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Accident prevention and risk communication in environmental protection: a sociopsychological perspective

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Abstract

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The prevention and management of environmentally damaging accidents has become an important responsibility of industry and government. One of the ways to help prevent and cope with industrial accidents is to encourage risk communication. Risk communication should take place not only between the firm and the public with which it deals, but also among the firm's employees. This discussion examines the technical and subjective aspects of various risk analysis and communication approaches, emphasizing the need to pay much greater attention to the sociopsychological dimension of risk behavior in industrial workplaces. It offers a number of practical guidelines for successful accident prevention and risk management.

Introduction

The increased relevance that industrial activity has come to have for the environment means that employees as well as employers need to alter the ways in which they think and behave. This change involves a process of adaptation that affects the entire range of the human being's psychological and mental functions. This change in attitudes, judgements and habitual behavior also applies to the handling of environmentally relevant accidents, which differ from other kinds of accidents and incidents in the workplace in that their impact is not

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confined to the people and the firm directly involved. Preventing and overcoming them therefore necessitates an especially keen sense of ecological responsibility.

One manifestation of this change in awareness in West Germany is the Accident Ordinance (*Störfallverordnung*) that went into effect on 1 September 1988. Eighteen months after the catastrophic fire at Sandoz (the Swiss chemical firm), the safety standards for technical systems were tightened (TÜV, 1988). The number of types of system classified as hazardous was raised from 17 to 23; and the number of hazardous materials increased from 145 to 319. The operators of hazardous systems were henceforth obliged not only to report incidents but also to inform the authorities of when hazards were likely to occur. Operators of systems requiring a license have to keep an up-to-date inventory of materials classified as hazardous, their whereabouts, and the amounts on hand. Hazardous systems must undergo risk analysis, and a checklist for maintaining and monitoring them must be established. The Technical Control Board (TÜV) in Stuttgart estimates that about 5,000 plants will have to draw up procedures for such risk analyses.

The improvement in the safety of industrial plants, which is the objective of the Accident Ordinance, is based on two main strategies: the broadening of government supervisory jurisdiction, and placing a greater onus on the firm to keep the authorities informed. Both areas pertain primarily to the type and condition of technical equipment, reflecting the fact that these approaches to the prevention of accidents tacitly stem from a safety philosophy centered on technology. The safety of an installation is not solely a matter of technical equipment, however, but also depends on the competence and motivation of the people dealing with these systems, their assessment of the risk involved, and the organizational structures in which they operate.

This observation calls for a psychological and socio-organizational analysis of accidents and, building on this, the development of concepts and measures covering person-related factors and the organizational structures within firms.

Analysis of accidents

The employee directly confronted with an accident in the plant is subject to specific demands stemming from the fact that accidents occur unexpectedly, their causes and effects are difficult to assess, and they leave little time to react. The chances to intervene are reduced even further as a result of the fact that accidents have powerful dynamics of their own that emerge as they happen.

Examining the histories of spectacular industrial accidents, one finds many human and organizational conditions that were the cause or partial cause. Information about the critical condition of a system was not acted on in time, if at all; information was incorrectly interpreted; the intricacies of the system were not grasped; information was not passed on to colleagues; the chain of com-

mand was obscure; technical competence and the decision making authority diverged; employees were ill-prepared to cope with critical situations; the safety of one's own installation was overestimated; the environmental impact of possible minor accidents was underestimated.

