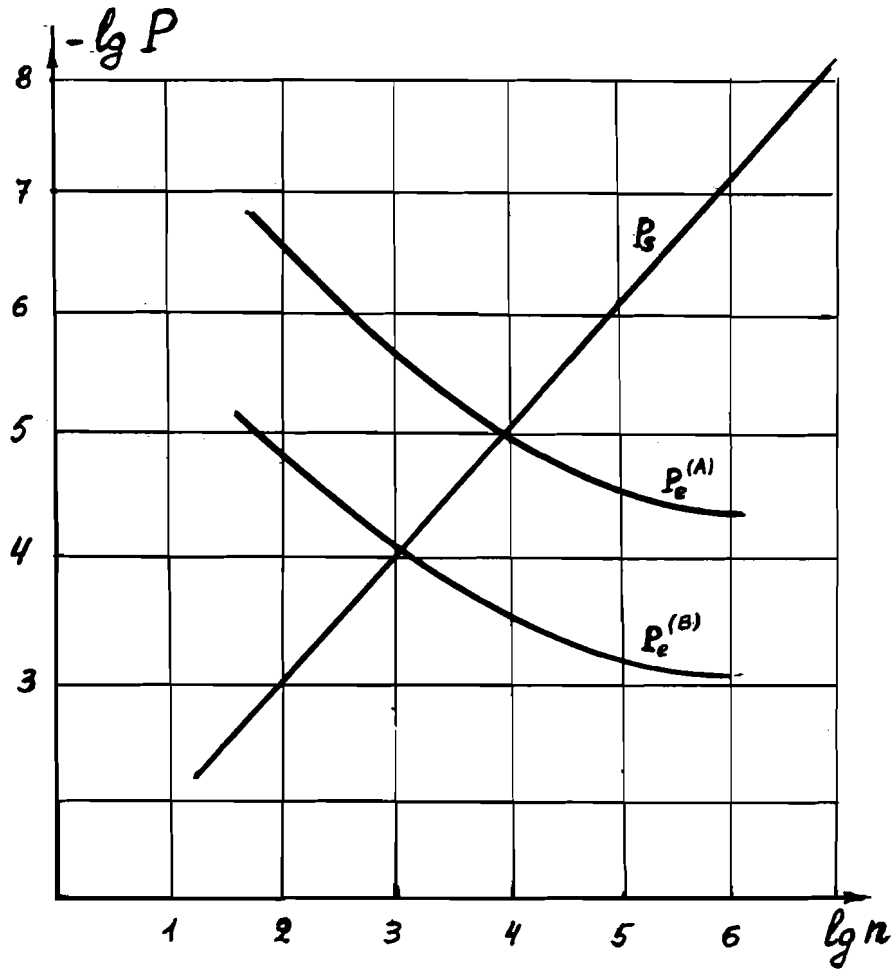


Fig. 3

LEARNING FROM CHERNOBYL.
The right to information and
the problem of communicating
about major hazards.

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Abstract

The management of the Chernobyl emergency can be regarded as a challenge to experts' and politicians' credibility and to the whole system of information and communication in the field of high-risk technologies.

During the emergency period following the Chernobyl accident, the citizens of almost all European countries discovered: 1) that they had never been informed before about the possibility of being exposed to such kind of hazards and about possible protective measures; 2) that the experts had different points of view about the interpretation of the same data and gave different advices concerning the actions to be taken; 3) that it was not completely clear which were the responsible authorities and the measures to be followed to cope with such an event.

Because of the lack of specific information channels and procedures, the mass-media functioned as the main reference point for citizens willing to know what was going on, for central and local authorities that had to inform the citizens about the measures to be followed, for "official" and "dissident" scientists asked to offer explanations.

It has been maintained that, because of this crucial role, of the mass-media and because of their specific way of selecting and distributing information, Chernobyl may be considered as a sort of mass-media construction. From the point of view of the perception of the risks, Chernobyl is certainly also a mass-media construction. But this element should not hide the fact that one crucial problem has to be addressed: i.e. which forms and channels of information and communication (the second term implying a multi-way relationship) are/would be the best suited to meet the right to - and the need of - information in a field (high-risk technologies) often characterized by controversial scientific interpretations and advices, conflicting political interests, secrecy, and a transboundary dimension both in space and in time. In this respect, the structural constraints of the whole information system must be taken into account.

Risk communication studies may offer some contributions to deal with this problem. But it is necessary to be careful. On the one hand, it has to be stressed that the information and communication processes concerning major hazards cannot be confined to the post-accidents situations, otherwise the so-called lay people will be and feel overpowered by a lot of information which will turn out to be particularly alarming

because it concerns hazards that people hardly suspected to be exposed to. On the other hand, risk communication could be regarded and used as a legitimation device (i.e. communicating in a more "nice" way in order to make otherwise unacceptable decisions/actions to be accepted). In this case risk communication would not meet the right to -nor the need of- information; and probably it would be also not very effective as legitimation device because in our contemporary "global village" it is quite difficult to control and manipulate all forms and contents of information to obtain uncritical consensus.

The Chernobyl challenges

When faced with the evidence that a meltdown occurred at the Chernobyl plant, all the scientific and political world showed surprise. And for the citizens of many european countries an hard experience of unveiling started.

The majority of experts in the nuclear field showed surprise in realizing that an event calculated to have such a low probability of occurrence could have happened. Central and local authorities in all european countries found themselves to be unprepared to cope with such an unsuspected event. Citizens of countries without nuclear plants discovered that they were nevertheless exposed to radiation coming from very long distances, and citizens of countries with nuclear plants discovered that the existing safety measures were not sufficient to protect them from radiation exposure.

But why all this surprise, especially among experts? One possible answer is that, even if it is obvious that very low probability does not mean "impossibility", the problem of coping with the occurrence and the consequences of a large but very unlikely accident had been underestimated and somehow regarded as a waste of time and money. Moreover, while important efforts have been made to examine all the theoretically conceivable causes of various kinds of nuclear accidents (but there are controversies concerning the assumptions and methods used to calculate the probability of occurrence of such accidents), less had been done before Chernobyl concerning the forecasting of all possible post-accident conditions and the related consequences for human health and for the environment; not to speak about the social, psychological and political ones. And what resulted to be particularly surprising in the case of the Chernobyl accident are precisely the scale (in space and in time) and the seriousness of its consequences. While the accident of Three Mile Island had already shown that at least one very important element that can provoke major accidents had been underestimated by risk assessors and by the responsible authorities, that is the so-called "human factor" (1), the Chernobyl accident demonstrated that the whole contemporary society is a sort of experimental field for complex technologies (2).

Following the Chernobyl meltdown, citizens of many countries found themselves exposed to hazards they did not know or expect; and many people became the victims of an high-risk technology that scientists demonstrated not to know as well as some of them pretended, and that political authorities proved to be unable to control.

In few days it appeared in fact clear that there was disagreement between experts regarding relevant issues like the dangerousness of low doses of radiation for human health, the very definition of "low doses", the possibility or impossibility

to define a safe radiation threshold. And on the basis of this disagreement about scientific -or "trans-scientific" (3)- issues, experts expressed different opinions about the interpretation of the same data (for instance, what was considered by some radiologists or doctors, a "safe" dose of radiation in milk or vegetables, was regarded as an "overdose" by others), and gave different or even conflicting advices with regard to the protective measures to be taken.

Disagreements and conflicts were also deep at the level of the political authorities. First of all, in some countries it was not clear which authorities were responsible for taking actions in face of such a wide radiological emergency, and/or there was an overlapping of responsibilities between different ministers and between central and local authorities (4). Therefore conflicts arose concerning both " who" had to decide, and "what" had to be decided. Regarding this last point, conflicting advices given by different experts were used by different political authorities to justify one decision or the opposite one (like forbidding or not the trade and the import of some kinds of food).

What became manifest from this situation was that the existing emergency plans were insufficient (when not ridiculous) to guarantee citizens safety, and that almost nothing had been done to limit the harmful consequences of an unlikely but possible major nuclear accident abroad or within each country.

The disagreements between experts and between political authorities about the seriousness of the accident, about the danger for health and environment and about the measures to be adopted, were reported by the mass-media; which were in turn accused by many scientists and politicians to create confusion, alarmism and distrust in science and progress. And it had also been stated that there had been two Chernobyl, the real one and the one constructed (in alarmistic and unscientific terms) by the mass-media (5).

From the point of view of the perception of the situation and of the risks involved, it can actually be argued that Chernobyl was also a mass-media construction in the sense that the invisible danger was made "visible" by using spoken or written words like "radioactivity" or "Iodine 131", and by showing satellite photographs of the Chernobyl fire and pictures of people evacuated from the area or hospitalized. But the fact that the media had a major role in the way risks were perceived does not mean that risks were just imaginary; nor that by worrying about what to eat, drink and so on, or by extending the fear of accidents from one to all nuclear plants people were shown to be irrational. On the contrary, they behaved in a very reasonable way given the fact that the few elements of certainty known by everybody were that a large and unsuspected accident had happened in a very dangerous plant, that an invisible cloud full of a dangerous "substance" was moving about in Europe, that some of that "substance" was in the air, in the water, in the soil and in the food, that some scientists were of the opinion that to ingest even very small quantities of such "substance" was harmful while other scientists disagreed, and that some authorities decided to forbid the trade of some food and other measures while other (central or local) authorities disagreed on such measures.

The media did not "create" confusion, nor did they "invent" scientific controversies and political conflicts : they reflected them (6). Therefore the Chernobyl challenge to experts' and politicians' credibility was not due to the mass-media but by the

breakdown of a model of science that does not fully recognize its limits and that seems to go too fast (7), and by the evident unfairness of a model of politics where citizens are excluded from decisions concerning risks that they have then to run.

Certainly the world of mass-media too is far from being a "pure" one, and during the Chernobyl emergency some journalists made mistakes or deliberately tried to manipulate news. Many newspapers and TV and radios gave uncorrect and sometimes wrong information about what occurred at the Chernobyl plant, or about the levels of contamination due to the fall-out (8). Moreover journalists and directors of newspapers and TV or radio programmes selected which data and which experts' or politicians' opinion to stress or to neglect; and they made their selection according to their political views, to their resources, to criteria of news "marketability" and to external constraints.

Some of the external constraints are specific of each media: for a TV programme it makes a difference if an event can be filmed or not, while this does not matter for a newspaper article; and for a radio broadcast it is important to have the possibility of obtaining recorded material, while for a written (and therefore more "controllable") article it is important to find exact data and figures and reproducible pictures.

Other constraints are instead structural of the information system in general. They are problems of sources accessibility, reliability and verifiability at the national and international level, problems concerning the choice of the appropriate information channels (obviously not only the various mass-media), and problems regarding the role of the media in the strict sense of the word: that is "media" as tools of communication between different sectors/groups of society.

With respect to these structural constraints, Chernobyl can be regarded as a challenge also to the whole system of information and communication in the field of high-risk technologies.

High-risk technologies and the problem of secrecy.

The first informational problem that emerged at the very beginning of the Chernobyl emergency, i.e. when the first considerable increases in radioactivity levels were detected in Sweden, had been a problem of information channels.

In Italy -for instance- the first news arrived from Cairo, where the message of a Swedish amateur radio-operator had been received; immediately the Italian national press agency ANSA sent some correspondents to Sweden to verify the news, which were then transmitted to the newspapers (9). This quite adventurous procedure is certainly not suited to assure quick and proper exchange of information between authorities and scientists of different countries in cases of abnormal findings that may indicate catastrophic events, not only in the nuclear field but also with regard to releases of genetically engineered organisms, spread of chemicals in air and water, and all activities that may provoke major hazard having a transboundary dimension in space and time.

The second informational problem that came up after radiation increases were monitored in northern European countries, was a problem of source accessibility, i.e. the impossibility to obtain quick and complete information from the Soviet authorities about what was happening at Chernobyl.

This was mainly due to the secretive management of nuclear technology in general and to the lack of an international agreement on early notification of nuclear accidents.

As it has been demonstrated by other serious nuclear accidents -like the ones at the British plant of Windscale (now Sellafield) in 1957, at the US military nuclear plants of Hanford, Savannah River and Fernald during many years, at the German plant of Biblis in 1987, etc. (how many are still kept secret?)- secrecy within and outside the country where the accidents take place is not a peculiar characteristic of the Soviet political system, but it is a necessity of the technological-organizational nuclear system. This is especially true in countries where the civil and military uses of nuclear power are directly connected (10). But not only: as the NUKEM scandal showed (11), also countries that are not producing nuclear weapons can help others to produce them. And even putting aside the civil-military connection, nuclear technology asks for secrecy because of its centralized and hierarchical management, its vulnerability to terroristic and wartime attacks, its ever decreasing public acceptability that could arrive at the bottom (it is the case of the Italian referenda against nuclear power in 1987) if more or less serious accidents are made public. It is probably not a matter of chance if- for example- in France, one of the biggest producers of nuclear power for civil and military purposes, the media spread the news of the Chernobyl accident and fall-out later and dedicated to them less space than the neighbouring countries sharing a similar contamination.

Nuclear secrecy (like the secrecy related to other high-risk technologies) is more a threat to humankind and environment, than a protection for economic and political interests of industries and states. Being this an explicit matter of judgment, let me also add that in case the environment would be seriously and irremediably damaged and -as a consequence- the human species endangered, industries and states would not count very much.

The IAEA has a fundamental role in preventing illegal trade in nuclear material and in controlling its transport. The problem is how to improve control procedures concerning the whole fuel cycle in order to avoid not only other NUKEM-like scandals, but also the possibility that accidents happening in plants or in waste storages of each country will be kept secret both within and outside the borders. The problem of controllability is a very difficult one, but also a crucial one for the implementation of important international agreements like the Vienna Convention on Early Notification of a Nuclear Accident signed the 26 September 1986, exactly 5 months after the Chernobyl accident.

Obviously the same problem -limitation of secrecy and controllability procedures- are very important also with respect to other high-risk technologies: chemical production and biotechnologies can be even more difficult to control -and secrets easier to be kept- because of their smaller production scale and more widespread diffusion.

Coming back to the Soviet authorities' silence about the Chernobyl accident, it has to be said that it lasted only (but crucial) 72 hours: in the evening of 28 April 1986 the Soviet representative to the IAEA informed the IAEA Director General that an accident had occurred at 1.23 a.m. on 26 April 1986 in the fourth unit of the Chernobyl plant (12).

This can be regarded as a sort of victory of communication technologies over nuclear secrecy: satellite photographs of the Chernobyl fire prevented any attempt to keep it longer secret and

to pretend that increases in radioactivity were due to something else. Sophisticated communication technologies seemed therefore able to gain verifiability of news in spite of non accessibility of the official sources of information. It has been argued that the satellite photographs of Chernobyl dramatically demonstrated that government control over the flow of information is decreasing, and that boundaries are now so porous that shutting off communication is impossible (13). This is true, but there are important distinctions to be made: 1) highly sophisticated and very expensive communication technologies are unequally distributed in the world (14), which means that economic and technologically developed countries have the possibility to gather information about third world countries (and in case use it as a resource against them) while the contrary is hardly possible; 2) the fact that communication technologies are used in a country does not mean that citizens of that country are enabled to see or listen what their government finds out thanks to such technologies; 3) borders are increasingly porous, but if a government decides not to let journalists enter certain areas and if there is nothing -or nothing big enough- to be photographed even with sophisticated technologies, then environmental (not to speak about social) catastrophes can be detected/monitored but the origin can be kept secret.

Scientific data and information processes.

When the origin of the considerable increases in radioactivity levels in many European countries became known, problems arose concerning the gathering and the harmonization of data at the national and international level, about the interpretation and evaluation of data to decide on the measures to be taken, and on the communication of scientific data to a wide public. In other terms, there had been problems concerning the reliability of scientific sources, the choice of information channels (between experts, between experts and political authorities, and from them to the public), and the use of the media.

During the Chernobyl emergency, the radiation monitoring systems of European countries were shown to be differently organized. In Italy, for example, the monitoring network was not homogeneously distributed in the national territory, reflecting not so much the distribution of the few nuclear plants working at that time in Italy (two in the North and one in the South, plus one in the stage of decommissioning also in the South), but the unequal social and economic development of southern and northern areas: in fact the radioactivity monitoring stations (mainly the ones of ENEA - National Commission for Nuclear and Alternative Energy- and the ones of the Local Health Units) were mostly in the North. In face of the the Chernobyl fall-out the monitoring network had to be extended, and university laboratory and other centres in the whole country were asked to cooperate. But then another problem emerged: different laboratories were using different instruments and producing non homogeneous data, therefore ENEA-DISP (Safety and Protection Division) had the task to collect and harmonize them (15).

In other countries different problems arose: in Austria -to give another example- the surveillance system for environmental radioactivity was almost equally distributed in the country (but with a higher density of monitoring stations along the borders and in the North), and worked quite well. But the number of radiation protections experts was too low -mainly because of the

absence of nuclear plants in Austria- and data transmission and evaluation proved to be difficult (16).

At the international level, the EC countries had the duty (provided for by the EURATOM Treaty) to communicate the data on radioactivity contamination gathered in the national territory to the EC Commission. And this did not happen without problems because in the beginning the data coming from different countries were not homogeneous.

On the basis of these examples, it is easy to see that data gathering and interpretation are a not simple and uncontroversial processes. During the Chernobyl emergency, controversies cropped up concerning the reliability or -on the contrary- arbitrariness of producing from very unequally distributed data some "average" data covering more or less big areas: the critics of average estimates maintained that it was scientifically wrong and politically unfair (because of the consequences regarding the protective measures to be taken) to speak about averages when the meteorological conditions had caused a very different distribution of radioactive contamination also in relatively close areas, and consequently different levels of dangerousness for people. Defenders of average estimates maintained on the contrary that these estimates were correct -and useful in deciding on measures- because of the trade of non-locally produced food in the short term, and because of the entering of radioactive isotopes in the food chain in the medium and long term (17).

These controversies concerning the gathering and the use of scientific data, and the mentioned controversies about the evaluation of data to establish "safe" radiation doses (also the guidelines prepared by the ICRP -International Commission for Radiological Protection- had been questioned and lower radiation admissible doses suggested), were made public by the media. Scientists working within official and non official institutions -and having different opinions- were interviewed; and TV and radio debates between experts, political authorities and sometimes environmental groups were organized. Some of them had been very useful in order to give citizens some elements to understand the main features of the situation: in fact, because of the the lack of other information channels (a part from some telephone numbers of health and civil protection authorities where people could ask for information), the media had been the main reference point for citizens wanting to know what was going on, for central and local authorities that needed to inform citizens about protective measures, and for "official" and "dissident" scientists asked for explanation. In some cases detailed and clear maps of the fall-out were shown, the causes of the accident at least partially explained, and comparative (within the various areas and in different days) levels of food contamination discussed. But very often the language used was cryptic, the arguments given for or against measures were unclear, and disagreements which were not exclusively scientific but also political in nature were not made explicit but treated with a falsely neutral language.