Such person-related and organizational factors in industrial accidents have attracted increasing attention in various areas of social science research in recent years. Perrow (1984), for instance, has reached an audience far wider than the experts. To Perrow, the causes of catastrophic events do not lie in the failure of a system's individual components, but in the specific structure of certain high-risk systems, nuclear energy being a case in point. The complexity of these systems and the close coupling of the system's components have led to a situation in which unavoidable accidents in subsystems can no longer be contained. One part malfunctions, causing the entire system to crash. Perrow regards such technical systems as uncontrollable in principle and calls for them to be abolished. This conclusion depends on the level of analysis selected. If one joins Perrow in looking at large-scale technical systems like nuclear energy, space travel or ocean shipping as a whole, one loses sight of the ways in which individuals act. Their behavior appears to be insignificant and interchangeable and promises no improvement in the overall situation. Accentuating the macro level of the system in this manner necessarily gives rise to biases in observations and judgements. Conversely, it is also biased to focus mainly on the micro level (e.g., the perception, judgement and actions of individual actors, or the failure of components). The significance of minute problems becomes exaggerated, and the overall picture gets lost. Scientifically speaking, the micro view and macro view of technical systems and their accidents are equally possible and legitimate. No scientific criterion compels preference for one or the other. The appropriateness of each of them, however, certainly depends on the observer's perspective.

Let us assume that poisonous chemicals from a chemical firm have been discharged into a river, destroying all life in it for years. The external observer who learns of such an event from the newspaper or sees the dead fish floating on the river may come to the conclusion that this accident is typical of chemical plants of this type and that it could happen again and again. The industrial manager in charge of the plant when the accident took place is likely to analyze it on the micro level. He knows that a valve became stuck, and he may know at the same time that this type of valve is no longer in use elsewhere in the plant and that even the defective valve was scheduled to be replaced in the next few days. From his view of things, he comes to the conclusion that this kind of accident could not recur.

The observers judge the course of events differently because they are viewing it from different perspectives. The different levels of analysis can incite controversies that lead to mutual recrimination. Those who see the events in terms of systems can say that those who see them in terms of details are too close to the problem to properly gauge its seriousness. For their part, those belonging to the

latter group can accuse the former of not possessing adequate knowledge of the details involved (an argument usually equated with lack of expertise).

Technical vs. human failure

In risk research and day-to-day operations inside plants, it has become customary to distinguish between technical and human failure (Hartwig, 1988, pp. 74–107). Is such a distinction logically tenable, however? Is not every malfunction caused by human behavior? Is it even possible for technology to fail? Is the idea that technology can fail not an inadmissible sort of fallacy? Is it not perhaps an objectively inadmissible attribution intended to exonerate humans? In short, are we not being too lenient on ourselves by blaming technology for mistakes?

Logically, the so-called failure of technology can be described completely in terms of faulty construction, maintenance, and/or operation. This is true even if the action in these three categories is fully in accordance with the state of the art in research and technology and with operating instructions. Take a burst pipe, for example. It may be attributable to the walls of the pipe being too thin, a hairline crack that went undetected during an inspection, a failure of the operating staff to note an increase of pressure in the pipe as shown by the appropriate gauges, or to all these factors. In any case, the reason that the pipe burst is not that the material itself made a mistake, as it were.

Making mistakes is a privilege of humans — in the above example, of the design engineer, the maintenance worker or the operator. To what circumstances *their* errors are to be attributed is quite a different and far-reaching question. Negligence? Inadequate training and knowledge on the part of the individual? A general lack of expertise among all specialists? Whereas errors attributable to a general lack of expertise cannot be avoided in principle, those stemming from specific failures of action or organization can be influenced through proper managerial or organizational precautions.

Technical risk

Precaution begins with a risk analysis. Because safety can never be completely guaranteed, risk analyses can only be presented as statements of probability, that is, as the assessment of risk.

Risk analyses (Fritzsche, 1987) allow one to forecast the behavior of technical systems (such as a chemical plant). Because these systems are designed, built, maintained and operated by humans and are subject to physical and social factors (such as earthquakes and sabotage, respectively), risk analyses provide forecasts on the behavior of a man-machine system in a specific physio-technical and social environment. These forecasts must be understood as

applications of mathematical models (e.g. the theory of probabilities) and inherent natural laws (e.g. iron's modulus of extension) to a specific technical system.

Risk analyses can thus incorporate in their calculations only those events that have already been identified as possible causal sequences of events. The scope of that vision, however, is restricted by the limits of scientific and technical knowledge and by the analyst's power of imagination. Analysis of major accidents has repeatedly shown that their causes often, if not always, consist of chains of events that had not been included in the risk analyses.