As a consequence, citizens felt overpowered by a lot of controversial and sometimes not understandable information that questioned the reliability of scientific sources and the credibility of experts and politicians. And that turned out to be particularly alarming not only because (as previously said) it concerned hazards that the so-called lay people hardly suspected to be exposed to, but also because it sounded either not very

reliable or unintelligible.

Right to information and communication problems.

The Chernobyl challenge to the whole system of information and communication in the field of high-risk technologies can be summarized in the following points: 1) secrecy may heavily undermine the right to and the need of information; 2) problems may emerge if there are not adequate and coordinated political and scientific information channels at the national and international level; 3) not to be and feel overpowered and passive victims of someone else decisions, and to better protect themselves, citizens have to be properly informed in all stages of decision-making concerning high-risk technologies and not only in cases of large accidents; moreover they should have the chance to ask which kind of information they need and to express their own opinions in a two-way, or better (given the plurality of social roles and interests) a multi-way communication process.

So far, the first two points and some elements concerning the third one have been analysed. It is time to remind these elements and to address this final point.

In order to properly inform citizens in all stages of decision-making in the field of high-risk technology it is necessary to make accessible and understandable the information which is available (given the constraints and the scientific uncertainties/controversies mentioned before) on the hazards involved in such technologies, on the safety measures provided for both routine and emergency situations, on the criteria suggested for the choice of the site, on the relevant legislative provisions, and on the allocation of responsibilities.

In this respect, some important steps have been taken at the legislative level -or are in course of debate- in the USA and in the EEC (I admit my ignorance about non-EC European Countries -included eastern countries- and about other developed and developing countries).

In the USA, the National Environmental Policy Act (NEPA) approved in 1969 includes procedures of information about the environmental impacts of proposed actions, and a freedom of information provision regarding environmental matters. And it is well-known the system of the public hearings used in that country (and also in Great Britain) aimed at enabling an informed participation of citizens, starting from the early stages of the decision-making processes (for instance, siting of hazardous installations). This system has proved to be a good step in the direction of active citizens participation and a way of improving political and scientific authorities' (for instance, regulatory agencies) responsiveness; even if it has been argued that more is needed to really achieve these ends, and that in order not to be just symbolic rituals, the public hearings should be reformed (18).

In the EEC, a proposal for a Directive concerning the freedom of information on environmental matters is under debate, while the Directive on Environmental Impact Assessment -approved in 1985- states that both the authorities responsible for the authorization procedures and the public concerned have to be informed about projects regarding nuclear and integrated chemical plants, toxic wastes reprocessing plants, and other installations involving adverse environmental impacts. Moreover, article 8 of the so-called Seveso Directive requires that Member

States inform all persons likely to be affected by major accidents (included citizens of other States) of safety measures and behaviour to be adopted in case of accidents related to the industrial activities covered by the Directive. Nuclear plants are not covered by the Seveso Directive, therefore after the Chernobyl accident a proposal has been submitted by the EC Commission concerning the information of the population about health protection measures to be applied and steps to be taken in the event of radiological emergency (19). Hopefully this proposed Directive and the one concerning freedom of information will be approved. But legislation has to be implemented in order to be useful, and the conditions to achieve implementation and -more in general- to bring about effective information and communication processes are not only of juridical nature. Risk Communications studies can help in identifying some of them.

Controllability is one element. It is not enough to state that information has to be made accessible or has to be actively distributed, nor to indicate who should do that: it is also necessary to control if this is done and how, taking into account that the procedures and the forms of information can be as important as the contents of it.

Language is an important element in this respect. If the accessible information is cryptically worded or full of unexplained technicalities, citizens will find themselves in the situation of young Renzo in front of the unintelligible Latin sentences of lawyer Azzeccagarbugli in the "Promessi Sposi" of Manzoni: they will find it useless and even suspicious, or just boring in the better case. Language is not neutral because of the different cultures, values and power relations underlying it, and there is no neutral way to present information; on the contrary "framing effects", i.e. different reactions to the same data framed in different ways, have been observed (20). But some criteria of correctness can be probably found: for example, to make explicit all the assumptions made, the sources of the data utilized, the methodologies chosen and their limits.

Openness is an other crucial element. If scientific uncertainties are hidden in order to give a reassuring image of risky technologies and of the ability of scientists to master them, in case of accidents people will feel not only shoked but also disenchantad and cheated. The same applies to political and organizational difficulties regarding the management of complex technologies (21). It is true that generally people look for reassurance and that science has been (after or together with religion) a main source of it. But an ill-grounded reassurance (not to speak about ill-grounded self-confidence) sooner or later turns out to be dangerous.

Multi-way communication is also fundamental. Usually information flows are supposed to go from the source to the receiver (or receivers) in a one-way process. But in order to verify the effectiveness of information (for instance, in case of emergencies like Chernobyl, to verify if citizens received the information about the measures to be followed and understood them), it is necessary to have some feedbacks. Which means that procedures should be found to give the opportunity to the usual receivers to become sources of information (about their needs, their difficulties, their perception of the risks, and their willingness to run them or not) in a multi-way process of communication between experts, politicians, various organized interest groups, and concerned individuals. In this multi-way communication process, the mass-media can have a privileged role as tools of communication between different sectors of society

that would probably never meet otherwise, both at the national and the international level.

The purposes of communication have also to be examined and made explicit. In the field of hazardous technologies, communication procedures in general and risk communication studies in particular can be used as legitimization devices: that is, finding a more "nice" way to tell things in order to make accepted/tolerated otherwise unacceptable risks, technologies and policies. In other words they can be used for manipulatory purposes instead of being aimed at giving people elements to form their own opinion and at informing them about the measures (if any) to mitigate the risks they run in routine and in emergency situations (22).

The Chernobyl challenges to experts' and politicians' credibility seem to indicate that it is less and less easy to legitimize decisions and keep consensus by reassuring citizens on the basis of false or ill-grounded (or excessively self-confident) information about the hazards at stake, and about the scientific uncertainties and the political-organizational difficulties involved in managing high-risk technologies. And the widespread (even if unequally distributed) diffusion of communication technologies indicates that in our "global village" it is becoming increasingly difficult to keep secrets about "inconvenient" events, and to control all forms and contents of information in order to obtain uncritical consensus.

Learning from Chernobyl has been and is an hard experience. Especially for those who suffered and are suffering -directly or indirectly- for it. Hopefully it will help avoiding some future Chernobyl in the nuclear and in other fields. Humankind is not allowed to face many of them.

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RISK MANAGEMENT OF INDUSTRIAL HAZARDS

IN CANADA

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Abstract

The approach to risk management of industrial hazards in Canada is based primarily on a cooperative approach rather than the usual regulatory approach. It is expected that this approach will lead to higher levels of safety and a more competitive position for Canadian industries. In Canada, legislative authority for risk management is mainly vested in the Provinces with some residual areas being a Federal responsibility. The Major Industrial Accidents Coordinating Committee (MIACC) was formed to coordinate activities of Provincial and Federal governments, self regulation programmes by industry, and safety efforts by other sectors of society. The expectation is that the cooperative approach, with some regulations as necessary, will result in higher compliance with safety practices.

The paper will present the results of studies by Canadian industry, Provinces, Federal ministries of Environment, Transport, Emergency Preparedness, and others, presented to the 2nd annual meeting of MIACC, November 29-30, 1988. The conclusions of the MIACC meeting and the implications for the timing and implementation of risk management of industrial hazards in Canada will also be presented.

MIACC

MIACC is the Major Industrial Accident Coordinating Committee and it is the unique Canadian approach to the risk management of major industrial accidents. The objective of MIACC is;

"to provide, for all interested parties, a focus for actions and leadership to reduce major accidents involving dangerous substances in terms of number and severity as they impact on public safety, health and the environment, by improving prevention, preparedness and response programs."

MIACC functions as a voluntary organization of stakeholders who meet at an annual convention to present progress on the objective and to establish policy directions and task forces on a cooperative basis. The second convention was held in November 1988. A key concept is that of a "stakeholder" who is defined as;

"groups that have a vital interest in developing a workable approach for managing chemicals, are directly affected by the issue and can make important contributions to its resolution" (ref.1).

Stakeholders include: Federal departments of Environment, Transport, Emergency Preparedness and Health and Welfare; three representatives of Provincial governments; chemical and petroleum industry associations; fire and police associations; university representatives; and public interest groups.

The MIACC approach resulted from an extensive process of consultation and consensus-seeking over a number of years. There was early recognition that a cooperative approach rather than a strictly legislative approach would be more effective in Canada. Many of the stakeholders have legislative or self regulatory capabilities. In Canada the provinces have responsibility for preventative and response activities for major industrial accidents. Also Canadian industry, with its very small national population, must maintain its competitive position in order to survive. Finally, there is a high level of concern for safety and the protection of the environment in Canada.

A key issue is whether or not the MIACC approach will work and will be an effective alternative to other approaches. The next few years may provide the verdict. However, it must be recognized that different approaches have different problems and this complicates the evaluation task. For example, experience in the U.S. OSHA program is summarized as follows:

"The OSHA rule (on provision of Material Safety Data Sheets) is now being implemented, but corporate compliance and agency enforcement have been problematic. The agency is investigating over 6000 alleged violations by firms, mostly small companies, during 1986; trying to enlighten its own inspectors as well as regulated firms as to what chemicals are subject to the rule and what constitutes appropriate methods of implementation; seeking help from Customs officials on how to enforce the rule against foreign firms whose chemicals are imported into the U.S.; and initiating additional related inspection and communication programs...all with a reduced budget and opposition from the President's office and the small

business sector of the chemical industry" (ref.2, p52).

The MIACC approach is one of coordination of activities of others through the review of activities, gathering of information, and monitoring the progress of levels of safety. Legislation is considered on an "as necessary" basis where the voluntary approach will not work or has reached its limit of effectiveness.

BACKGROUND

Thirty years ago the chemical industries in Sarnia, Ontario joined together to form the Chemical Valley Emergency Coordination Organization (CVECO), an association to prevent and mitigate the risk of a major chemical accident. Thirteen industrial plants and the local community entered into a joint planning exercise which has resulted in an integrated emergency response plan. The plan includes annual testing, provision of sirens for warning of an incident, purchase of equipment by industry, a joint industrial/community management committee, etc.

Fort Saskatchewan, Alberta, has also had a joint industry community emergency response capability for many years. In Quebec the VARENNES industrial society has worked closely with community officials to institute zoning changes to reduce exposure to possible accidents. There are many other examples of successful long term safety activities to manage risks from major industrial accidents.

After the Mississauga train derailment, which had only a few injuries but evacuated 250,000 people, Canada, in 1985, provided regulations for the movement of dangerous goods under the Transportation of Dangerous Goods Act. These regulations have been adopted by the provinces. This act requires the existence of an emergency response plan in the event of an incident and also specified a list of some 400 dangerous goods which provide the starting point for MIACC's list of substances.

Since 1979 Transport Canada has provided one central 24 hour source of information for responding to spills of chemicals, called CANUTEC. It has on file over 25,000 data sheets on products shipped by producers. If either the shipper or the PIN number can be identified for a transportation release then information can be provided to assist in responding to the incident.

Prior to the Bhopal incident the Canadian Chemical Producers' Association (CCPA) had started a self regulating activity "Responsible Care: A Total Commitment". Each member of the association is required to implement the responsible care program reflecting a new "corporate environmental mentality". The statement of commitment reads as follows:

"The Canadian Chemical industry is committed to taking every practical precaution towards ensuring products do not present an unacceptable level of risk to its employees, customers, the public or the environment. The most senior executive responsible for chemical operations in each member company of CCPA has formally accepted these principles" (ref.3).

A key program of Responsible Care is the Community Awareness and Emergency Response (CAER) program. To date 100% of the 224 plants in 110 Canadian communities have participated in a CAER seminar. Eighty-seven percent of plants have had discussions with the local community, 40% have draft community emergency response plans and about 16% of all plants have had at least one of the annual field tests required by CAER.

The responsible care program of CCPA also requires plant safety assessments, a CAER type program for the shipment of product including minimum risk routing, a community right to know policy, a program of care in the storage and production of chemicals, a hazardous waste management code of practice, a panel of the public to provide feedback and a chemical information "hot line".

In anticipation of the need for information, the Federal Department of the Environment started in 1983 to develop a series of EnviroTIPS-- Technical Information on Problem Spills, which provide information on individual chemicals, their properties, their hazards, how to handle them to minimize risk, and so forth. There currently are 50 manuals.

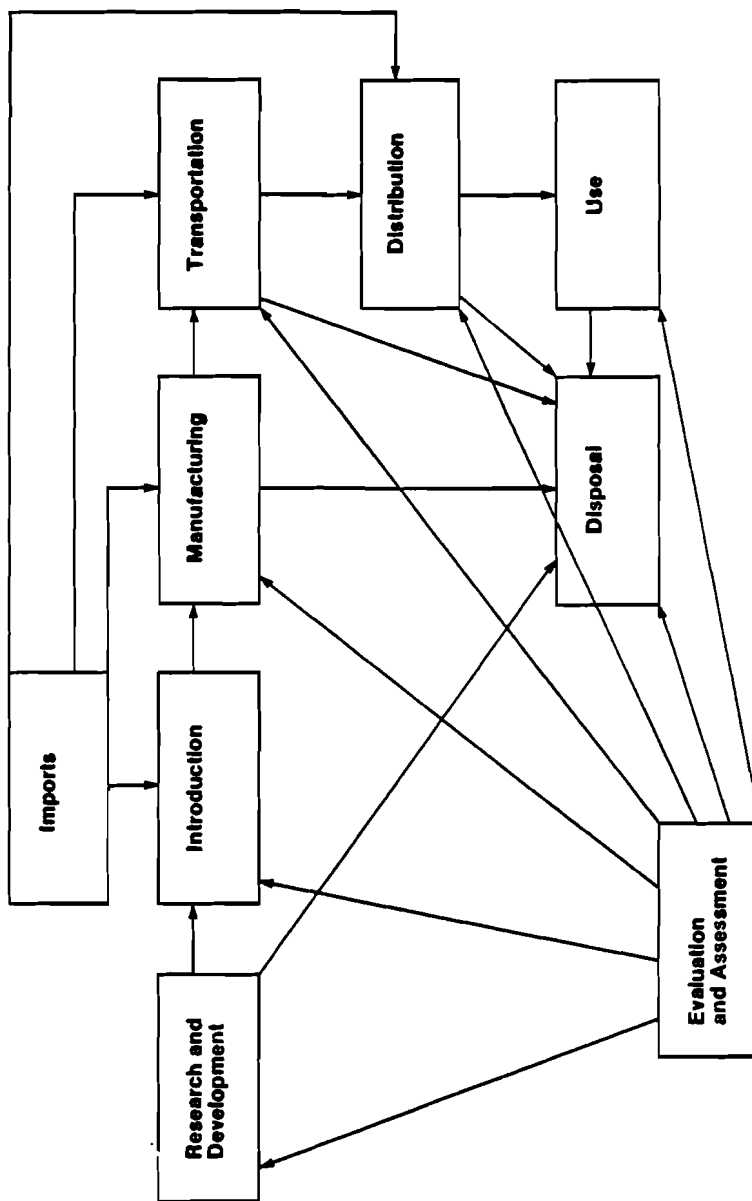
The concern for the environment in Canada, combined with the desire to have a strong economy, led in 1984 to the initiation of a task force of industry, government, public interest groups and labour to study how chemicals should be managed. The result was the concept illustrated in Figure 1 (ref.1), that chemicals should be managed from "cradle to grave". The task force also emphasized the need for monitoring and evaluation. Finally, the task force demonstrated that the cooperative approach would work since the CCPA undertook to implement the recommendations that applied to their industrial sector.

The Department of Health and Welfare, in developing an approach to risk assessment and management in Canada, developed a conceptual approach that has a heavy emphasis on the monitoring and evaluation of regulatory decisions.

After Bhopal a Canadian committee was formed by Environment Canada to assess the Canadian situation. This committee was a cooperative effort by industry, government and public. It made 21 recommendations on actions required in Canada to ensure the safety of, and public confidence in, the production and use of chemicals (ref. 4). By the end of 1988 monitoring of the progress on these 21 recommendations has identified over 200 programs, plans and activities of agencies and organizations in Canada. These varied from training programs for first responders to the establishment of provincial disaster funds for compensation of victims.

In October 1988, Canada initiated the WHMIS system of Workplace Hazardous Materials Information System under the Hazardous Products Act. WHMIS, in a similar way to the transport of dangerous goods regulations, has been implemented by adopting legislation in all the provinces of Canada. This act requires the provision of information to all workers handling dangerous chemicals. It is providing a heightened awareness of risks in the workplace.

FIGURE 1 Stages in the Life Cycle Approach to Risk Analysis and Evaluation.



RISK MANAGEMENT - THE PROBLEM

The mayor of Mississauga, Hazel McCalleon, has said "accidents happen in communities not on the floor of the House of Commons". This could be paraphrased as "accidents happen on the plant floor not in discussions about approaches to risk management". There are many studies of major accidents that lead to the conclusion that accidents happen when a technical system gets out of control and there is no person on the plant floor who has the needed training and experience, the right equipment and the correct knowledge to regain control.

The management of risk is a difficult task. There are thousands if not millions of situations that can cause out-of-control accidents and potential disasters. All but a few of these situations are dealt with by people and equipment in the system. How can the few that are not, be identified before the fact? After the fact it is relatively easy to discover what went wrong and what corrective action was not taken as the reading of any inquiry document will demonstrate. But how to do this and take corrective action before the rare event?

A recent workshop on the impact of organizational structure and management on risk was held by the World Bank. While there was agreement that there was a problem it was felt that several more workshops would be necessary before the problem was defined and the search for solutions could begin. The problem is confounded by several factors;

1. The very low frequency of potential disaster situations.
2. The complexity of levels of government, governmental departments and overlapping regulations.
3. The communication problem between industry and government and within industrial organizations.
4. The difficulty of having people "take care" in situations that appear to be relatively risk free.
5. The rapid changes in technology, production, government actions, and world events.

These difficulties can generally be summarized as the "compliance" problem. Will the approach to risk management be followed? Will the operations follow the plan? Any effective risk management strategy has a monitoring and measure of effectiveness component. However, given the very low frequency of critical situations and the high frequency of system failure, even for the best systems, the evaluation of compliance is itself a difficult task.

The morality of the problem must also be examined. Is it worth finding a solution to the problem? Given that we know many situations in the world where a few thousand dollars will save many lives through the provision of medical care, through the provision of education or through the provision of technology, are there solutions which have a high enough level of risk reduction to justify spending resources?

It is generally assumed that given the magnitude of the potential disasters associated with major industrial activities that there are relative risk reduction-cost effective activities that should be under taken. This dimension of the problem should always be kept in the forefront, especially given the difficulties of finding good solutions to the problem.

One problem in Canada is that many cities do not view industrial accidents as a priority and some chemical plants have had difficulty obtaining community cooperation in developing response plans. The likely reason is that the risks are perceived to be minimal and not of concern to the population. In some instances where there are no off-site risks this may be an accurate evaluation. However, it does pose problems for a comprehensive approach.

Any approach to risk management will take several years to develop and to implement. A major incident will lead to a political response and if there is an incident in the development period of a risk management approach then it is possible that this will lead to adjustments in the approach and the reduction in effectiveness. Since zero risk is not possible and disasters will happen the response of the risk management approach to the political response must be a consideration in the selection of solutions.

RISK MANAGEMENT - THE CANADIAN APPROACH

The events leading up to the MIACC approach have been described above. They are characterized by a cooperative self-interest approach to the problem with the absence of a "grand plan of attack" that is typical of Canadian solutions to problems. The chemical industry was concerned that regulations copied from elsewhere would be neither effective nor efficient. Governments were cognizant of the difficulties of implementing policies across the provinces with their different situations and the public was demanding quick action to protect the environment.

There were basically three options, 1) a federally regulated approach with comprehensive legislation and regulations, 2) a laissez faire voluntary approach, or 3) a cooperative approach that recognized the existing voluntary activities and then attempted to fill in the gaps of legislation or other programs as necessary. In regulating the movement of dangerous goods, the first approach was taken but in the case of major industrial accidents the third approach has evolved.

The main reason was the expectation that at the level of the plant floor, on a day to day basis, the cooperative approach would lead to a higher level of safety. There does not exist techniques for evaluating or rationalizing this option. It was arrived at through the course of events and through a political type consensus seeking process. It is still thought to be the best approach and only time may provide a measure of its relative effectiveness.

A key component of the evolution of MIACC was the willingness of the chemical industry, through self regulation, to undertake to implement a program which meets or exceeds the requirements found in other countries. There was a commitment from the top down and the active involvement of the local community, both factors which hold promise for effective results. It should be noted that a survey of Canadian opinion indicated that few people trust the chemical industry. Thus the cooperation with government and public interest groups is required to give credibility.

Limitation of resources was also a key consideration. By concentrating on coordinating activities and identifying and filling the gaps the available resources could be more effective.

The complexity and extensiveness of the existing initiatives and activities was also a key factor in the decision. In response to Mississauga, the Ocean Ranger, Bhopal, etc. many local communities, provinces and industrial associations had taken action to improve their planning, preparedness and response capability. Because of the self initiation of these efforts it was expected that they would be more effective than new regulation imposed from above.

The speed of implementation is a major advantage of the MIACC approach. Historically, in Canada, major legislation of this type could take 3 to 7 years to develop, promulgate and provide regulations. On the other hand some progress could be made immediately using the cooperative approach.

A major concern about the MIACC approach is that not all industrial sectors/activities are amenable to self regulation. Not all chemical companies are members of CCPA. There are industrial sectors such as mining and pulp and paper which have the potential for major accidents which are not yet involved in MIACC. Recent incidents such as the fire in a PCB waste storage facility in St. Basile-Le-Grande, in October 1988, with 3500 people evacuated for 17 days underscores the fact that many existing regulations are not complied with effectively. The approach of self regulation has lower public credibility. Some provinces such as Quebec and Alberta have implemented extensive risk management activities while others have not even considered the needs.

Government legislation to support voluntary or self regulation programs will be considered on an "as necessary basis". For example, if there are chemical companies who are not members of CCPA and who are not undertaking CAER programs then appropriate legislation could be introduced by a province based on guidance developed by MIACC. The legislation would follow the approach already developed by the industry association and thus would not impose any additional burden on them but would in fact act to equalize the competitive position. Similarly, in the event of an incident leading to a political response, the approach developed under cooperative self regulation could form the substance of the new legislation. This would provide for rapid yet appropriate and well developed legislation.

MIACC - PROGRESS REPORT

Progress is measured annually at the national conference which also appoints the steering committee for the next year and identifies objectives for working groups. At the first conference in November of 1987 the MIACC concept was developed and a consensus reached on its suitability as well as 13 working groups to begin the task of monitoring the existing activities and filling in the gaps. The second conference in November 1988 received the report of the working groups and proposed a number of major thrusts for 1989.

The following highlight some of the results of the working group activities in 1988-1989:

1. For the major chemical plants it appears that within two years all major producers in Canada will have joint industry community hazard awareness and emergency response plans and that these plans will have had field testing.
2. The Canadian Manufacturers' Association will shortly issue a series of manuals on hazard identification and risk management which are specifically aimed at small and medium sized firms.
3. The conceptual approach to risk assessment was developed and standards for definitions, etc. presented that are consistent with other Canadian risk management activities.
4. The fire and other emergency response forces are establishing national standards for the training of first responders.
5. A set of manuals will be published by Emergency Preparedness Canada to guide communities in developing general emergency response plans incorporating major industrial accidents.
6. Canadian municipalities were surveyed to establish a base line for the measurement of community preparedness.
7. An examination of existing buffer zone legislation is underway and national guidelines can be expected shortly.
8. The chemical information system in Canada is being examined with a view to linking the existing 10 separate data banks and user information systems.

The top priority for 1989 is the development of joint industry community response plans. In particular, methods of overcoming the reluctance of communities to participate actively was identified as the top priority.

The communication function was also identified as a priority for MIACC given its voluntary cooperative approach and the need for public acceptance.

A priority approach to risk assessment and management has been proposed, as illustrated in Figure 2. This will provide for the maximum effectiveness in the implementation of risk management activities over the short term as well as maximizing the incentive for cooperation.

The importance of monitoring and evaluation of progress were identified as a priority and a working group established to suggest measures and the creation of base-line measurements.

FIGURE 2 Strategic Approach to MIACC Risk Management

STRATEGIC PRIORITY LEVEL	RISK	TRIGGER LIST OF SUBSTANCES AND PROCESSES	PREVENTION AND RESPONSE PLANS	ROLE OF INDUSTRY
1	<p>HIGH</p> <p>Possible deaths off-site</p> <p>Few events</p>	<p>SHORT LIST</p> <p>High threshold quantities (e.g., OECD)</p>	<p>SPECIAL PLAN REQUIRED</p> <p>Additions to existing fire, police and health services</p>	<p>CENTRAL</p> <p>Knowledge base, preventive leadership</p>
2	<p>MEDIUM</p> <p>Possible injuries off-site</p> <p>Deaths on-site</p>	<p>MEDIUM LIST</p> <p>Medium threshold quantities (e.g., TDG Schedule 12 or EPA modified)</p>	<p>EXISTING PLANS REVIEWED</p> <p>Modifications and training as appropriate</p>	<p>COOPERATIVE</p> <p>Complement government activities</p>
3	<p>LOW</p> <p>Possible injuries on-site</p> <p>Many events</p>	<p>LONG LIST</p> <p>Lower threshold quantities (e.g., reduced WHMIS list)</p>	<p>OPTIONAL PLANS</p> <p>Perhaps only in larger cities</p>	<p>SUPPORTIVE</p> <p>Integration with existing work place health programs</p>

The regionalization of MIACC activities based on the national approach and providing the opportunity for provincial and local coordinating activities is to be studied by observing the pilot initiatives in the provinces of Quebec and Alberta.

The identification and participation of other industry groups not currently in MIACC is an important priority for 1989.

DISCUSSION

The risk management of major accidents is subject to the difficulties of most risk management activities: no data, no models and no experience. The usual approach in such a situation is to gather the people with the most understanding and the people who are impacted and try to reach a consensus. To those in the scientific community and those seeking assurances of no risk this approach is not entirely satisfactory.

However, there seems to be no real alternative but to get on with the management of risk and at the same time put in place a system to measure and evaluate the performance. Furthermore, new methods must be developed to model the expected compliance of the approach selected and thus begin to estimate the expected reduction in risk when compared to a laissez faire approach.

It would seem that a study on a multi-country basis is required to generate the data necessary to evaluate approaches to the control of major accidents within a reasonable period of time.

This paper has not considered nuclear power plants, since in Canada they are wholly under the control of governments or government owned companies and are not considered by MIACC. They are, as in many other parts of the world, heavily regulated and represent one extreme in the range of approaches to risk management. The regulatory authority has complete control over design, construction and operations of these plants. There is always some one looking over the shoulder.

CONCLUSIONS

The Canadian approach to managing the risk from major industrial accidents is unique in that it is based on a voluntary cooperative self regulation approach. The diversity and the complexity of the task is thought to be more effectively and efficiently addressed by this approach. The expectation is that the result will be safer than other approaches.

There is no proof that the approach taken is better than alternative approaches.

The MIACC approach is made possible by the leadership shown by the chemical industry and key government departments as well as the active cooperation of many other sectors of the Canadian economy.

The approach is a direct result of the historical development of stakeholders reaching consensus through extensive consultation and discussion within an understanding that action must be taken voluntarily or by government.

Progress to date appears to be occurring faster than strict legislative approaches and the activities underway compare favourably in effectiveness with other initiatives in other countries.

There is a need for a study of the effectiveness of approaches taken in different countries and in different industries to identify conditions which actually improve safety for the public and the environment.

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**The Market Failure as a Functional Economic
Moment**

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Preface

I attempt to present some more theoretical considerations regarding the distribution of costs which are caused by large accidents and the political management of these costs. One mechanism I shall examine more thoroughly is the Polluter-Pays-Principle, which I analyse in the context of policy analysis.

My two main hypotheses are:

* The political management of market failures, in particular of negative externalities, is simulating the market mechanism in a way, that the allocation of resources might become economically optimal, although the political aspect of distribution of those costs is largely ignored. The meaning of the Polluter-Pays-Principle tips over to, what I call provocatively, the **Victim-Pays-Twice-Principle**.

** My second hypothesis is, that there is an economic necessity to keep the distribution of the costs asymmetric, as otherwise international disasters of high severity might endanger the existence of an entire market or segment of a market.

The market is not able to integrate all consequences of an accident on its own as certain qualities of large accidents exclude parts of it to become an object of market transactions. There is need for political action as accidents do not only damage material goods, but might threaten social systems.

I assume in this paper the management of large accidents and their consequent social, political and economic costs to be a **social problem**, which cannot be treated sufficiently within the social sub-system from which it emerges. Niklas Luhmann characterizes in his book "Ökologische Kommunikation" (1986) ecological problems as those which have to be resolved in diverse subsystems, as there are: economy, science, politics, religion and law. Luhmann states that the essential problem, why ecological problems could not be resolved till now is, that in those distinct sub-systems different approaches and conceptualizations of the issue are applied and they do not treat the identical social problem but different parts or elements of it. This phenomenon appears also in the different meanings the notion of risk has in an economic, political or technical context.

The increasing intensity and frequency of large accidents, the resulting alarm on the political side and the increasing scarcity of common resources, which obliges to rethink their management on the economic side, emphasize the importance of those issues. They also question the progress of a society that sets equal societal with technical progress; Adorno summarizes this reasoning when he remarks:

"Keine Universalgeschichte führt vom
Wilden zur Humanität, sehr wohl eine
von der Steinschleuder zur Megabombe."
(ADORNO, Negative Dialektik, 1975:314)¹

Large Accidents

Before I shall analyze the political management of the cost distribution resulting from large accidents I want to analyze the

¹ "No universal history leads from the savage to humanity, yet there is one from the slingshot to the mega-bomb." (My translation. M.H.)

notion of accidents more carefully.

Charles Perrow ² describes technical accidents as functional disruptions of a technical system, which can be characterized by two factors: complex interactions and tight coupling.³ Perrow concludes that accidents become normal or unavoidable, as they originate from the construction of technical systems;

"(T)hese systems require organizational structures that have large internal contradictions and technical fixes, that only increase interactive complexity and tighten the coupling". (PERROW 1984:5)

An accident in this context is defined as

" a failure in a sub-system or the system as a whole that damages more than one unit and in doing so disrupts the ongoing or future output of the system." (PERROW 1984:66)

This approach has its merits for the conceptualization of accidents as consequent products of a certain organizational structure and allows also to perceive an accident **not** as an outer-societal force, as it is done in the main stream of disaster research. At the same time this approach represents the traditional conceptualization of disasters as an unwanted event, that has to be located in time and space. I shall call this type of disaster a '**centered disaster**' ; the classical ideogram is the explosion of a steam engine, that did not only fulfill the requirements of a **limited geographical and social place** - a center - but could also be perceived with the human senses. A 'social place' means the limitation to one

² Charles Perrow, *Normal Accidents - Living with High-Risk - Technology*, 1984
Charles Perrow, *Complex Organizations*, 1986

³ The precise description of those two factors and their explanatory power can be found in Perrow's "Normal Accidents - Living with High Risk Technology" and shall not be repeated here.

social group, in particular to those operating the machinery.⁴ Furthermore, from a point of view of society, these processes were reversible, that is, the damage and the consequences can be managed with societal means.

Disasters of a new type, which I would call '**non-centered-disasters**', have different features, which not all have to appear at the same time:

First, they cannot be perceived with the individual senses, but only on an aggregated, that is: societal level of perception; or they cannot be perceived at all.

Secondly, they do not necessarily have an individualized center.

Thirdly, they are, because of their geographical or temporal extension not limited to a certain group of society.

Fourth, those processes are irreversible.

Fifth, the management of consequences is characterized by a high degree of scientific and political uncertainty.

The very nature of non-centered-disasters can be illustrated by the accumulation of environmental pollution, that tips over to a disaster.

This kind of impacts are not ruling out the type of centered disasters, although they are of increasing importance.

By taking those features into consideration I implicitly propose to extend the notion of disaster - even when this does not correspond with the form of perception and conceptualization of accidents by organizations, that are supposed to manage them.

Those organizations which manage the 'emergency

⁴ Till the beginning of this century, disasters in technical systems and their ecological consequences were perceived to be outside of society; their consequences were mainly restricted to the working class. Ortega y Gasset (La rebelion de las masas 1930) was the first one to debate the masses breaking into the bourgeoisie world; with the masses also the negative consequences of the technical systems emerge for the public. (f.ex.; SARTRE, Critique de la raison dialectique, 1960)

planning, 'search and rescue' and first steps of 'reconstruction', react on the impact of the event on a social system. This impact is defined in a way, that the decision, when and how to intervene, can be made dependent on the impact only and does not require particular instances of decision-making. This impact can be distinguished according to the dimension of its geographical and temporal extension, the dimension of intensity - measured in units of destruction or fatalities - or a combination of those.

While the organizations in their process of defining the impact follow the logical pattern of cause-effect-relations as main point of reference, the non-centered-disasters cannot necessarily be traced back to individual origins; they have no predictable patterns of extension. That makes interventions difficult as there is no sufficiently understood cause, but much effect.

I am interested in the impacts of those accidents, as they call for a management different to centered disasters.

Being interested in the management of those disasters I concentrate on one form of market failures namely negative externalities and leave aside all other forms as there are asymmetric information and (natural) monopoly.

Market Failure

A market failure can be defined as a situation in which the optimal allocation of resources to reach an maximal overall-utility - that is the utility for producer and consumer - can be provided only by the intervention from the outside, may it be the state or actors like f.ex. neocorporate settings.

A disaster can be taken as a market failure because the optimal allocation of resources is endangered by this event and it is a product of economic transactions, if we perceive the market as being closely bound to the material production which proves to

be essential .

The forms of state intervention that attempt to stabilize the market are:

First ,the state initiates the entire process of management of market failures.

Secondly , main parts of reliability that are normally taken over by the individual polluter are ensured by state authorities.

Thirdly, the state provides immediate emergency aid.

Further activities by the state concern the regulatory policy and the provision of coercion to implement policies even when they are pursued by non-governmental institutions,that shall be discussed later.

Taking up the economic reasoning on the market failure,we can distinguish two sets of problems ,that could be called

a) Procedural Problems

and

b) Distributive Problems.

The procedural problems are concerned with the set of actors and the rules applied which are supposed to resolve the pricing problem within the political or legal setting , while the distributive problems point to the groups that are supposed to bear the costs or enjoy the benefits of this activity.Both are **political** problems .

Focusing on the procedural problems we find several approaches to deal with the market failure; the common origin lays in the political context.

We can distinguish two main solutions,namely the "state intervention or regulatory policy " and the so-called "bargain-solution " .

Both procedures need a yardstick to ensure the performance as

well as the acceptance by a broad general public. The yardstick is coercion or power: to forbid or stimulate certain activities or to impose rigid control with the possibility of direct sanction for the individual responsible as well as an entire market segment.⁵ The legitimacy for this procedure is gained by the functionality of the system and the carrying out of the essential political conflict - the conflict about the distribution of societal wealth. The applied procedures are supposed to reach two goals: the (temporary) solution of the political conflict and, simultaneously, the provision of an optimal allocation of resources for the market. As it is a political setting, that attempts to ensure the optimal allocation, I speak of the **simulation** of market mechanisms. It has to be underlined that these procedures are able to reach the contradictory goals, when certain circumstances are fulfilled. There are some strategies that can mainly be applied in the situation of centered disasters.

In the case of geographical and temporary limited disasters, in which the group of victims can be individualized, what I would call the **strategy of substitution**⁶ provides a balance between the risks taken and the benefits gained for a particular group. In short: risk is translated into monetary units as long as the consequences and their probabilities are known and the victims can be individualized.

As these costs occur only with a certain, low probability that can be deduced from societal experience, the strategy of substitution could provide, due to reasonable forecasts, adequate prices for the risk taken. It has also to be emphasized that with a limited and known group of potential victims, negotiations can be started.

⁵ To discuss this point more thoroughly, all possibilities to regulate and the developed mechanisms and instruments should be presented. This cannot be the task of this paper.

⁶ Of course, there are several modes to provide this result, which I do not want to discuss here.

Some of the features of non-centered-disasters necessarily change the ways of managing their consequences as pursuing f.ex. the strategy of substitution when there is a purely randomly created group of victims, which can be constituted only after they are already victims, seems to lead to enormous constraints for the management, as the possibilities of reimbursement changes:

- the ad-hoc constitution of the group of victims does not allow negotiations, as no organizational structures exist; this favours individual legal processing which is costly.

- The number of victims is increasing, which endangers also the reimbursement of the responsible polluter or/and its insurance company. It becomes financially unbearable for individual organizations.

- The increasing number can also be produced by the internationality of disasters, which poses totally new problems; some of them are attempted to be solved within international settings like the European Community, as shall be discussed later.

To avoid these problems, which are mainly of financial nature the market failure is not any longer a functional disturbance of the market, but a strategy of market actors to ensure the production and keep severe perturbations from the market.

Talking about strategy, I emphasize that a market failure is a situation in which the market is not able to find a price for a good.

Strategy means, that the market might be able to find a price, but it might be a very high one, when it has to reflect the probable damage of a disaster as well; the market actors prefer to make other actors carrying the burden of responsibility for this (probable) costs.

It is evident that this kind of management only is functioning in very particular fields which are characterized by a high degree of interest from the state or by the fact that additional costs occur

only with a very low probability.

The strategy transfers the burden of costs with a low probability to state actors and keep so the group of persons or organizations that benefit from an activity apart from those paying the costs. The market mechanism would lead to the congruence of the group that pays and benefits.

Real Costs

To give some empirical insights I present some estimates that were made in a study by Heising and George 1986⁷. The scope of this study was to find the overall costs the the US-american economy caused by a severe nuclear accident.