Scientific theories are not perfect likenesses of the reality to which they refer. At most, they represent the best possible images of reality at a specific point in the history of science. Similarly, risk analyses of technical systems are, at best, the optimal risk assessments to be arrived at on the basis of rational methods and a given set of experiences at a given time. This stance limits the validity of technical risk analyses. They are no more and no less binding than subjective risk assessment and therefore cannot be regarded a priori as superior to them.

Subjective risks

Unlike technical risks, subjective risks represent intuitive assessments of hazards as they arise in everyday life (and, of course, as part of the daily routine in the plant). The two forms of risk evaluation are often contrasted as the judgements of the expert and the judgements of the layperson. Experts often resolve the differences between the two by simply regarding lay judgements as wrong and ignoring them. They regard scientific assessments of hazards as rational; evaluations, and even fears, based on naive judgements are considered irrational by the experts.

Intuitive risk assessments differ not only in their results but also, and primarily, in the way they come about and in the type and number of factors that the particular observations take into account (Jungermann, 1982; Kahnemann et al., 1982). These factors include:

Voluntariness: risks to which one voluntarily subjects oneself are rated lower.

Locus of control: events that one believes controllable through one's own alertness and action are perceived as being less dangerous.

Familiarity: risks with which one is familiar are underestimated in the potential danger they pose as compared to other risks.

Fairness: risks tend to be accepted when the underlying action also benefits those who bear the risk.

Potential for catastrophe: one accident affecting many people is interpreted as an expression of a risk greater than that of many accidents that, individually, affect few people.

Linked probabilities: linked probabilities tend to be overestimated.

Intuitive risk evaluations are a key determinant of action when an accident occurs. The human being who takes action when an accident occurs responds according to his or her subjective assessment of risk. That judgement may be shaped by scientific and technical expertise to varying degrees, but it can never be free of spontaneous and intuitive evaluations of the situation (Ruppert and Ettemeier, 1988).

This fact is not a shortcoming but a virtual prerequisite for suitable action when an accident happens. Retrospectively, the parameters of the specific and unforeseen accident may appear to have been central to the course it takes, but they are rarely accounted for in formal analyses of accidents. Indeed, the well-known environmentally relevant industrial accidents are known precisely for the fact that they originated in unforeseen and maybe unforeseeable situations. Responding to an accident therefore must not consist solely of following step-by-step instructions and procedures. It demands behavior appropriate to the situation, possibly even behavior that deviates from the norm.

Taking action when accidents occur

According to Hacker (1986, p. 420), "the more reliable a component of a technical system, the less reliable the person operating within it when something unusual happens." Derivable from concepts of action theory and supported by experiments in the psychology of work, this thesis is perhaps confirmed by environmentally relevant accidents.

With many large technical systems that pose potentially great hazards, certain mistakes must be avoided. However, if an operation is absolutely flawless, workers gain no experience of handling critical situations, which makes it difficult for them to do the right thing when an accident does occur. Some typical reactions in such situations can be distinguished:

- shift responsibility (calling for one's superior, for example);
- carry out routine actions;
- follow regulations (shift responsibility to those who answer for the regulations);
- obtain information in order to reduce uncertainties — look for written documents or instructions, confer with colleagues;
- ignore the problem;
- break with routine behavior;
- generalize from routines of action familiar from other situations or other contexts.