The authors distinguish between three different levels of severity of the disaster and four possible levels of regulatory responses.

All cost estimates reflect the restoration of the status quo and the costs of substitution; they do not consider societal changes.

The levels of severity are :

- * severe core damage (TMI)
- * core melt (Chernobyl)
- * worse accident (?).

These accidents are imposing some regulatory responses which are supposed to be:

- * total moratorium
- * partial moratorium
- * stringent regulation
- * no change.

⁷ in : "Nuclear Financial Risk" ,in: Energy Policy 2, 1986

The on-site-costs as well as the off-site-costs of an accident are estimated with each 3 billion \$.

The estimated total costs for the american economy reach from 3 billion \$,when there is no regulatory action taken and only the on-site-costs to be paid, to 1200 billion \$ in the case of a total moratorium.The amount of costs - if there are any regulatory measures taken - reaches from 934 billion \$ to 1200 billion \$.The period of time for which these costs are estimated is 10 years.

Doubtlessly: those costs have to be related to the probability of their occurrence.

For the rest of this paper I shall not deal with the problem of the probability,although it has to be kept in mind.Some problems support this decision:

- * high risk technologies are a field of high uncertainties
- * within the last years estimates of the probabilities for High-Risk-Technologie changed dramatically.
- * environmental disasters ,which I introduced above, are not easily estimated and appear to be not unlikely; their probability might be rather high.

Economic Management in Political Settings

The essential problem of the political management of market failures regards the compatibility of the different goals that have to be reached in politics; the compatibility between "distributive justice " and " optimal allocation of resources " is not given as the goals might contradict eachother.The only applied form of compatibility is to be reached on the level of '**monetary comparability**' .

The simulation of the market mechanism reproduces also the exclusion of elements that ,or cannot be provided by the market - like most public goods - or cannot be priced.The simulation of the market is an attempt to re-integrate negative externalities into the market with the help of coercion.Re-integration means that the responsible polluter should pay the costs ,if they want to enjoy the benefits of an activity.

In this context the costs might be:

**** economic costs**

that are investments into developing and implementing a technology that reduces the emission of toxic substances and avoids accidents.Also the already caused damage has to be repaired and the substitution of one technology with another has to be considered.

**** social costs**

"...der Begriff der Sozialkosten bezieht sich auf alle diejenigen negativen Effekte und Verluste,die dritte Personen oder die Allgemeinheit als Folge der Produktion zu tragen haben und für die der Unternehmer nicht ohne weiteres belangt werden kann.(...)Um als Sozialkosten anerkannt zu werden,müssen Schäden und Mängel zwei Eigenschaften aufweisen.Es muß die Möglichkeit bestehen sie zu vermeiden ,sie müssen Folge der wirtschaftlichen Produktion sein und auf dritte Personen oder die Allgemeinheit abgewälzt werden können."(KAPP 1988:10)⁸

**** political costs;**

⁸ " ... the notion of social costs refers to all those negative effects and losses which have to be borne by third persons or the public as result of production; the manufacturer cannot be easily made reliable.(...) To be accepted as social costs,losses and shortcomings have to have two properties.There must be the possibility to avoid them,they have to be caused by economic production and it must be possible to transfer them to third persons or the public." (My translation,M.H.),K.W.KAPP,Soziale Kosten der Marktwirtschaft,1988

or transaction costs, that have to be paid to make the entire process work. They are the costs of procedure for political and legal actors.

All those costs have two common properties:

- 1) they can be expressed in monetary units and
- 2) regard reversible processes or reversible parts of processes.

Reversibility in this context could be defined by the time horizon of a society or a sub-system of it. Both properties are necessary to make the management of the issue compatible with the implicit requirements of the market.

Within a political setting, the issue of large accidents could - potentially - be solved in a different way as the economically optimal level of safety does not necessarily correspond with the politically or socially optimal level.

Polluter-Pays-Principle

One mechanism that is increasingly discussed and implemented, which attempts to balance out market failures is the Polluter-Pays-Principle. This principle adds to the market mechanism the task or constraint

"...that the polluter should be charged with the cost of whatever pollution prevention and control measures are determined by public authorities, whether preventive measures, restoration or a combination of both."

with the restriction :

"...in other words: the Polluter-Pays-Principle is not in itself a principle intended to internalize fully the cost of pollution." (OECD 1975: 6)

Within the Polluter-Pays-Principle several characteristics appear, which should be made explicit:

First, this mechanism is imposed by state authorities and implies coercion.

Secondly, it addresses the issue to a legal arena.

Thirdly, the costs are the very point of reference and by that the mechanism provides the compatibility between the addressed legal and economic system; otherwise it might be difficult to re-internalize the negative externalities, as they do not exist for the market.

Fourth, this principle allows also to cover international consequences of disasters which become of major interest.⁹

Within the European Community the problem of legal compatibility is resolved as the Polluter-Pays-Principle is laid down in the Single European Act, 130 R and in a recommendation of the Council, March 3, 1975, n. 436. The EC-Commission underlined that this principle shall be applied in tight connection to the economic aspect of environmental problems and that

"I costi ambientali siano presi in considerazione nello sviluppo dell'economia." (MELI 1989: 5)¹⁰

Exceptions can be made if the functioning of the labour market is endangered. There are three types of costs mentioned in the EC-recommendation, namely

*the costs for reduction of pollution,

*the costs of its elimination and

*the costs of reparation, which have to be paid by the polluter. On the one hand the EC emphasizes the reimbursement of costs, the optimal functioning of the market and better development of the economy in general and on the other hand

⁹ For a more detailed discussion see OECD, *The Polluter Pays Principle* 1975; MELI, M., "Le origini del Principio 'chi inquina, paga' e il suo accoglimento da parte della Comunità Europea" in: *Rivista Giuridica dell'Ambiente*, 1989 (2), forthcoming provides particular findings regarding the EC-policies.

¹⁰ Environmental costs have to be taken into consideration in the development of economy. (My translation, M.H.)

civil responsibility is stressed.

This allows the conclusion that the Polluter-Pays-Principle is not thought exclusively as market simulation, but should introduce also political attributes.

The Polluter -Pays-Principle is considered to be the very mechanism for the political system to bind back the costs to the benefits, or in other words: to internalize the whole bundle of costs. In this paper I am not interested in the numerous technical problems of the Polluter-Pays-Principle, I am rather interested in the form how this political mechanism approaches the problem of the distribution of the costs of large accidents.

Some features of the Polluter-Pays-Principle do not allow to deal sufficiently with problems emerging from the non-centered - disasters.

** The legal (and political) actors have to carry the burden of prove in a field of science based technology that is mainly characterized by scientific uncertainty and little societal experience. The competing schools and approaches make it difficult to decide for non-scientific actors.

** Non-centered-disasters can have many polluters which cannot be individualized. In legal terms : we have no origin and consequently no responsibility.

** As we have no individual origin the course of actions to be taken is externalized to administrative actors, which then have to provide the lacking safety or common resources. The internalization of the costs does not work.

** The burden of prove is even heavier as the disasters often can only be perceived on an aggregated societal level; the monitoring and analysis of the consequences of a disaster can be made only by organizations that invest into sophisticated machinery as well as highly educated researchers. The construction of a particular reality concerning the risk of large accidents is - because of the

little and unequally distributed knowledge - easier to adapt to particular interests.

Resulting from the uncertainties involved many distributive and procedural problems might emerge. The conclusions that might be drawn from this shortcomings of the Polluter-Pays-Principle regarding non-centered disasters are of major interest .

The Polluter-Pays-Principle as a political mechanism to simulate the market,helps to legally externalize the costs of disasters and has an important legitimating function.The political problem of the distribution of the costs is vastly ignored.

In this paper I wanted to focus on the mechanisms build in the political procedures and ignored the power relation that largely shape the application of these procedures and the results achieved. I wanted to show that those mechanisms create an asymmetric distribution of costs even when applied with the best intentions.When there is compatibility to be reached between distinct sub-systems, the interest in optimal allocation of resources becomes the dominate paradigm of political management.

Victim-Pays-Twice-Principle

The market - per definitionem - is supposed to internalize all costs as well as benefits. I attempted to show in this paper that disasters might create social and economic problems ,that endanger the existence of certain high risk industries and of social systems. This is the reason why the costs are externalized from the market.

Coming back to the real costs: I presented an example about the costs of a nuclear accident for the US-american economy,which

mounted up to 1200 billion \$. In the Federal Republic of Germany the private reliability for nuclear accidents is 1 (one) billion DM. The rest has to be taken over by the state and/or the victims.

When the market is not able to manage its own externalities, the population, which was already victimized, has to pay - directly or indirectly through taxes - the costs of damage and necessary restoration (if this is possible at all).

Even mechanisms like the Polluter-Pays-Principle do not seem to be adequate procedures to distribute the costs more just, but seems to be a legitimating façade for the mechanism that makes **the victim pays twice** : as a victim and as members of a social system which have to reconstruct their social and natural environment - often without having had any benefits from the production of a good, that damaged this environment.

Conclusion

The considerations presented in this paper were not only of theoretical nature but can be referred to concrete political issues. In the Federal Republic of Germany the environmental issues are thought to be managed sufficiently by the market. An increasing frequency of disasters, particularly in the field of pollution creates enormous problems for the public, to financially bear certain types of activities, specially when it appears to be rather certain that some of them destroy irreversibly the social and the natural environment. To resolve this problem it is inadequate to introduce economic reasoning as the origin of the entire problematique can be found there.

On the other hand market mechanisms are excluded for nuclear power production. Additional danger, is produced by this procedure and it does not even produce economic benefit for society.

This lack, respectively, too much of intervention is not only due to power relations, but result also from the mechanisms build in the political procedures.

FIGHTING IN DEFENSE OF MAN

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Three social investigations on DAILY PRESS, SCIENTIFIC EXPERTS, ORDINARY PEOPLE, respectively, on the occasion of major catastrophies:

- (1) Chernobyl Image in the Italian Daily Press
- (2) Behaviour of Radioprotection Medical Doctors in the Aftermath of the Accident
- (3) Public Opinion Poll on Energy and Environment.



"He explained to me that social scientists have a responsibility to not simply study man's oppression of man, but forcefully seek its end...Ecologists fight in defense of a pollution-free world. Zoologists fight in defense of endangered species. Surely social scientists could fight in defense of man."

(Vic LIEBERMAN in an obituary for his friend and teacher, Anatole SHAFFER)

Abstract

Major accidents, occurred in the latest years, did show an immediate impact of catastrophic nature in the chemical and physical consequences.

An even greater relevance derived in the social, psychological and institutional impacts: the main purpose of the present article is investigating these aspects, via a resumè of three special studies performed by ENEA (Italian Commission for Nuclear and Alternative Energy Sources).

The perspective adopted is that of the social perception of the accident.

(1) An accurate analysis of the Italian daily press during ONE year after the Chernobyl accident intends to measure the above mentioned perception, operating in such a way as a sensor of public opinion or as a thermometer of the society milieu.

(2) A second category sensor adopted is that of the radioprotection medical doctors: their reactions are studied in actions and words, summarized in interviews.

(3) A public opinion poll on energy and environment problems created by the large accident occurred in Soviet Union is used as a third sensor in order to evidentiate the switches in attitudes (from 'digito monstrari' to 'digite verso' and viceversa) in the minds of the people.

From the intersection of the three special studies it is then possible to establish four major issues:

- the role of the political institutions;
- the social concern for the environmental situation;
- the role of the expert and his social image;
- the need for better information.

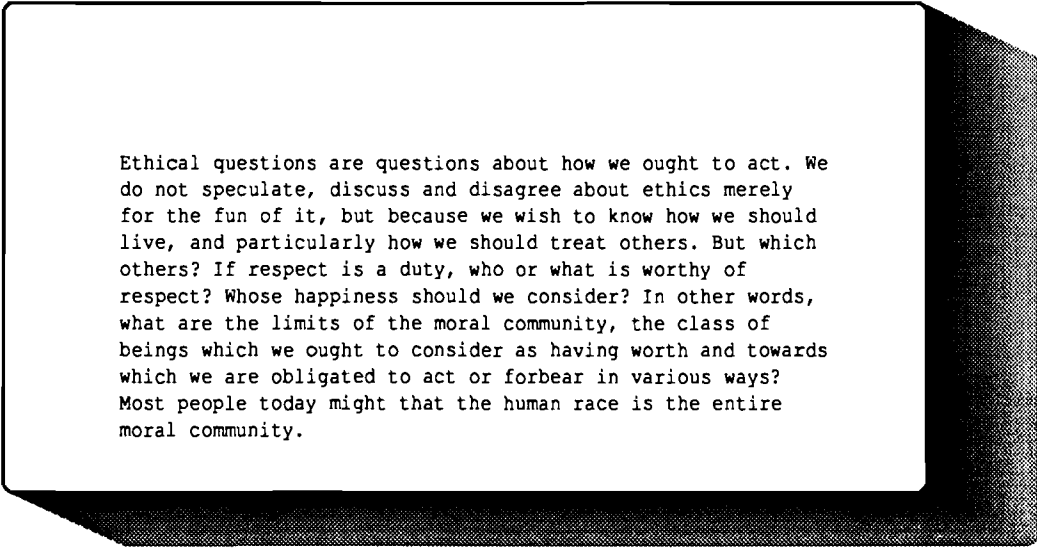
Introduction

Plato, at his time, raised a question: "Why the man and not the crane?" Today this question is very significant for environmental analysts and to answer is not simple.

H. Rolston says that the man vascular system includes arteries, veins, rivers, oceans and atmospheric currents, so that it is not possible to distinguish between the "world" and "my body". This is a just issue to demonstrate that the nature is inside us too, that environment is also inside us, so that we are inside the environment.

W. Inge, a churchman: "many people believe to feel drawn to God or Nature, when they detest only the man". This assertion is important, because it is professed by a churchman. Often and unawares we hide behind naturistic or religious recall an estrangement from another man.

Heliot Marshall says that before human control on nature all was worse. It is possible but, from an environmental point of view it is not possible to deny that man can live without bears, eagles, ants, but he cannot be indifferent to their existance without ceasing to be a man. Their disappearance is a warning: we can disappear too.



Ethical questions are questions about how we ought to act. We do not speculate, discuss and disagree about ethics merely for the fun of it, but because we wish to know how we should live, and particularly how we should treat others. But which others? If respect is a duty, who or what is worthy of respect? Whose happiness should we consider? In other words, what are the limits of the moral community, the class of beings which we ought to consider as having worth and towards which we are obligated to act or forbear in various ways? Most people today might that the human race is the entire moral community.

Environmental Risk and New Technology: an actual dilemma

Increasing risks in energetic and environmental terms, deriving directly and not from use of heavy technology, are adding up.

It is matter of discussion if it is possible to plan a different relation between risks and benefits deriving from technology.

The terms of the problem can be clarified by the following statements:

- there are technological innovations
- there are politics of technological innovation
- there are risk policies (preventive ones, cautious ones, or post factum)
- there are technological conflicts with respect to the choice between technologies, to the risk-benefits, trade off, to the technological-mix
- there are technological options that prefigure a different technological "regime" and a different culture of risk.

The last statements coincide with the question less agreed.

There is, in Italy, a certain lack of maturity in facing policies, risk, innovation, regulation, etc., in terms not proper of sociological, political, jurisprudential sciences, as well as in facing the current political debate. The same lack of maturity is apparent in the cultural issues that more likely contribute to assess public opinion.

The lack of maturity consists of the still poor capability to make autonomous elaborations, of the dependence on foreigner models, on the scarce insight of the most considerable aspects, on the trial to simplify, on the still too simple ideas of the problem dealt with.

On the other hand both technological innovation and technological risk just recently became categorized themes of the political process and of the public debate in Italy.

The main task is to find out the useful instruments to define correctly the problem of synergy between technological innovation and risk policies that unfold on different levels of reality: sociotechnical systems and organizations, politics and public administrations, culture and social change.

Often these various components are dealt with as if they had the same structure, that is as if they could be accessed through the same methodology of analysis, generally an economicistic and technicistic paradigm.

Viceversa it is worth to take in account that in analyzing the conflicts and the social changes there is an increase of complexity and contingency.

In democracies this must not be seen as an unsormontable difficulty.

Technological innovation and risk are matters of systematic policies, that results to be inadequate.

The innovation policies often are not addressed to develop objectives and to the capabilities to attain goals politically defined, while risk policies are an analytical construction more than an institutional compact reality.

However the crucial point is that the two policies usually are dealt with as two separated bodies, conceptually and institutionally, so that their synergy is, to date, only occasional and not foreseen.

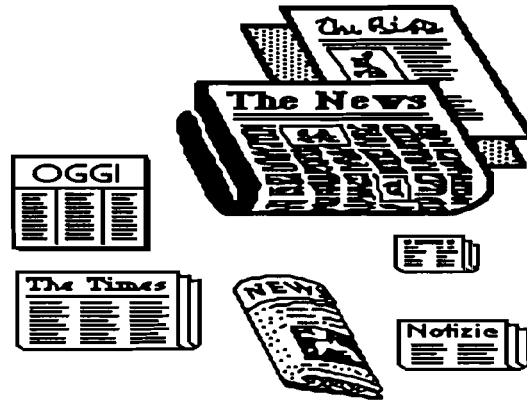
To make possible a synergy between the two policies the following moments must be considered:

a) The innovation policies should have the availability of more sensitive and focused instruments, beyond the current policies of demand and supply commonly used;

b) The effectiveness of these policies relies upon the answering capability or resilience of the institutional system responsible for the innovation and for the enterprises system.

These answers can be cured and strengthened by coherent regulatory and institutional policies that facilitate the jump to higher level of organizative and technological rationality.

1. Chernobyl image in Italian daily press



Chernobyl: information and opinion

In May 1986 the accident at Chernobyl nuclear plant filled the first pages of Italian daily press, with an average increase of the sales equal to 30%.

During this period there was a crosscorrelation of many issues: what we want to stress here concerns the function of media facing the emergency.

Communication mass media work every day following standard routines, so discounted that one seldom asks about their logic of operation. In front of an emergency this standard procedure falls into a crisis, or in any case, it reveals its hidden mechanisms: this is what punctually occurred in relation with Chernobyl event.

The accident took place on 26 April 1986 at 1.25 a.m.. Soviet media, in absence of governmental bulletin, did not mention the notice; au contraire western media "jumped" on the event since Swedish nuclear authority discovered an increase in atmospheric radioactivity.

In the first days, the disaster dimension was emphasized: it is true that an increase of the radioactivity causes short, medium and long term injuries, but a damage which can be instantly quantified is an interesting piece of news.

This is a common behaviour in the western press and corresponds to a hidden code that defines the criteria that an event must possess to become a scoop.

The basic characteristics for which an event becomes a piece of news, are the following seven:

- its strangeness, also in relation to media public;
- the importance that an event assumes for the life of the people;
- the possible consequences on daily life and oneself interests;

- the phisic and psicological nearness;
- the capacity to play on emotions and to create a suspense;
- the development which an event promises;
- the exclusive right characteristic.

These are the reference-points on which a pressmen normally measures the capability of a subject to grip the public: a notice that has the seven qualifications, or most of them, deserves the first page.

The value-news, in case that an event is in possession of it, operates in two different ways:

- they are criteria to choose the available material and
- criteria to propose this material.

Another element, able to bias news production, setted up sources: reporters prefer a set of sources that, on the one hand reflects the social structure of the power and, on the other hand organizes itself into journalistic rules of procedure.

Sources, that in the first days after Chernobyl accident credited a high mortality, were United States and internal at this Administration. In that time elapse two requirements met: the media need of informations able to make an accident a notice-event and the opportunity of United States sources to fill the Sovietic empty space. The accident, like an uncommon event, should have exhausted its capacity of value-news during the first days of May if the radioactive cloud should have remained on Sovietic Union.

When the cloud arrived on western emisphere the event became notice as it involved each of us: from this time the nuclear culture of every nation engraved greatly on press evaluations. The most evident example derived from French daily press, that only on May 12th noticed that the atmospheric radioactivity had not stopped at Soviet and east national borders and spoke, clearly, about nuclear disinformation, charging the government with irresponsibility to have buried data on radioactivity increment during the first days of May. Afterwards French press believed, for two weeks, only government sources. The silence was justified as the official Agencies are, at the same time, appointed develop and check of atomic energy, in consequence of a fundamental nuclear choice.

Le Monde accuses nuclear lobby that cannot, at the same time, be judge and parties to the case: but why did the press, also Le Monde, give trust only to the institutional source and wait that the events had characters of news, traditionally defined, to arrive on first pages?

Opinion pluralities of western press has been a function of presence in the nations of different and clashing interests groups, movements, political organizations, parties, lobbies.

Eric Oberhausen, the president of Western Germany Nuclear Protection, attributed a different attitude of his national press in comparison with

France, to the fact that the French have not the same sensibility and are not exposed to critical groups.

Italian information moved during the first two weeks of May in German similar way, casting doubt on criteria of value-news and attendibility of institutional sources.

We shall deal with these topics in the next pharagraph.

Basic assumptions of the investigation

The Chernobyl nuclear accident has been an event which made real, even on continental scale, and no more only possible, the problem of radioactive pollution.

Direct and indirect consequences, headlines on front pages, stimulation of intense debating, did offer and still offer food for thought, which looks far from conclusion. One of most considerable implications is the sociological impact of the event. Here communication processes and the opinion making by the media assume a role of major importance.

In fact, as previous occasions teach, even specific technological evaluations show clearly a social-cultural substrate. For example, Vincent Covello, writes on a Washington Post editorial (October 31, 1979) that a truly unexpected result emerged from the Kemeny Commission Report on the Three Mile Island accident. A group oriented to investigate a technology ended up to discuss about people. In the very words of the Commission: "It became clear that the fundamental problems concerned people".

Emergency conditions due to accidents in energy production power plants require, in general, performances very sofisticated in terms of information processing and communication techniques. Handling of social problems of emergency makes indispensable, in fact, the activation of information mechanisms of high complexity: these latter ones need specific attention from the viewpoint of the organization.

All these considerations hold particularly true in the case of nuclear accidents because:

- (1) the information emergency connects the entire communication network of the social system;
- (2) the request for information is set up at high levels for long periods;
- (3) a particularly delicate and careful handling of communications is needed in order to avoid the danger of the so called information catastrophies.

In this explosive scenario the leading part of the play goes to the mass media. Both in the emergency phase and in the post-emergency follow-up, a proper reading of the mass media may represent the opening of meaningful windows of observation over social processess activeted by the accident.

The present investigation constitutes an analysis of how a particular communication mass medium (the nine best selling daily press newspapers) dealt with Chernobyl facts. The analysis intends to understand how facts and consequences may have modified the attention ranking and the relevance of some issues (i.e. energy policy and environmental risk) in the news agenda.

The choice of daily press has been motivated by reasons of technical order and economic nature.

It is well known that the daily press reflects from one side the view-point of the writer and on the other side tends to reflect view-points and opinions of the readers to whom the newspaper is sold. In other words the newspaper influences the public opinion but it is also influenced by the people and this way operates as social thermometer.

The multiformal global village network consents today the use of a practically endless number of indicators, often of uneasy access and interpretation, for describing social phenomena.

The most troublesome problem for sociologists has been, and still is, that of finding indicators at the same time meaningful, synthetic, user-friendly and not trivial in order to explain and analyze society phenomena in real time.

This is the reason for the picking-up of the daily press as one of the most sensitive and frequently used sensors.

Characteristics that make daily press so important are:

- (1) the ability to record and store events through news;
- (2) the possibility of quantifying messages;
- (3) the potentiality of searching and merging different and independent theme areas;
- (4) the daily press diffusion all over Italy;
- (5) the easy and unexpensive day-by-day data collection.

It is also well-known that in presence of catastrophic events or highly emotional events, an increment of the number of sold newspapers is recorded, despite of the massive coverage by the electronic mass media. The exigency of the people to live events in first person and not via technical media may be an hypothesis of explanation of such phenomenon.

The newspaper consents, furthermore, the individual choice of both type of journal and selection of matters and therefore gives the reader-citizen-social actor a feeling of greater freedom.

The anomalous event cannot be conceived as an autarchic occurrence per se: the ensemble of associated processes depends, in a very strict sense, on how the event has been assessed by the media. The previous sentence does not intend to emphasize the influence of the voluntary element but intends to outline the subtle distinction between objective reality and social reality.

Exceptional and relevant events may induce noteworthy mutations in the interactions between the two types of realities, in the way they "collide" against social actors and communication channels.

Chernobyl days did activate such social mutations: the explosion on front pages of daily press of energy system risk and safety jargon set up an evidence of their relevance in the society life, i.e. the deep contrast between the technical risk acceptability and the social risk acceptability.

Now the purpose is explaining the choices followed by the ENEA's researchers for describing the Italian daily press attitude in front of the Chernobyl event.

Research range

The range of the research is formed by the first 9 national wide-best-selling newspapers and an ensemble of local newspapers edited in towns around nuclear power plants or sites chosen for the construction of future nuclear power plants.

The examined articles are contained exclusively in the "national" pages of the different newspapers. The separation inside the newspapers between national pages and local pages is looked like an artifice in many cases; but it is useful in order to determine the limits of research range and to succeed in our goals.

The analysis has been developed on the whole set of the 9 newspaper articles, since the trends detected did not justify, as we shall see later on, a separate analysis and even because our research range was the information in its whole meaning as trend analysis.

Time elapse

The research covers a time range from the first Chernobyl accident notice (April 29, 1986) to the conclusion of Italian National Energy Conference (February 26, 1987). Moreover, have been taken into account the articles appeared in the daily press a year after the accident.

Framework of the research

In the first phase of the research, has been operated a census, via schedula, all over the articles which are concerned with energetic themes, directly or indirectly linked to the Chernobyl accident.

In the second phase, these data, ordered by a set of variables, have been introduced in a data base and processed in order to obtain some indications, useful to describe the analyzed phenomenon.

Choice of the variables

The variables describing every article are the following:

DATE / SUBJECT / TYPE / DIRECT - INDIRECT / RANGE / GEOGRAPHIC LOCATION / AREA / EVIDENCE / ENERGETIC SOURCE / AUTHOR / NUMBER.

The choice criteria for the variables are:

- "editorial" characteristics of the article (Type - Range - Evidence - Author);
- article content (Subject - Area - Energetic source - Geographic location);
- connection with the event "Chernobyl" (Direct/Indirect).

We have associated, for each of these 11 variables, with the exclusion Data and Number, a set of descriptive indicators, from a minimum of 2 to a maximum of 41.

1 - DATA

Its importance is of "descriptive" type, i.e., for providing a base for a frequency distribution of the number of articles per day, month and year.

2 - SUBJECT

The subject variable is one of the main variables of the research in order to provide to the articles a well defined character. It is described by a very large number of indicators, larger than 40, and it determines "whom the article is talking about" and provides, therefore, a description of the presence/absence of the different subjects.

Among the indicators describing this variable, one can find together with the governmental Boards, like Ministries, the Parliament, the First Minister, politic parties, also "green" movements, State Agencies and Lobbies.

The goal of this variable is to answer to the question: "who is talking" by the article.

3 - TYPE

This variable is described by 9 indicators. The goal of its presence is to answer to the question: "what the article is talking about". This information is related to the topic or the topics contained in the articles. Its indicators contain both chronicle and scientific information and legislative initiatives and give the newspaper attention toward the different topics. Some indicators appear very often simultaneously, for in the same article a number of topics may be present.

4 - DIRECT / INDIRECT

This variable, described by two indicators (Direct - Indirect), tends to locate the article in reference to the Chernobyl event. Several articles about environmental and energetic themes, along the data collection, would have not been in the press in absence of the Chernobyl accident. Articles stimulated by the accident have been defined as "indirect".

5 - RANGE

This variable is described by two indicators (General - Particular) and has

been set in for evaluating the different attention given by the headlines to the different themes. An article has been considered of General Range when matters connected to the overall dynamics of the accident and to the consequences with respect to whole society are treated. An article has been considered of Particular Range when matters referred to a portion of the society are treated.

6 - GEOGRAPHIC LOCATION

This variable (Italy and sublocations, Abroad) covers a double goal: (1) to give a territorial curve of attention; (2) to evaluate the weight of the national presence with reference to actions, initiatives and motions developed at local level.

7 - AREA

The four areas picked up are the following ones:

- (A) Safety and Health Protection;
- (B) Interaction between Central and Peripheral Organizations;
- (C) Energy Policies;
- (D) Energy Issues and Environmentalist Moviments.

The choice of these areas has been motivated by (1) interests of energy researchers with reference to their occupational role within ENEA, (2) a number of findouts derived from the reading of a large amount of articles.

Area A has been set in in order to evaluate the weight of this theme for the population subjected to the radioactive cloud.

Area B concerns a more political momentum; in fact it evaluates the presence of relationships, conflictual or not, between central and peripheral organization of the society.

Area C covers the presence of articles in which the main theme is debating national energy policies.

Area D is oriented to measure the importance of the "green" segment of society which traditionally has been playing a role of opposition in Italy against (1) nuclear energy, (2) National Energy Plan.

In general the AREA variable has become the principal variable among the "independent variables", with respect to others, on the whole set of the research.

8 - EVIDENCE

This variable identifies the degree of importance given by the newspaper to the articles. Indicators (Very High, High, Medium, Low) identify on a nominal scale the degree of "pressability" of the treated topic and, consequently, the higher or lower attention that the reader will be provided in receiving the news.

9 - ENERGETIC SOURCE

As soon as our research was going on, one becomes aware that the starting matter (i.e. Chernobyl) has been amplified inducing intense debating not only on nuclear issues, but also on other energetic issues. This variable

identified the type of energy (coal, oil, gas, renewable sources).

10 - AUTHOR

Beside SUBJECT , AREA and ENERGETIC SOURCE, who is writing? This variable tends to identify nature and background (specialist, non - specialist) of the authors. The goal is to investigate unusual columns over themes uncommon for a daily newspaper and it suggests overall considerations on the role of experts and their use of the daily press.

11 - NUMBER

This variable describes the number of daily articles and gives, therefore, a valid indication over the long period.

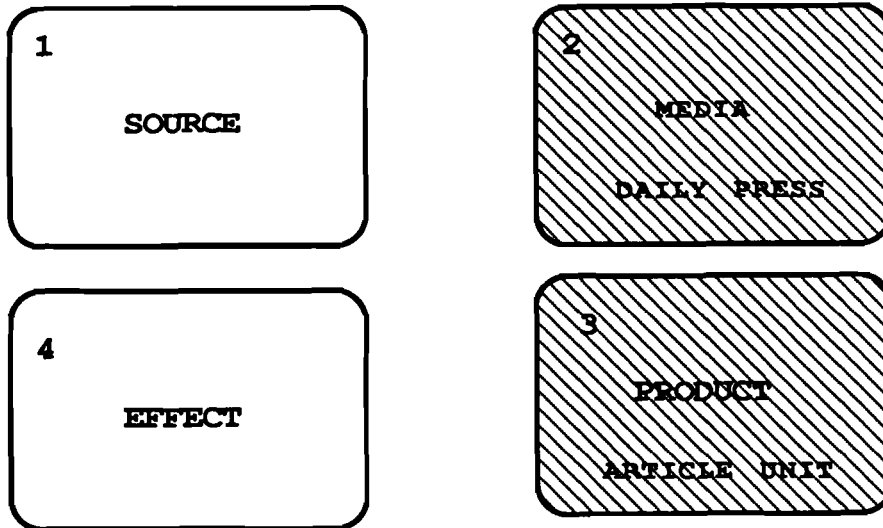
Results of investigation

OBJECT: Analysis of the attitude of the daily press during and after the Chernobyl emergency; Investigation over major measurable characteristics.

RESULTS: The event relevance influenced and partly changed national energy policy megatrends.

The vector and direction of the daily press production, in the tensely debated situation occurred in the after - Chernobyl period, has been analyzed.

The process under study can be schematized into four stages: (1) Source, (2) Media, (3) Product, (4) Effect.



Our interest is focused exclusively on stages (2) and (3).

MEDIA is represented by daily press and connected social implications; PRODUCT is defined by the article unit.

Total results of investigation is available c/o ENEA of Rome (G. Borrelli et al, 1988 in bibliography). Here the purpose is the synthesis of major outcomes, that are the following ones:

a) One of the roles of media, and press in particular, is to manage emergency situations, as it allows to link together different spheres of social life.

b) Uncertainty is the characteristic element of first news. This uncertainty is imputable to Agencies that must manage the emergency.

c) Reduced the weight of the accident the information has partly normalized and into newspapers themes have prevailed as energy pianification and environmental iusses.

d) Political topics have been prevalent in information. For this, also themes containing an innovative dignity, i.e. themes promoted by "green movements", have been suggested in conformity with traditional policy.

e) Press has been mouthpiece of diffuse mistrust about ability of Government to manage complex socio-technical systems and to behave during an emergency.

f) This mistrust is transferred by institutes to technical corps, involving also social actors like scientists, that at first time was in favour of people.

2. Behaviour of Radioprotection Medical Doctors in the aftermath of the accident



It has been said from several parts that the accident of Chernobyl has embodied for the Italian people an event of outstanding psycho-sociological interest. The aim of this work is to evidence some aspects of the psychological impact on a category of physicians who professionally, before than institutionally, deal with radiological risk prevention.

It has been , in fact, interesting to point out how these physicians have felt the attitude of the people, how they have lived the events, how they have judged the organization and the intervents of the public Authorities.

The Italian Association of Medical Radioprotection (AIRM) has conducted a study by means of questionnaire distributed to all the authorized phisicians with the auxiliary goal to verify the effectiveness of the cultural activity of the association.

The former questionnaire could give a useful index to be related to the different measure of the impact in Italy and to the different cultural and formative contest of the phisicians.

The main goals of the inquiry aimed to point out the attitudes of the "rank" of the authorized phisicians about:

- information
- perception of the risk by population
- personal risk evaluation
- effectiveness of the countermeasures and credibility of the Authority.

Main results of investigation

The most significant and relevant results of the inquiry are the following:

1 - The mass media acted in a fundamentally "alarming" way, inducing then in the people the feeling of serious "personal" danger;

2 - As a consequence the fear of people seems unjustified for 54.1% of the interviewed and justified for the 43.5%;

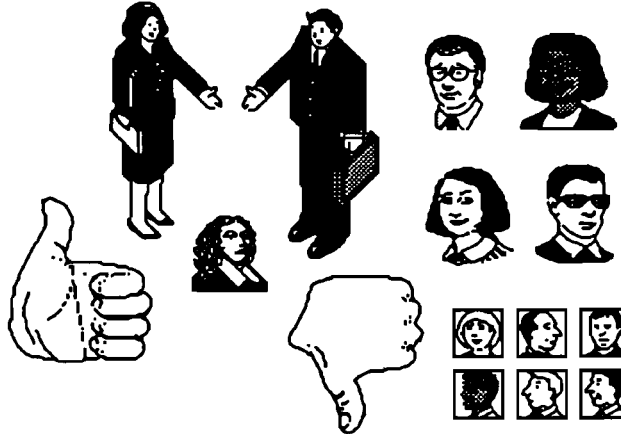
3 - The "discussion" about the effects of the Chernobyl accident in the mass media has involved, mainly, "not always reliable and qualified" scientists (misleading the people because of the multiplicity of interpretations of the contamination data, and, by itself, corrupting the image of the "science");

4 - The Administrative Governments worked without a strategic plan that could be, perhaps, elaborated also by means of "reliable" competences;

5 - It looks hidden, beyond the results of the questionnaire, the experience of who, due to his "culture", tries to introduce "rationality" in the emotive living of important social events. This experience puts forth the problem of relation between "intellectuals" and "politicians" in managing risk prevention and health protection.

As far as it is concerned with the relation with Institutions responsible of the public health it is possible only to draw indirect impressions. From the answers to some questions concerning the medical expenses as Chernobyl consequences, the radioprotection standards and the performances of the Emergency Commission, dissatisfaction is inferred and in some cases distrust toward the Official Institutions.

3. Public opinion poll on energy and environment



An optimism, often unjustified, about the national capability to supply the energetic provision has accompanied a growing care for the pollution. This optimism is often due to a poor information on technically complex themes: "The need of clearness on one side and the need that the messages be appetizing on the other side, define an objective "stress field" in which mass media act. The difficulties arising from this conflict assume particular remark when the object of the message has scientific aspects, and in a more evident way when health problems and environmental risks from technological systems are involved" (Borrelli et al, 1988).

Another remarkable point is the growing mistrust of the Italians in the capability of the rulers to manage complex technological systems as the nuclear are.

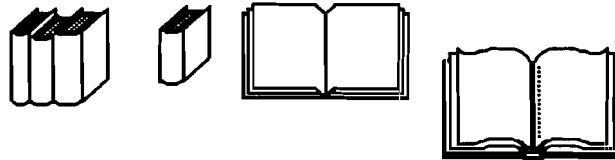
In effect "the growth of the ruling functions and the succeeding feeling of "burocratization" of the functions push the citizen to consider the government as an entity alien from people and, from several points of view, as impersonal" (Borrelli, Sartori, 1986) The industrialized societies ask more and more the contribution of specialized men and corps as a support to political decision; the specialization has created technical elites that give rise to suspects and suspicious from the people" (Borrelli, Sartori, 1986). Moreover in the last few years the evaluation criteria of a project have been strongly modified by the people adding new elements, that increase the number of factors to be considered and that involve subjects never considered.

This determined an increasing mistrust of the Italians with respect to the Institutions, that has consequences in the nuclear policy too.

The citizen could be forced to accept the nuclear choice in situation of energetic crisis. But this should leave the fundamental political question unresolved, that is the relation between people and political power based on a

distrust in the complex sociotechnical system.

The answers given about the higher level of safety of the western power countries power plant versus those of the Chernobyl type are very interesting. This question concerned the opinion about the judgment of the experts.