Many of these actions are a form of escapism or evasion. Because a prudent analysis of the problem is often not possible in a crisis, alternative action is taken, representing an attempt to retain at least some capacity to react in what for the actors is a chaotic and usually overly complex situation. The accounts of the sequence of actions taken in accidents that have attracted public atten-

tion are all alike. One example is the report published in a German weekly, which described the behavior of engineers and the fire department when electrical cables caught fire in a Spanish nuclear power plant (*Der Spiegel*, 1989). According to the article, panic broke out in the control room. The engineers "were all screaming at the same time and scrambling to get out." When the fire department arrived, "not a single engineer was willing to direct the efforts to extinguish the blaze." The fire department went in without guidance or special equipment. The unsuspecting officers directing the fire brigade ordered water to be used. No one had told them that oil and cables were burning and that foam would have been more appropriate. The rescue operation almost turned into a catastrophe. The water flooded the basement of the power plant, and in the attempt to draw it off, more water was pumped out than was sprayed in. It was never clear where all the water came from. The director of the power plant was notified of the incident half-an-hour later by a concerned citizen calling from a telephone booth.

Of course, it can be assumed that most accidents are handled in a proper and orderly fashion by employees. Obviously, however, problems too complex for the actors do recur, and elicit panic-like responses. These are the exceptions in comparison to the vast number of routinely managed accidents that must occur. It is just that such exceptions keep coming up, and preparing for them is difficult. They demand creativity and the willingness to take responsibility. The necessary actions are more like an experiment in overcoming chaos organizationally than in carrying out routine action correctly.

If the point is to facilitate action appropriate to the situation created by an accident, it is necessary to be clear about the obstacles to eliciting the desired behavior. Those who have only a very limited range of activities and responsibilities in normal operations and who are only accustomed to carrying out the instructions of their supervisors are scarcely able to behave flexibly on their own account when accidents occur. They will continue to exhibit routine behavior under exceptional conditions.

Creative, safety-conscious behavior does not pay when it is not totally clear afterwards that such behavior was imperative. Let us assume that the foreman at Chernobyl had shut down the power plant at the moment he became aware of an operational irregularity. What would probably have happened to him? With some degree of certainty, experts would have later shown that the situation to which he reacted had been completely harmless and his response downright hysterical. This presumably would have meant that he would be declared unfit for the job because his inappropriate reaction had caused great damage to the plant. Naturally, a reasonably intelligent person can foresee such a response. But this then means that a "rational" worker who also has to consider the personal consequences involved will not react decisively to an accident until it is certain that the situation's potential for catastrophe will be evident to anyone in retrospect as well. By then, though, it may be already too late to take pertinent measures.

Psychological, mental and organizational factors like these determine the development of events in an accident. Prevention involves being aware of them and arranging things adequately; the main difficulty is to ensure that employees and organizations are prepared for the unexpected. Greater flexibility and allowing more people the authority to act may be key guidelines in this regard.

When dealing with crises that have impacts beyond the boundaries of the plant, one must bear in mind more than just the plant's internal processes. Under certain circumstances it is necessary to inform the general public. Including the public must not be seen solely from the standpoint of acceptance. The public is one of the key considerations in the proper management of crises. In this sense, the credibility of the information disseminated by the firm is exceedingly important. In the wake of an accident there is no time to generate that credibility; it has to be established beforehand through constant and open dialogue between firms and the public.

Experience has shown how difficult it is to convince the general public to protect itself when the impact of an accident goes beyond the boundaries of the plant. Although catastrophes attract a great deal of public attention, it is hard to make people believe that they must act themselves. In general, indifference and optimism are the order of the day. Optimism sometimes lingers even after catastrophes have already struck. Studies on the accident at the nuclear power plant on Three Mile Island in 1979 and similar incidents show that people do not evacuate after receiving only one notification or recommendation from a single source. They first begin to seek information from other sources. When accidents occur, the credibility of people passing on information depends on their perceived competence (intelligence, authority, experience, fairness, objectivity and altruism, for instance) and other characteristics such as their speaking ability, avoidance of jargon, clarification of technical interrelationships, and their ability to listen, give feedback and respond to emotions (Covello et al., 1988).

Practical approaches to taking action

The human and organizational conditions which give rise to accidents, and the public interest in environmentally relevant accidents, call for further development of practical types of action that both reduce the probability of accidents and facilitate a dialogue between firms and the public at large. This section presents three approaches to taking action that can serve these requirements in different ways.