- Do engineers overemphasize the technological function ignoring or forgetting the duty to sustain and enrich our lives?
- Are engineers merely hired in the service of corporation or other sectional interests, working as mercenaries without worrying about the end they are meant to serve?
- Has human well-being been narrowly conceived in materialistic terms, ignoring others dimensions of human life such as beauty, truth and justice?
- Do engineers regard the service to human as the only form of ethical behavior, with no thought for the rest of nature except as a resource?

Well, only the 19.3% "agree" with the experts and the 9.6% affirm that "probably it is true", while the rest of the sample, with different nuances, express a sense of distrust peaked with a 30% "absolutely I don't believe them".

It doesn't seem venturing to deduce from these answers "the lessening of the role of the expert" in the emergencies, as guessed by several parts (Otway et al.1986). The problem is to look for the reasons of the "lessening" considering the heavy utilization of scientists and technicians by the mass media in the emergencies or about technically complex themes.

The excessive presence of the "expert" could weaken his role, in the same way the excessive driving care advertising could attain results opposite to the original ones.

Another problem could be searched in the "managing" of technicians and scientists by the mass media. Considered that many informations on the Chernobyl accident came from institutional sources, not ready and confusing in the first emergency period, it is pointed out (from the newspaper) that the presence of technicians and scientists has been more quantitative than qualitative. The "scientist" did not substitute the institutional representative, he was instead together" making himself drawn in the mistrust against the Central institutions responsible of managing the emergency.

The "Greens"



A large part of the Italians think that the green movement does not conduct a positive action.

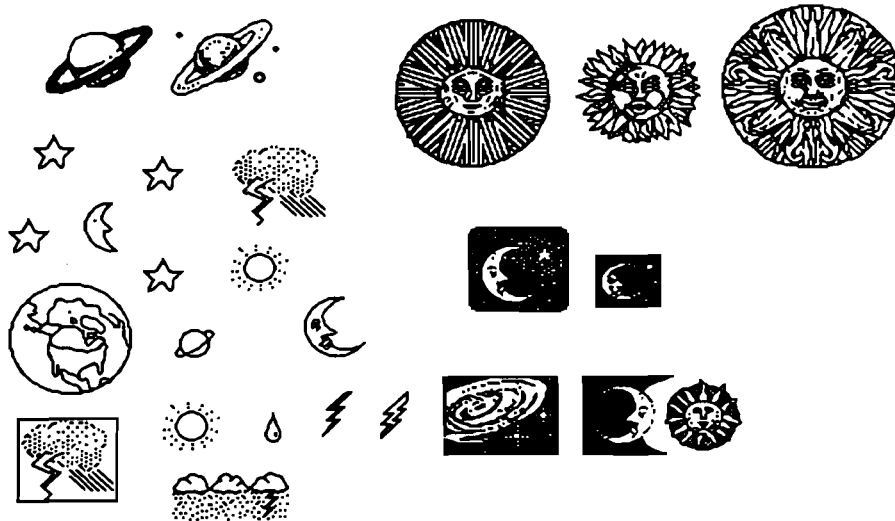
This contradicts the intention of the Greens to present themselves as an innovative group in the Italian political arena. The image of a movement is determined by several factors, not last is the way they are presented by the mass media. In the time immediately after Chernobyl, the news about Greens were presented by the newspapers according to two main modalities.

The former modality saw them as protagonist of "chronicle", while the latter saw them as bearers of innovative requestes. These two conditions go often together: "The chronicle tale of the green events carries a symbolic content. The chronicles of the enterprises of Greenpeace are a clear example. The conflict consists of cultural aspects through symbolic happenning (promotion of new ideals) and of a political level (the search for new allied)" (Borrelli et al. 1988).

The simple chronicle originates a dimension in which social actors, bearers of different requestes, face each other.

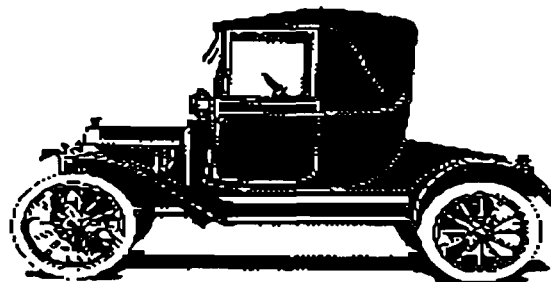
In defining the "dimension" the role of the press is marginal since it represents just the means but not the maker of the dispute. The results of the public opinion polls show that the feeling of many people is turned by well established values (rules, ethics, tradition and traditional policy) that do not permit to get perception of the originalities.

With regard to the people who will take advantage of an higher level of care of the environment, from the analysis of the public opinion polls, three different positions are identified.



The first one, expressed by "all the men and environment" can be defined "holistic"; the second one expressed by "ourselves and our sons" can be defined "anthropocentric"; the third one expressed by "nature itself" can be defined as "cosmologic". Only the third one denotes an innovation in the thinking way of the people with respect to the environmental themes.

Another index of the sensibility of people towards environmental quality is the availability to lessen the use of personal cars.



Answering to the question "Sub to which conditions are you available to give up to use your car?" the Italians gave two main options. The most common possibility (.70%) requires for more public transports, and the others require that "all" the people give an example.

In these terms the problem has no solution. In fact, one of the major sources of difficulties for public transport is the private traffic, and to ask for an example from "all" the others is a non sense.

Nowadays the personal car has become an "intimate good" more than a "status symbol".

Our values, and therefore our actions, are closely tied in with our perceptions. What in ordinary language is often called a person's attitude towards something may be described as a combination of how they perceive it and how they think it ought to be treated. The language we use is often an indication of our attitude, as well as a device for changing the attitude of others. People who refer to "nigger" or "honkies" indicate a perception of a racial group as inferior, and an intent or desire to discriminate. More subtly, to refer to duck or deer as "game" indicates a view of wildlife as a resource and approval of the killing of species thus designated.

We will try to point out some considerations about the attitudes of people with respect both to energetic and to the environmental problems.



1 - The care of Italians of the energetic problem, particularly for the supply of energy sources, are weakened, after the crisis of '70ies. Actually people is sceptical with regard to various hypothesis like black-out or going back to Arcadia.



2 - At the same time, new anxieties come out for environment and pollution.



3 - After the Chernobyl accident, nuclear energy is no more considered a valid substitute for oil, just since the new environmental anxieties. On the other hand, solar and eolic sources of energy, "alternative" for definitions, have been overcome by the more traditional and well established hydroelectric and natural gas.



4 - The attitude with regard to nuclear energy is adverse not only because of the Chernobyl event but also because of an apparent distrust in the capability of the Authorities to manage a complex technical system.



5 - The same distrust in the technicians and scientists come forth, since they are seen as "accessories" to the Official Technical Institutes.



6 - The information level about energetic and environmental themes increased, at least in quantitative terms. It is doubtful that it increased, in qualitative terms too.



7 - Sociodemographic criteria (i.e. educational level, economic status, geographic location) do not permit a sharp cut between in favour and adverse to nuclear energy, but at least they permit to divide in more or less well informed. In other words the opposition to nuclear energy and the joining environmentalist movements crosses all the classes of the Italian society.



8 - The need of participation to the choices that before were delegated to scientific and technical institutions increased. These Institutions are no more felt as instruments of civil and social growth. The actual and future decision making will have to take in account this new reality.

4. Common results to three investigations

1 - Distrust in the Institutions

The sentiment of distrust crosses horizontally the society. It emerged both from the public opinion polls and from the physicians inquiry. The daily press also expressed several times the same sentiment and assured itself the role of "official speaker". It is worth to underline the ambivalence of the relation mass media versus reader, whose limits of reciprocal influence are not clearly distinguished.

2 - The care for environmental situation

This care is one of the fundamental points that emerges from the polls. In this case, by considering the specific role of the physicians, it can be said that this care goes beyond detailed sociodemographic characteristics.

3 - The lessening of the role of the expert

This topic emerges strongly from the analysis of the daily press. Physicians express reservations about experts called to manage the Chernobyl emergence. The public opinion, on the other hand, expresses a major reliance in citizen action as support to technological decision. Notwithstanding this the citizen trusts the scientist rather than the Institutions.

4 - The need of better information

Although the level of information on complex themes appears increased in quantitative terms, both the public opinion, the physicians and the press think that the attained level isn't still enough quantitative to avoid misunderstanding and confusion.

P.S. Distichs are drawn from A. S. Gunn and P.A. Vesilind cited in bibliography

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**THE EVOLUTION OF FRENCH OPINIONS ABOUT
NUCLEAR MATTERS BEFORE AND AFTER CHERNOBYL**

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ABSTRACT

Data from opinion polls are used to follow people acceptability and risk perception concerning nuclear energy. Impacts of major events, such as Three Mile Island and Chernobyl are observed on public opinion. Social responses to such events are particularly noticed in two domains : those of information and communication in emergency situations.

Keys-words : public opinion ; nuclear energy acceptance ; major event ; social response.

INTRODUCTION

Since 1977, major french firms and institutions have supported the AGORAMETRIE system [1] which deals with the analysis and the follow up of public opinions about controversial matters that agitate French society. This system is based on annual surveys of representative samples of the French population ; among other topics, it covers nuclear matters ; and it allows to observe the corresponding public opinion trends in the long term and sudden shifts related to major events, such as the Three Mile Island failure (TMI) in 1979, F. Mitterand's first presidential election in 1981 and more recently the Chernobyl accident in 1986. After a short presentation of the acceptability of the nuclear program during the last decade in France, social patterns are shown ; indeed, age, sex and occupation are important differentiation factors within opinions. Thereafter, some Chernobyl impacts on opinions will be described : knowledge about the accident, nuclear energy acceptance and perception of the information delivered. Finally, Chernobyl has provoked social responses, mainly in the communication field which will be emphasized.

NUCLEAR PROGRAM AND PUBLIC OPINION : AN OVERVIEW

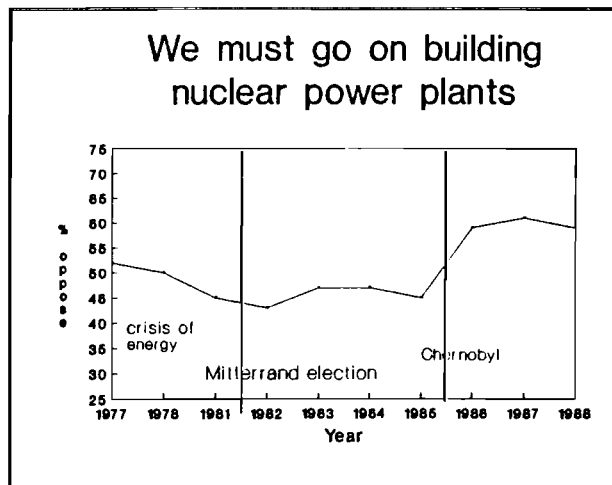
In France, the Seventies were a period of strong controversy about nuclear matters. Opposition emerged in 1973 with the development of the French nuclear energy program, demonstrated actively in each power plant site and culminated in 1977 with the violent meeting in Creys-Malville, which provoked one death among the demonstrators. After this shock, ecologists and various opponents lost some supports and they failed to push their ideas on political grounds. In parallel, the spectrum of an energy crisis was moving away. Since then, the nuclear program gained a better image : opponents were a minority in the public if one considers the results of the opinion pools ; and demonstrations in nuclear installations sites decreased.

In 1981, after F. Mitterand's presidential election, the energy policy remained more or less unchanged. Public opinion about nuclear matters kept their previous levels, at least globally. Indeed, when we examine the degree of acceptability in various social groups, some changes can be detected ; for instance, educated people were more inclined to accept nuclear energy than before and retired people gave less support. Things remained like this until May 1986.

The Chernobyl accident showed that it was possible to suffer a major failure in civil nuclear power plants and that large scale impacts could occur. A sudden shift was observed in public opinion ; for the first time in the last decade period, opinion polls revealed a majority pro the existing nuclear policy but, simultaneously, con a further extension of the nuclear energy program. Moreover, these views were shared by all social groups. And till now, there is no real change in French public opinion.

The previous comments may be illustrated by looking at percentages successively obtained for the following proposition : "We must go on building nuclear power plants". This proposition, which has been in our surveys since 1977, is related to the overall acceptability of nuclear energy. In the Seventies, it was associated with clear ideological positions and opponents to the proposition were strongly against the nuclear establishment. In recent years, the proposition took a slightly different sense ; its cons have joined the previous ones as also people who think that electricity needs are satisfied by the existing nuclear power plants and who are less preoccupied by the energy crisis (in 1988, 55 % think energy crisis is extremely worrying ; they were 80 % in 1977).

FIGURE 1



In Figure 1, we can see the 15 % rise of cons after the Chernobyl accident and note the zero impact of TMI in 1979 on French public opinion [2]. This 15 % shift was also observed after TMI and for the same question in the surveys performed by Cambridge Reports and by Harris Poll [3] in the United States. In each situation, supporters of the proposition lost 5 %, interviewees who did not know from 20% fell to 10 % and as a consequence, cons gained 15 %.

FIGURE 2

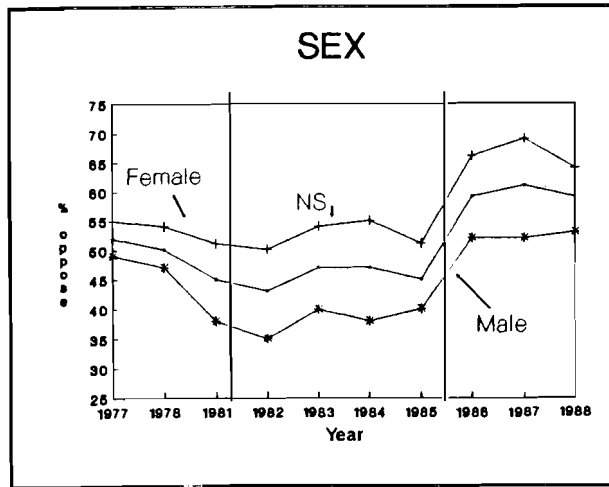


Figure 2 shows a clear difference between women and men for this proposition : women are 20 % more opposed than men are, but the trend over time is exactly the same for both groups. This sex effect concerning nuclear subjects has been regularly stated in our public opinion pools and risk perception surveys [4]. An other huge difference, 20 % at least, exists between the left and the conservative political positions, as is shown in Figure 3 ; leftists are more inclined to refuse nuclear power than rightists ; here again, trends over time are quite parallel. Figure 4 underlines interesting features about nuclear opinion and social class ; indeed social classes react diversely and two examples are given in the Figure. On one hand, retired people were pro nuclear energy but they have been impressed severely by the Chernobyl accident and now, opponents rise to 60 % among them. On the other hand, before 1981 teachers were continuously reluctant towards nuclear energy ; but after Mitterand's first presidential election, they partly agreed with the socialist new energy policy and their resulting adjustments led them to a fifty-fifty balance between pros and cons.

FIGURE 3

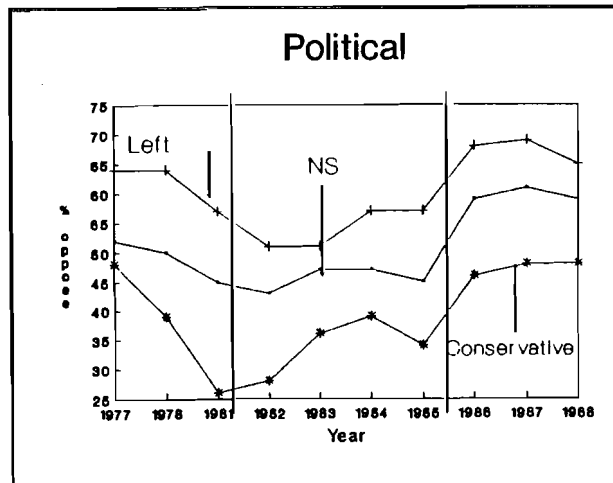
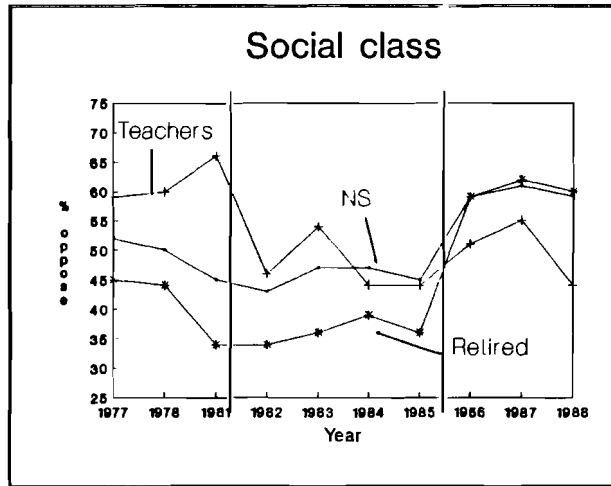


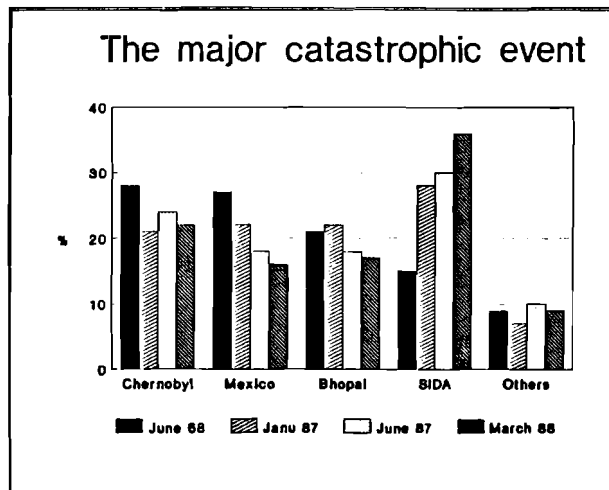
FIGURE 4



CHERNOBYL ACCIDENT PERCEPTION

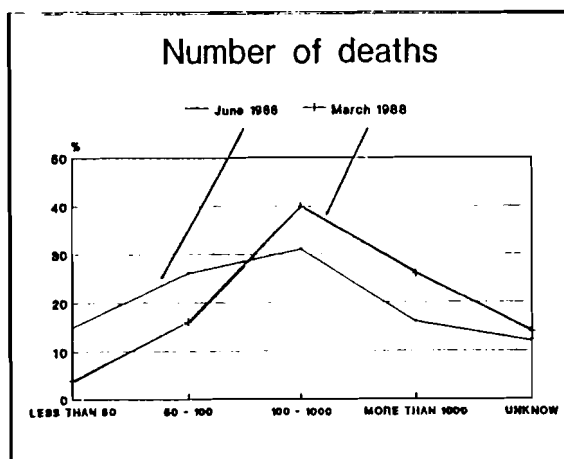
If TMI had no effect on French opinion, on the contrary Chernobyl has been perceived as a major catastrophic event and it is always considered as such in people minds. Figure 5 gives the results, for four replicates in the last two years, for the question : "Among the following catastrophic events : Bhopal, Chernobyl, AIDS, Seveso, the Mexico earthquake,.... which is the most frightening for you ?" ; and they are 20 % to privilege the Chernobyl accident.

FIGURE 5



Do people have a right knowledge of Chernobyl consequences ? To the question : "Up to now, how many deaths were caused in USSR by the Chernobyl accident ?", they are less than 15 % to say "below 50", i.e., the right answer ; and 65 % in March 1988 overestimated the number of deaths : 40 % assessed the number to be between 100 and 1000 and 25 % gave more than 1000 deaths. Such an inaccuracy, see Figure 6, does not seem to reduce but rather to increase. It may have several reasons. One is the first announcement by TV and newspapers of a 2000 deaths accident ; undoubtedly this high value, easy to remember, has impressed lay people memories. An other reason is the quite common association of many deaths with any catastrophic event. Moreover, people suspect that truth is largely hidden and this suspicion leads to an overestimation.

FIGURE 6



After Chernobyl, changes were observed for many questions dealing with general nuclear risks : now, people think that risks are more actual and difficult to reduce. But at the same time, individuals do not challenge the economic advantages due to the nuclear energy program ; nuclear industry is already several years old and public perceive it as an important social sector.

INFORMATION DEMANDS

Informations given after Chernobyl have been received by the public with more scepticism and suspicion than confidence. Sociologists know that when people are interviewed about information with respect to some topic, they always say that there is a lack of information and always ask for more information. Nevertheless in the days after Chernobyl, specialists were speaking diversely and medias were confusing, either excessive and then inaccurate, or unable to fit a public demand that was both considerable and vague. This explains why, since 1986 more than 60% of French have thought that Chernobyl impacts on France were hidden, why most people trust physicians, consumers associations and ecologists when they discuss Chernobyl impacts and nuclear matters and mistrust politicians and why only 20 to 40 % of French accept the information given by institutions.

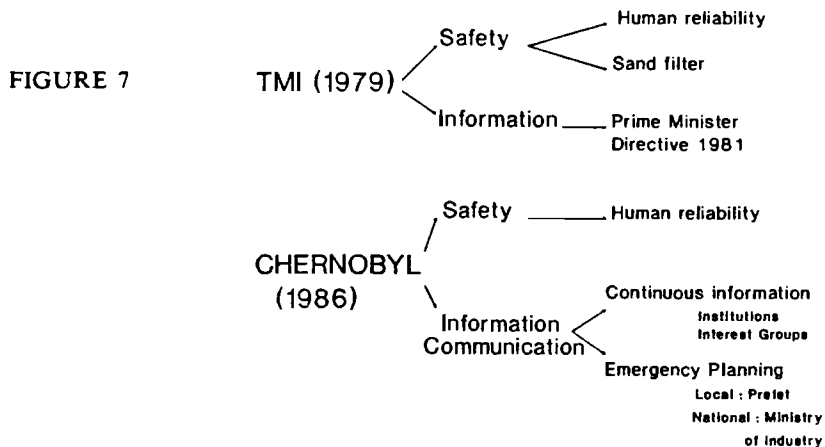
Two social groups asked actively more information. One is the farmers' group who noted how atmospheric radioactive releases could affect large areas and prevent usual consumption of agricultural products ; the other one is the corporation of physicians who justified their demands by their duties and by the psychological assistance they should give to patients and to populations.

Before Chernobyl, farmers strongly supported the nuclear program. Since May 1986, they have reached a new position globally more reticent [5]. Farmers unions and the agro-industry were given informations by authorities about feasible counter-measures relating to crops and cattle, to vegetal and animal productions and their transformed products. A comprehensive booklet is in preparation for a wide diffusion.

Physicians in France are in favor of nuclear energy, in their majority. After Chernobyl, they had to answer questions from their patients and relatives ; interviewed in 1987, they judged that their knowledge about the types of risks, emergency planning, environmental measurements, and internal contamination was not sufficient to give wise advices and to quiet anxious individuals [6]. So, radiation protectionists did a tremendous task of training and of information in 1987-1988, which was mainly directed towards physicians in small towns and rural areas [7].

SOCIAL RESPONSES

Any major catastrophic event, thanks to media coverage, has the potential to impress lay people, to raise safety and environmental protection questions and to involve assessments, contradictory debates and new policy guidelines. Natural disasters, transportation accidents, industrial and nuclear failures provoke such a re-examination and critical analysis of the concerned safety system : obviously learning from experience leads to technical improvements, but it also yields adjustments in the safety organization. The clear impacts of TMI and Chernobyl on France appear in Figure 7 where in-plant safety and out-plant nuclear activity management are equally concerned.



In both cases, the information and communication sector has been developed, structured and improved through a dynamic process involving elected representatives, energy producers and governmental authorities, taking into account CEC Directives (i.e., Seveso Directive, Article 8) or Recommendations, satisfying some demands from the public and interested groups. In that sense a social response has emerged, which illustrates both the difficulty for society to prevent such extreme situations and its ability to react in the short term.

Indeed the Local Information Commissions, which should be placed at major nuclear installations, came from the Premier's Minister's Directive of December 15,1981 ; these structures took benefits from the poor communication management demonstrated during the TMI crisis. In these local commissions, leaders are the regional elected representatives and the operator is the main partner ; subjects under consideration are information exchange on normal operations conditions and incidents notification ; and an agreement between the operator and the administrative authority, i.e. the Prefet, concerns the exchange of technical information needed for the management of crisis situations at the local level [8].

Before Chernobyl, at the national level, information about nuclear issues was considered as satisfactory. The Ministry of Industry released on a continuous basis general scientific information and safety reports data ; for crisis management, propositions were under consideration ; and the CSSN (Council Superior for Nuclear Safety) was a consultative institution where 35 experts with nuclear, technical, economic and social competences gave advices to the Minister.

After Chernobyl, more emphasis was put on emergency management and the related communication problems [9]. In Figure 8, a short chronology lists actions of information and communication and the organizational decisions.

Concerning information, the main fact was that the Ministry of Industry got a new mission : to coordinate and to release nuclear information to the public and to medias at the national level [10]. This task is now performed by a permanent information unit. The consultative institution CSSN was replaced by CSSIN (Council Superior of Nuclear Safety and Information) ; now, CSSIN includes 6 experts from public communication and one among them is the vice-president of the Council. Moreover, this new state organization faces a citizens' interest group, the CRIIRAD (Commission Regional of Independent Information on Radioactivity) founded in May 1986. This group joins university and independent laboratories which perform environmental monitoring ; it is managed by volunteers and financed by Regional Administration funds. At the local level, there is a free access to safety data through phoned services both in the plant and in the Town-Hall of the Prefecture, i.e. the main city of the administrative region where is the plant [11].

FIGURE 8

CHERNOBYL April 26, 1986

Information crisis cell :
Interministerial May 14, 1986

Phoned information May 16, 1986

Minitel information May 22, 1986
Summer 1986 CRIIRAD

CSSN → CSSIN March 2, 1987

MAGNUC :
Minitel information system .. March 3, 1987

LAW : Prevention of Major
Technological Hazards July 8, 1987

ORSEC-RAD

Parliamentary Office of Scientific
Choices Assessment Dec. 17, 1987

Proposal : Nuclear Safety and Information Agency

In crisis situations, the need for a better communication has been recognized. For concerned populations at the local level, a public relation unit and a press center operate at the Prefecture when the Intervention Particular Plan comes into force. And simultaneously, a national information crisis unit in the Ministry of Industry has the task to give harmonized informations to the public and to the medias.

CONCLUSION

Any catastrophic event has numerous diverse impacts. For concerned communities, sanitary and economic effects are often immediate and dominant. The initial shock is followed by questioning and controversies which develop on a large scale. Opinions may change, strong demands are formulated, which require responses and new measures from authorities ; lessons must be taken into account.

Chernobyl is a clear example of these combined effects which affect individuals, communities and governments. For France, major impacts have been observed in public opinion and in the field of nuclear information and communication. Some impacts are negative when they frighten and make suspicious some population segments ; but some others can be considered as positive when they lead to a more transparent nuclear policy and when they make the access to information easier for interested citizens.

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"The System's Ability to Learn: Some Basic Problems in Post-hoc Accident Assessment".

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The aims of post hoc accident assessment are to assemble information through scientific investigation to discover the cause of the accident. This is essentially regarded as a learning experience, on the basis of which, measures may be taken to avoid the replication of such an accident under similar conditions. This assessment of cause cannot be separated from the assignment, or release from, blame of parties or institutions concerned in the accident or with the facility where the accident occurred. This introduces a legal dimension, and concepts from legal practice are incorporated into scientific investigation, such as "foreseeability", "state of the art" and ultimately "negligence". In addition, of course, surrounding legal perspectives, are diverse political perspectives also concerned with criticizing or defending powerful institutions and policy commitments.

A key question underlying these contending frameworks is whether there is a pure, objective scientific framework that can be found and used, both to arbitrate between the others, and to provide new, organized conceptual knowledge with which the system of practices can learn and improve.

The case study will consider this question, and the problems of post hoc accident assessment which are located in the collection and dissemination of information. This is highlighted where the investigatory body is responsible both for disseminating information to avoid accidents, and with gathering evidence for the assessment of an accident, with the possibility of prosecuting for breaches of safety. These

responsibilities call for different methods of handling information. The proactive role aims to prevent accidents through inspection of sites and provision of advice on safe practices: information is provided on an informal and individual basis. The reactive role aims to identify unsafe practices which may have led to the accident, but the information gathered and disseminated in this case is public and formal. Both involve making judgments, but in the latter case, the judgment is made publicly and has wider repercussions than judgments made in a proactive capacity.

Much work has been done in the Sociology of scientific knowledge on the role of institutional contexts in the construction of scientific knowledge, relative to the specific interests of participants. This same social dimension is also applicable in scientific investigations of accidents within a wider social context, however in this case, interests stem from the structural position of the investigatory body. Ultimately, the assumed division between technical and legal or political problems comes into question.

To give a simplified example for comparison, after a motoring accident, the parties involved file personal reports to their insurance companies for assessment. The facts of the accident are usually selected and presented by each motorist to ensure that least blame is to fall upon him. There is a definite personal interest involved in selecting which of a range of possible facts are significant: for instance, if the collision occurred on a bend in the road, the motorist who was distracted and driving too fast on the wrong side may not wish to select this as a highly relevant fact, and may instead give greater significance to the bad road conditions, or the weather. This is a personal, and small scale accident, the main aim of the assessment of cause being to assign blame, with the possibility that sanctions may follow.

In large scale accidents, however, such direct personal interest is not so easily attributable to the selection of

significant facts, as it is the investigatory body, in consultation with the parties concerned and through independent investigation, that gathers and presents the information on the basis of which assessment is made. So a further level of social negotiation is introduced. Where in the small scale accident, personal interest may complicate the direct presentation of information for assessment, in the large scale accident, wider structural requirements which dictate the interests of investigatory bodies brings about this complication.

A significant complicating factor which highlights basic problems of post hoc accident assessment is the structural location of an investigatory body that is charged with both proactive and reactive response to accidents and whose power is unevenly weighted to apply the ultimate sanction, criminal prosecution. Thus its investigation proceeds in the selection of significant facts not with personal interest in mind, but with the unstated, and perhaps unperceived, institutional interest of fulfilling its reactive role, and considering available information only in the light of possible criminal prosecution. As a particular kind of hard evidence is needed for criminal prosecution, a broader base of evidence may be deemed insignificant, and not publicized. However this evidence, if publicized, may contribute to the learning process which is the aim of accident assessment.

This process will be examined through considering the post hoc accident assessment of an explosion in the valve house of a water transfer scheme in the north of England.

The Abbeystead disaster

The Lune-Wyre water transfer scheme in North Western England operated through the early eighties until 23rd May, 1984. Prior to this date, the villagers downstream from the outfall end were concerned that the recent flooding around the village was caused by this new water transfer scheme. Keen to deny this, the North West Water Authority invited a party of villagers to

inspect the outfall works. On the evening of 23 May, 1984, a group of 44 people including 8 water authority employees, assembled in a valve house set into a hillside at the outfall end of the Lune Wyre transfer scheme at Abbeystead to view a demonstration of water pumping.

The pumps were switched on and the party waited for some time without the water appearing. Unknown to them an explosive mixture of methane and air was being pumped into the valve house ahead of the water. Suddenly there was an intense flash and an explosion. 16 people were killed, and 28 badly injured from burns and the collapse of the heavy cement roof.

Although methane is well known as an explosive gas and as a potential problem in underground workings, no measures to disperse gases had been taken in the Wyresdale scheme. The tunnel had been vented into the enclosed valve-house instead of the open air. Almost immediately after the accident, an official inquiry got underway with a view to establishing the cause, blameworthiness- if any- and future preventative measures.

Moments before the explosion, a father and his eleven year old son were standing looking into the water already lying in the tunnel end, discussing the possibility of fish living in the water. After the explosion, the father, who was badly injured and burned, pulled his son's decapitated body out of the rubble. In humanitarian terms, the lack of foreseeability of that particular accident can not be in doubt. However, the foreseeability of an accident relative to the conditions of design, construction and operation was in doubt, and it was with this question in mind that an understanding of this accident was sought for assessment, firstly by the investigatory body, and later through years of civil court cases brought by the victims for compensation. These latter cases were conducted in the High Court, and the Court of Appeal, where in the former the designers, contractors and

operators were charged with negligence, while in the latter, the designers alone were charged with full responsibility for negligence.

The investigatory body was concerned with foreseeability of the source and mechanism of ingress of the methane. The significant question was whether there was knowledge that methane would be produced by a known or detected source and would accumulate in the facility, at any time during the design, construction and operation of the tunnel, and if so, what measures had been taken to apply safety measures. The courts put greater significance into the lack of facility for ventilation of gases, where external conditions or prior knowledge indicated there was even a possibility of the existence of those gases. Thus the HSE, for possible criminal prosecution, was concerned with certain evidence of foreseeability, hence negligence, "beyond all reasonable doubt", rather than with less completely certain evidence of a kind which may nevertheless be important.

The investigatory body

The inquiry into the disaster was directed by the Health and Safety Executive (HSE), the executive arm of the Health and Safety Commission, which was set up to carry out the aims of the Health and Safety at Work etc Act of 1974. This Act was devised to replace existing statutes with new regulations and to create conditions for more effective self-regulation by restating the common law duties of employers and employees, and the duties of employers to persons other than employees on their premises. Thus the responsibilities of these bodies under the Act are to research, train, inform and advise as well as to direct investigations and hold inquiries. The HSE has the power to enforce the statutes of the Act, breaches of which may result in criminal prosecution.

These statutes may be breached where a company failed to take reasonably practicable steps to meet the statutory duties. An assessment of "reasonably practicable steps" is measured against the foreseeability of the accident, and the utilization of technical solutions at the disposal of the designers, contractors, and operators to practice within the "state of the art". This is in itself a problematic concept, but may be loosely defined as referring to that which is within common knowledge and practice. Thus the investigation was closely governed by the necessity to assess the foreseeability of the accident, and steps that could have been taken to avert the accident that were within common practice. (1)

For the investigation, the Health and Safety Executive brought to Abbeystead a team of 10 people including specialists from the Factories Inspectorate, Pipelines Inspectorate of the Department of Energy, and other fire and gas experts. This team was supported by hundreds of experts producing ancillary reports on a number of issues 'farmed out' to them by the HSE.

The investigation of the disaster was carried out by an attempted reconstruction of the accident, to the point prior to ignition of the methane. The replication was not exact as the build up of methane was less than that extrapolated at the time of the explosion, but allowed an explanation of the mechanism to be devised. It was deduced that methane had accumulated in a void along the tunnel roof, and was pushed through into the valve house ahead of the pumped water, where a source of ignition resulted in an explosion. The questions which followed were concerned with the manner in which methane entered and accumulated in the tunnel. As the HSE has a prosecuting role, the question of whether this accumulation and its potential effect was foreseeable at any stage during the design, construction and operation of the water transfer scheme was also pursued. If sufficient evidence of foreseeability, and therefore negligence, were proven, the HSE would bring a criminal prosecution for breach of the statutes of the Health and Safety at Work Act. Prior evidence for the generation of

methane in that locality, or evidence of methane in earlier similar tunnels, was thus relevant.

In order to answer the questions of mechanism of ingress and accumulation of methane, expert investigations were directed on the tunnel, and on samples taken from the tunnel, which were sent to outside laboratories for their analyses and reports.

The first technical reports were produced, but not released, in September/October 1984. Results were given on isotopic and chemical analyses of gas and associated water(2); the possible biological origin of structures found in the Wyresdale tunnel(3); the potential for samples of organic sludge taken from the tunnel to generate methane, questioning if the methane was of biological origin (4); the measurement of C14 activity, to determine the age of the methane in the tunnel, questioning if it was of geological origin "ancient" or "modern"(5); and reports were produced by HSE inspectors on electrical aspects, fire and explosion aspects, and civil engineering aspects of the investigation.

Evidence based on these reports was presented at the first public legal forum, the inquest for the victims of the disaster. The mechanism was described such that methane entered the tunnel through cracks in the tunnel lining, dissolved in groundwater which was known to add to water supplies in the tunnel, when it was not full. The tunnel had not been full, and water had not been pumped through the tunnel for 19 days before the accident. Thus the roof space entrapped the methane which was emitted from solution in the ground water in the reduced pressure of the tunnel.

The great weight of evidence at the inquest hinged on the source and ingress of the gas. It was given in evidence that it was of ancient origin, lying deep underground for thousands of years, its presence only apparent and only identifiable when it appeared. The judgment of the inquest, in October 1984 was that the disaster was an accident, that the explosion was unforeseeable.

In February 1985, the official HSE inquiry report (6) was released, though not the background scientific reports on specific issues such as carbondating of the methane. It also concluded that the disaster was not foreseeable, and that while strong recommendations would be made to the water industry to check the safety of similar installations, no criminal charges would be brought against the designers, contractors or operators of the scheme.

The selection of significant information on which the official inquiry report is based begins to become apparent when the background technical reports are studied. The analysis was broken down into compartmentalized data, as samples from separate parts of the site of the disaster were sent to separate laboratories for analysis, and these findings were returned to the HSE for "harmonization".

A particular example will be provided to illustrate these points. This example relates to the statement at the inquiry that the methane was of ancient origin and could have been lying in the ground for thousands of years, its presence only apparent when it appeared.

A sample of gas was reduced to a carbonate, and sent to a laboratory for carbon dating. The sample emitted C14 at a particular rate, indicating ancient geological origin of the methane in which the carbon was bonded. However, because of the general background increase of C14 in the atmosphere, this trace could not be definitively identified with the sample. In other words, there was a possibility of contamination. While the analysts could conclude that the carbon in the sample was mainly of ancient origin, that was all they could say. They advised against putting any kind of date on the sample. They could not confirm that it was absolutely of ancient or modern origin, that is, from deep coal or from recently decayed vegetable matter. It has to be remembered that all they were dating was the carbon, not the source of the methane, which

could have been generated recently and biologically, but still have taken up some carbon of ancient origin. However in the wider interpretation, these became synonymous.