(1) Risk communication within the plant

Communication within the plant about environmentally relevant potential accidents should continue to be developed. In encouraging such communica-

tion, one can draw on the environmental awareness of the employees, which is usually high. Thus, it is less a matter of instilling awareness than of developing competencies within the company (Dierkes and Fietkau, 1988). When dealing with the kind of control problems that accidents bring about, one should look especially to heuristic problem solving strategies (Sonntag and Schaper, 1988).

Knowledge about how to make the workplace safe does not lie solely with those who determine working conditions in their capacity as engineers or managers. It is acquired in all its complexity through day-to-day contact with technologies. (Of course, one must not overlook the fact that everyday routine and day-to-day experience can engender a false sense of security among employees.) In a study on drivers transporting hazardous materials, Fietkau and Timp (1989) showed that informal processes of communication between the employees are much more important to them than official information from the firm when it comes to managing their jobs and judging occupational risks.

The sense of responsibility among employees, their informed behavior, and their motivation to avoid environmental damage, suggest they should be involved more closely in the development and implementation of safety concepts than has hitherto been customary. One way to take fuller advantage of their competence would be to introduce risk circles (similar to quality circles) in which a guided exchange of experience could take place both among the employees and between them and the management. Risk circles could be an instrument for exchanging informal knowledge acquired through experience in dealing with high risk technologies.

The employee's knowledge based on experience is extremely important in avoiding accidents. It is evidently apt to lapse quickly, however. As Goodman and Garber (1988) demonstrated in a study of coal mines, familiarity with one's workplace can decline so quickly that after even brief absences (because of illness or a vacation) the accident rate clearly increases.

(2) Communication with the public

Environmentally relevant accidents are a focus of public interest. Just as it is necessary to develop appropriate forms of communication within the plant about potential environmental risks, so it is necessary to conduct public discourse about production risks. In the process, it is in the interest of the firm, too, to make clarity one of the highest priorities.

In this vein, Hance et al. (1988) have developed a manual for risk communication for the New Jersey Department of Environmental Protection. The idea is to enable government offices to communicate more effectively with the public about risk. By "more effectively" they do not mean that communication should be stressed to sell a poor policy, but rather that effective communication can help:

- to improve the understanding of the public's perception of risks and assess public reaction more reliably;

- to improve risk management through participation of the population affected;
- to encourage dialogue and reduce unfruitful tensions between government offices and the public;
- to explain risks more efficiently; and
- to teach citizens to deal with risks carefully and productively.

Following Hance et al. (1988), one can summarize these ideas by saying in general that just as much attention should be paid to the concerns and anxieties of the public as to scientific knowledge, and that the public's ability to understand this knowledge should not be underestimated. The suggestions contained in the manual by these authors cannot be recapitulated in detail here. The main ideas, however, can be synthesized in basic theoretical dimensions. Developed in the framework of person-centered psychology as dimensions for describing processes of communication in psychotherapy (Rogers, 1961; Biermann-Ratjen et al., 1979), they are also sound and acceptable in the context of communication between firms and the public on questions about risk:

- show understanding for the other person's inner frame of reference in an attempt to see the problem from that partner's point of view;
- be open in an attempt to avoid hiding gaps in one's own knowledge;
- seek congruence in an attempt to harmonize thinking, talking and acting;
- be explicit in an attempt to convey complex matters graphically, yet correctly;
- become process-oriented in an attempt not only to report about what is over and done with, but also to bring the other person into the process of thinking about how to proceed.

If the communication techniques behind these principles are made part of the risk communication between firms and the outside world, then the credibility of firms and their capacity for action can grow, thereby facilitating a public discourse about the environmental risks posed by industry. As commonplace as these guiding principles may sound, it is evidently difficult to practise them in the specific, individual case.