The sludge samples were sent to another laboratory where a different kind of analysis was carried out. This analysis was to determine whether the bacteria in the sludge were capable of producing methane, and were of the type that had previously been found in muds and other organic sludges. They concluded that it was unlikely that biological activity alone could have produced a sufficient amount of methane, which, they stated, fitted in with "what they understood to be the results of the carbon-dating: that most of the methane was of geological origin". They do point out that conditions in the tunnel being as they were, under certain circumstances, large amounts of methane could have been produced. However, their conclusions are persuaded by the carbon-dating results. It should be noted that from the uncertainty stated by the carbon dating laboratory, the significant item that was extracted for communication to the second laboratory was that the carbon was mainly of ancient origin.

Thus the findings given by the technical reports consist overwhelmingly of possibilities and uncertainties, with the researchers stating either that they could not give an unambiguous answer to the questions posed because they did not have information on the context, or the researchers discarding possibilities because their results did not fit into the picture being drawn by the earlier findings.

However, in the report, these results were harmonized to state that the methane was of ancient geological origin, from a deep unknown source, and that the tunnel sludge could not have produced the same amount of methane. In order to show the possibilities of reconstruction, the two tests, if done by the same laboratory, with the same focus for analysis could quite easily have yielded the results that while the carbon in the methane was of ancient origin, its source was in the sludge

which was being consumed by methanogenic bacteria, possibly carried in by groundwater from the coal measures. If both the gas and the sludge had been carbondated, it may have revealed that ancient carbon was in both. Instead, it was only confirmed that the sludge carried methanogenic bacteria, which is not unusual, and simply confirms what is well known within the biological discipline. However, by requesting separate analyses, with separate foci, an artificial distinction is drawn between the biological and geological origins of the methane.

Also, by focusing the alternative to ancient, unforeseeable methane on organic sludge in the tunnel, and not on methane generation from the known coal measures in the immediate locality of the tunnel, the inquiry increased the apparent credibility of the ancient, deep and unforeseeable methane interpretation.

The complex process of establishment of a technical fact can be seen in this example. When it is analysed closely in this way, the fact is underdetermined by the evidence: yet this underdetermination, and the viability of alternative facts, is obscured by the official process of reconstruction. The particular scientific fact so constructed had wide social usage, from providing a definitive statement to the early inquest, to its investigative use as the starting point for the further assessment of the accident, against which wider recommendations to the whole industry for future safe practice were constructed. A further important usage was in the defence case in the civil court proceedings for negligence against the designers, drivers and operators of the tunnel. was founded on denying negligence, relative to this fact.

As grounds for the decision not to criminally prosecute, the HSE inquiry report stated that the solubility of methane in water was not fully understood by the designers, operators, nor the water industry generally since published references to it in Chemistry had not been widely circulated in the civil engineering profession. (8) The HSE report noted that while

designers and operators believed methane was not emerging from the strata during construction, tests which were carried out in line with standard contract clauses could neither confirm nor deny its absence or presence amongst other factors, because other gases were present which confused possible methane readings. Existing test rules were inconclusive and thus useless. The report recommended widespread publication throughout the civil engineering profession of the possibility of the solubility of methane in water under pressure. Training to alert practitioners to this possibility would be necessary.

While the example of the methane's origins has been described in some detail, there were several other areas of discretion and interpretive choice over the establishment of important facts, and around the definition and significance of "prior knowledge".

Debate and further assessment of this accident continued long after the HSE inquiry report was published; much of it was conducted, as is often the case, in the glare of publicity around the issue of compensation for the victims of the accident. In the engineering journals, other literature sources, and throughout the 1987 civil court case, instances of apparent prior knowledge were cited, and the argument continued around whether this accident was precedented, or was a singular "Act of God". It was noted that the problems of methane dissolving out of water in underground workings following a series of explosions in Hungary were the subject of an international civil engineering conference when the transfer scheme was being designed. Other earlier instances of the presence of methane in sumps, aqueducts, pumping stations, valve houses, and boreholes, some resulting in explosions, were detailed in the engineering press and in the court cases. The denial that such events constituted precursors, thus negligence, and failure to learn, hinged on the differences rather than similarities that could be drawn between such installations and the Lune-Wyre transfer scheme.

The legal dimension overwhelmingly yielded not an addition to knowledge, but a denial of knowledge, and a denial of systemic similarity, which has implications for the lessons that may be learned from the assessment of this disaster.

The decision not to press criminal charges of responsibility for the accident meant that for many, the disaster then almost assumed the character of an "Act of God". This compromised the capacity of the HSE to perform its proactive role of educating the wider industrial system into better practices, although fulfillment of that role was one of the reasons cited for not pressing criminal charges. (6) That is, if criminal charges were brought, all information about the disaster would be subjudice, and it would be impossible to publicize recommendations for immediate safe practice to the water industry. Yet much information about the disaster's parallels and precursors was hidden from view by the way the inquiry was constructed that justified the lack of criminal prosecution.

The publicly unstated conflict of roles embedded within the regulatory institution was reflected in the scientific analytical knowledge which it generated. Thus in its reactive capacity it searched for a narrow range of certain evidence, which undermined its performance in its proactive capacity to provide a broad public base of knowledge of possibilities.

The selection and shaping of scientific facts should not be interpreted as an intentional "cover-up", or deliberate misrepresentation. The social context within which such assessments are made demands investigation and explanation to be provided in the glare of publicity, urgently, by a body that must fulfil roles which become contradictory. So in the interests of fulfilling a proactive role, and disseminating information as quickly as possible to avert replications of this disaster, the prosecuting reactive role may be avoided particularly where there may be no immediately obvious negligence. However, institutional interests dictate that justification must be given for not implementing this

prosecutory role; thus judgments about cause and responsibility which may internally be more tentative and informal become commitments which shape the marshalling and construction of scientific information into a more definitive and certain public form than is ultimately defensible or justifiable.

As noted in the Abbeystead case study, much of the significant information about accidents is uncertain, complex, and indeed, non-existent at the time of the accident. It has to be constructed by investigation, and construction involves building a tissue of assumptions and inferences to frame and buttress any facts. The context in which information about accidents is constructed contains important assumptions about the purpose, scope and social use of that information which are not usually explicit, yet which radically shape the information created and how it is either used or neglected. An important dimension to how information is created so as to give meaning to an accident is to define it, for example, as the latest in a string of near miss precursors that should have led to preemptive measures, or as an unpredictable "Act of God" from which we might learn some new technical insights, but not anything about the fallibility of social organisations.

How these meanings are constructed- the context of unstated assumptions and commitments which frame enquiry- is crucial in determining what the real and technological system learns from such accidents, which can in many respects be treated as a negotiable learning process just like that from more "positive" experiments.

Post-accident investigating authorities are often inhibited, albeit involuntarily, by the fact that they are partly evaluating their own past standards, practices and decisions, embodied in the regulated agents' action leading up to the accident. It is usually ambiguous whether those actions departed from norms or instructions laid down by regulatory bodies. The Abbeystead case shows this ambiguity. The defence argument could be restated as: we were only doing what every

commercial civil engineering company does when designing and driving a tunnel. That "State of the Art" in the trade was accepted by the regulators even though it turned out to be dangerous.

Thus the post accident inquiry was investigating the industrial actors to see how far they had complied with existing standards; but it was also investigating the adequacy of those standards, and the same body that was responsible for those standards was conducting the inquiry. The question of the adequacy of existing standards is composed of several distinct parts:-

a) were the standards themselves unacceptably weak in the light of existing knowledge and practices elsewhere, for example in other related industries, or in other countries?

b) were they lax but only with the benefit of hindsight? That is, was it the accident itself that showed weaknesses in preexisting knowledge, weaknesses which accident analysis could help to overcome for the system as a whole?

c) were the standards precise enough, for example in defining precisely what kinds of installation practices and conditions they covered? That is, they may have imposed demanding regulations, but may have been unduly vague and discretionary as to when those demands should be in force.

It is evident, therefore, that post accident investigation can be constructed against implicit standards, or frames of reference. In this case, the investigation took the regulatory process and pre-existing industrial practices for granted as unproblematic, and thus highlighted for examination the question of whether practices in this case deviated from those "standards". In the post-Chernobyl context, inquiry took the form of investigating design and operational aspects of RBMK management, and took for granted the political fact that

different countries operate with diverse reactor designs and standards, both technical and operational. There were alternative foci of inquiry available:

a) why were existing nuclear standards so inconsistent, when the accident environment is international?

b) why had nuclear authorities everywhere managed to avoid the realization that a nuclear accident could have more than local and environmental safety effects?

c) what does it say about the institutional psychology of nuclear power more generally, that precursors to the TMI accident and the Chernobyl accident had occurred, apparently without helping the authorities in either case to learn and avoid later accidents?

Without pretending to give answers to such questions, they indicated that post accident learning is shaped and limited by management of the inquiry agenda or framework. This is not necessarily deliberate. However, whatever the formal independence of the accident, investigators- let us say the IAEA in the case of Chernobyl- there are shared commitments between investigator and the investigated party which inevitably limit the framework, ignoring some of the questions which could be asked, and thus some of the learning which could be achieved.

Vaughan has described a similar, though in that case more formalised institutional structure in the NASA Challenger space shuttle case, with safety investigation agencies reporting to the agencies they were supposed to be regulating.

In the Abbeystead case, even where the issues were apparently far more confirmed and realised than for a major international accident such as Chernobyl, similar factors prevailed. As already indicated, the HSE was partly investigating itself when it analysed the context of the accident.

There are thus quite fundamental conflicts in a post accident situation between the need to attribute responsibility - in a sense learning about our institutions, their behaviour and capabilities- and the need to gather and disseminate technical information- learning improved technical practice. The second is conducted against a stabilized institutional background in which the first sort of question is at least temporarily, suspended. A basic problem is that this suspension may itself become institutionalized, and then limit what can be learned by the system as a whole. The technical knowledge constructed in post accident inquiry depends on the social role that assessment is playing, and consequent assumptions about what can count as evidence, what rules of legitimate inference prevail, etc. As we have shown, science does not simply provide one single, definitive set of methodological norms for this process.

Scientific institutions create and deploy knowledge in social settings, not a vacuum; and they use such institutional signposts to get started and frame coherent investigation. The difficulty is not so much that this happens- it is inevitable, necessary, and legitimate. It is aware that the process is unrecognized, and goes undebated. There is a deeper, more subtle problem than that when information is impounded and controlled after an accident, when an issue becomes sub-judice pending legal trial of responsibility.

In the Abbeystead case indeed, the more fundamental paving limitation produced counter initiative results in that the limitation on what evidence was identified from prior experience was created by the very option- to avoid criminal prosecution- which the authorities had chosen in the attempt to avoid placing restrictions on post accident learning. This perverse effect only demonstrates the two levels at which such restriction of learning can take place, and the relative invisibility of the level we have tried to highlight.

A final conclusion perhaps suggesting more general issues is connected to the observation above of a more subtle and extensive communality of commitments between regulator/investigator and regulated/investigated parties, than is usually recognized.

Evaluation of responsibility for an accident, as indicated earlier, has to take place against a normative yardstick taken to be legitimate. The Herald of Free Enterprise disaster may have been caused by failure to close the bow doors before leaving port: the implicit yardstick is the formal rule that all bow doors should be closed before leaving. But if it is discovered that an informal practice had evolved whereby nearly all ferries were routinely leaving port with their bow doors being closed as they left, the yardstick looks a little less "taken for granted" and new questions are suggested, such as: why had such an unsafe practice evolved, and who was responsible for creating and condoning it? If ferry masters were under commercial pressure to sail to a very tight timetable, and management rejected private warnings from them, is responsibility shifted? And is it shifted yet again if shareholders were "forcing" managers to extract a certain rate of profit? And if government inspectors knew of complaints about lack of warning lights and about crew working hours both of which contributed to the eventual accident?

Post accident inquiries are often conducted, as was the Abbeystead investigation, as if accidents are caused by deviation, from an established, properly designed and professional "state of the art" in a particular industrial or other sector. Normal practice is taken to be natural and legitimated, controlled by diligent external regulation and professional self-policing via the accepted mechanisms of peer review, quality control, etc. The legal framework of negligence is most strongly developed in this respect, where foreseeability of an accident, hence negligence, is defined against the existing state of knowledge or practice in the field in question. Implicitly, therefore, that "state of the

art" is assumed to be a fully acceptable and proper standard from which to measure lapses.

In many cases, however, we would suggest the majority, the existing "state of the art" is not at all problematic. Clearly in the Herald of Free Enterprise case, it could have been described as very unsafe, informal, and in effect unregulated. The same is true of many informally evolved working practices, though they have often been created to increase efficiency, safety or practicality of more theoretical designs and official standards.

In the Abbeystead case, the existing "state of the art" on water tunnel design and construction with respect to methane was unclear and inconsistent.

What could be said about it, however, was that it reflected commercial evolution and normal competitive opportunism in the civil engineering industry- for example companies looking to tender for water tunnel contracts after experience of other hydro-engineering schemes. The question of whether our commercial opportunities required new forms of expertise, and of what kinds did not appear to have been controlled. Thus the tacit model, of the "state of the art" being controlled and constructed by the more deliberate process of professional peer review and consensus, was misleading. The more fundamental structural issue raised by the accident was whether the existing industrial and technical structure as a whole was properly coordinated, controlled and regulated, a question which of course included the regulators as part of the problem as well as part of the solution. It is a more fundamental question about the structure of the technology seen as a dispersed organisational system.

Scientific post accident investigations throw light as if accidents and their gestation were the only time of "deviation" from what are assumed to be clearcut and proper rules. This perhaps reflects the institutional involvement in the design of that "normal" system. Yet it is increasingly appreciated that

normal practices are pregnant with accident potential (Perrow, 1984). Such practical systems evolve informally, often according to criteria and constraints that are highly localised, say to the shopfloor, or to one plant in an interdependent network. At that location or level they may be rational practices, perhaps even essential to getting the job done at all. (Wynne, 1988). If the water tunnel drivers had stopped work every time they suspected methane, or that a measurement formally required by regulations was inconclusive, they would have delayed the project by years.

Such situations are far from untypical, indeed they can lay claim to being normal. yet the wider appreciation of these "private" realities of technological practice- paradoxically ones well recognized by most ordinary people, who are often after all participants in them- are surprisingly resistant to more formal systematic appreciation and analysis by experts.

Although the problems of post accident learning ultimately defy complete resolution, wider appreciation of the internal processes of normal technological practice would help prepare inquiry, public and policy responses to examine a wider agenda of questions, about the routine regulation, and regulability of normal practices in the field in question. This would naturally include questions about institutional arrangements of control and regulation of the technology.

Accident investigating institutions could also advance their own and the wider system's learning by adopting methods and approaches which explicate and examine the unstated assumptions and commitments which shape, from its beginning, the process of scientific investigation. Since this is usually the first and most authoritative phase in shaping policy attitudes and social responses, it is particularly important that its practitioners, and the policy world, should be aware of the extra-scientific considerations which precede and shape it.

1. It also incorporated a need to define what was "common" or "standard" engineering knowledge and practice in relation to methane in similar schemes. As we shall see, what was or was not "methane" and "similar schemes" were open to crucial interpretive licence. In effect one had to open up the issue of the safety or acceptability of previous taken for granted attitudes, knowledge and practice in commercial civil engineering- as implicitly licensed by the regulatory body now investigating the accident.

2. The Fluid Process Research Group of the British Geological Survey: Isotopic and Chemical Analyses of Gas and Associated Water.

3. The Commonwealth Mycological Institute report.

4. The Rowett Research Institute report.

5. The Harwell Low Level Measurements Laboratory report.

6. Health and Safety Executive: The Abbeystead Explosion: Report of an Inquiry. London 1985.

7. Personal communication.

8. Implicit in this stance is an interesting ambiguity about the responsibility of a profession for not knowing something important for the safety of its practices - the solubility of methane in water under pressure- that was apparently known in other professional circles, and in the public domain.

Policy Responses to Large Accidents

International Institute for Applied Systems Analysis
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January 16-17, 1989

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Policy Responses to Large Accidents
International Institute for Applied Systems Analysis
A-2361 Laxenburg, Austria
(Woodak Room)

January 16-17, 1989

Final Agenda

January 16, 1989 (Monday)

- 08:30-09:00 Registration
- 09:00-09:10 Welcome address
R.H. Pry
- 09:10-09:20 Organizational matters
G. Krömer
- 09:20-10:00 Introduction
B. Segerstahl
- 10:00-10:30 The European Community Policy to Control Major Hazard
A. Amendola and P. Testori Goggi (presentation by H. Otway)
- 10:30-11:00 Coffee break

Session 1

Chairman: M. Poumadere

- 11:00-11:30 Estimation of Risk and Stabilization Mechanisms
V.I. Rotar
- 11:30-12:00 Policy Responses to Large Accidents: A Research Perspective
D.W. Fischer
- 12:00-12:30 Large Accidents and Risk Levels
P. Wulff
- 12:30-14:00 Lunch

Session 2

Chairman: L. Sztanyik

- 14:00-14:30 Systems Approach to Large Accidents Management
R.A. Perelet, B.N. Porfiryev and G.S. Sergeev
- 14:30-15:00 Criteria and Indices for Safety Analysis
V.F. Demin

15:00-15:30 Large Accidents and Demands to Safer NPP of New Generation
V.M. Novikov, N.N. Ponomarev-Stepnoi, and I.S. Slesarev

15:30-16:00 Coffee break

Session 3

Chairman: B. de Marchi

16:00-16:30 Learning from Chernobyl. The Right to Information and the Problem of
Communicating About Major Hazards
A. Liberatore

16:30-17:00 Chernobyl – Its Perception by the West German Population and its Impact
on Policy
H.P. Peters

17:00-17:30 Analysis of Accident Factors of the Possibility of Nuclear War
S. Kapitsa

17:45 Departure to Vienna

January 17, 1989 (Tuesday)

Session 4

Chairman: P.S. Gray

09:00-09:30 Economic Indicators for Risk Analysis
L. Krechetov

09:30-10:00 Risk Management of Industrial Hazards in Canada
J.H. Shortreed and D. W. Bissett

10:00-10:30 The Market Failure as Functional Economic Moment
M. Huber

10:30-11:00 Coffee break

Session 5

Chairman: H. Otway

11:00-11:30 Fighting in Defense of Man
G. Borrelli and N. Pacilio

11:30-12:00 The Evolution of French Opinions About Nuclear Matters Before and After
Chernobyl
M.H. Barny, S. Bonnefous, J. Brenot and J.P. Pages

12:00-12:30 The System's Ability to Learn: Some Basic Problems in Post-Hoc Accident
Assessment
L. Aitken and B. Wynne

12:30-14:00 Lunch

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Session 6
Chairman: B. Segerstahl

14:00-15:30	Summaries and Conclusions
15:30-16:00	Coffee break
16:00-17:00	Panel discussion
17:15	Departure to Vienna

(The presentations are scheduled to take no longer than 20 minutes in order to leave 10 minutes for discussion.)