(3) Mediation

Mediation is understood to mean a social technique by which conflicts, including conflicts of interest, between two or more parties can be settled by bringing in a neutral third party. The objective of the mediation process is to seek solutions that meet with the acceptance of all parties involved in the conflict and that avoid what are frequently time-consuming and ultimately not always satisfying disputes in court. The mediation process is characterized by the mutual exploration of latitudes for action and the quest for new solutions.

Today, processes of negotiation between industry, the policy making community and the public may be less a matter of getting what one wants than of avoiding misperceptions and misinterpretations of the other side, and lack of

reflection on one's own position. A mediation process geared to expanding the perspective of the participants can accomplish this task.

Mediation processes represent an instrument with which conflicting judgments of environmental risks can be handled and settled properly. Bingham (1986) has analyzed the success of 161 mediations dealing with environmental conflicts in the United States in 1984. In that country the number of environmental conflicts in which mediators have contributed to a solution has steadily increased since 1973, totalling 9 in 1977, 11 in 1978, 19 in 1979, and more than 160 in 1984. Furthermore, commercial and non-commercial institutions specializing in the mediation of environmental conflicts have been established throughout the United States.

In 29 of the 161 instances that Bingham studied (siting conflicts and policy dialogues), it was a matter of improving communication between the participants. In the other 132 cases, of which 99 were siting conflicts and 33 were policy dialogues, an explicit arrangement was the goal. In 103 cases (78%), an agreement was reached; in 29, no agreement resulted. An agreement was reached in 79% of the siting conflicts and in 76% of the policy dialogues. The solution that was arrived at in the siting conflicts was fully implemented in 80% of the cases and partially in 13%; in only 7% of the cases was implementation unsuccessful. Only 41% of the solutions arrived at in policy dialogues were fully implemented, with 18% being partially implemented and 41% not being implemented.

In the Federal Republic of Germany, mediation procedures are not widely used to solve environmental conflicts. However, researchers have been conducting an increasingly intense and controversial discussion about the degree to which such procedures can be integrated into Germany's legal and administrative system (Bohne, 1984). Regardless of how the legal and administrative issues of mediation procedures are judged, if the Federal Republic of Germany could achieve the kind of success that the United States has scored in managing environmental disputes over such decisions as where to site facilities for the incineration of hazardous wastes, it could mean significant progress compared to the legal stalemates that frequently develop.

Conclusion

Industrial accidents are just as much a consequence of human action as the smooth functioning of a technology. The engineering, maintenance and operation of an installation, as well as the organization of work processes and emergency measures, are human decisions or result from them. They remain human actions even when they are embedded firmly in scientific knowledge, technical standards and experience.

In the context of efforts to avoid accidents involving large technical systems, the omnipresent "human factor" — man's perceptions, decisions and habitual

ways of acting and reacting — has not yet been given due attention. The interplay between the human being and technology is often organized without regard to the insights of sociopsychological and social science research. These insights are supplanted by commonsense judgements or, at best, understood as appendages to technical measures.

For the most part, however, the relevant areas of research are unprepared to respond to the call to integrate psychological and social science knowledge into the prevention and management of risk involving large technical systems. Admittedly, many case analyses are available, along with a number of theoretical and conceptual insights and the results of basic experimental research, but so far too little has been done to put these concepts into practice and follow up with thorough scientific evaluation. In this respect it is still necessary, at least in the Federal Republic of Germany, to reduce the antipathies that exist between empirical social science and industry.

Beyond that, it will be necessary to build up realistic expectations of what psychology and the social sciences can and cannot contribute in this area. One must not be led to expect patent recipes. The opportunities lie instead in organizing communication about risks — both within the firm and between it and its social environment — with the goal of liberating the potential for creativity, discussing experiences and coordinating activities. The organization of this process is not easy. Those who attempt it must be competent in their field and independent of particularist interests. It may be done better and more credibly by persons whose positions give them a certain distance from the firm and — where communication to the outside world is concerned — from other social groups. The practical assistance that psychology and the social sciences can offer in this area does not consist of assuming the role of a referee or evaluator, but rather of organizing suitable communication structures within which appropriate solutions to problems can develop.

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