Paper 7

The problem of radiological and conventional risks: similarities and differences in prevention. Trade off's between routine doses and major accident prevention

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1 Introduction

There is hardly a field in safety at work or environmental protection where so much fundamental knowledge is available as in radiological protection. We know quite well at what quantities of radioactive substances ingested or inhaled, the risk of cancer is noticeably increased above the background. We are far away from this knowledge when dealing with all the proven or supposed carcinogenic substances we handle outside radiological laboratories. Although radiological protection has reached very far in this respect, still a lot of interest is put into the scientifically very interesting question of what very low doses are doing to mankind, what the relationship between doses and their effects might be in that range and whether there should be a lower bound to the ALARA principle. But all this progress in knowledge will not reduce the probability, that another catastrophe, maybe smaller, maybe larger than
Tschernobyl might happen. We should focus our efforts to prevent this kind of terrific hazard. There is enough potential for it to happen again sooner or later, from all the strong radioactive sources scattered around the world, from nuclear weapons and from technically more or less safe nuclear power plants [1, 2]. Do we reduce these hazards by increasing the purely scientific efforts or by a rigorous application of ALARA principles to low doses? My answer is no. Do we have any chance to minimize these risks by other means? I reckon the answer is yes. The key to progress is more emphasis on the behavioural aspects. These seem underdeveloped in comparison to the technical and scientific efforts. The goal of this paper is to show that some improvement in this respect is indicated.

2 The importance of behaviour in the chain of accidents

There are often figures of 70 or 80% mentioned as mainly behavioural causes for accidents. It depends on how closely we relate faulty behaviour to the immediate causes and sequences of an accident. If we look at it in a broader angle, behaviour is always involved. It starts with political decisions such as having nuclear power plants or nuclear weapons. It continues with how much effort is put into technical safety concepts, into training and discipline of the staff. I want to explain this further using an example.

When the authority asked for a costly amendment to achieve better redundancy in the command and cooling systems of a Swiss power plant, the managers of the power plant did not agree and ordered a risk study, allegedly in the hope it would show such an amendment unnecessary. This hope would not indicate a behaviour according to "safety first", as certainly adequate for a nuclear power plant. If a technical fault would have occurred hereafter, the decision of the managers would have been such a behavioural aspect. In this specific case the story took an unexpected turn: The risk study revealed that the risks envisaged by the authority were even much larger than assumed, especially in the case of a fire reaching the command cables. Of course, the management of the power plant could give a different interpretation to their ordering a risk study before executing what the authority asked first. Such a study could give the hints to a most efficient amendment. Whatsoever, I do not want to be controversial on this. Also on technical safety versus safe behaviour I do not like to construct a conflict. On the contrary, the behaviour of "safety first" will lead to steady improvements of the technical safety which in turn will result in a higher tolerance for behavioural deficiencies of the staff. Otherwise the management would loose credibility. If the
management does not permit a decline of discipline, a net and continuing improvement results from such a concept.

If behaviour is taken in such a broad context, it becomes most important for the prevention of both conventional and radiological accidents. It would be interesting to track down behavioural deficiencies of the management and the directly involved staff before and during the sequence of events of some accidents, however I am not prepared to do this here. Let me just mention once more the prominent and painful example Tschernobyl. Ironically, it happened when testing a safety system. But the behaviour of the people in charge, violating basic prescriptions for this type of reactor, is very difficult to understand. A minimum of safety culture would have prevented the catastrophe. Especially in power plants of higher technical vulnerability, the safety culture of the management and the staff is of primordial importance. But I would like to see a prominent safety culture also in our power plants. Allegedly there is. Is it? I expected to find a confirmation. However what I found did not match the expectations. I would like to discuss this by using some Swiss data.

3 How to measure safety culture?

"Safety first" is a slogan of the world-wide operating company DuPont with about 80 000 employees. IAEO [3] uses a more sophisticated definition: "Safety culture is that assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance." We will see that the results of DuPont in conventional accident prevention are by an order of magnitude better than those of nuclear power plants.

Our age has found means to measure behaviour and attitudes by questionnaires and audits. The ASCOT guidelines are on this line [4]. Or we can use a WANO index. The number of accidents per 200 000 hours of work is such an index. It is wise to count only accidents which lead to a temporary incapacity for work at least on the following day. This is the US definition for labour accidents. According to the definition of the EU a labour accident must produce at least three calendar days of incapacity for work [5]. The results for these two definitions cannot be
much different, as the healing time for an injury leading to an incapacity for work peaks at seven days. Some injuries take considerably longer, but our data show a rapid decrease for shorter times. Healing within a few days is hard to imagine and it is found seldom in our data.

Let us quickly consider the essential qualities such a simple index should have.

There should be enough cases to lead to a statistically significant number (not too much variance)

The possibilities of fiddling or cheating should be minimized

The index should be objective, clear and fair.

The psychological pressure exerted by the index should not give rise to counterproductive reactions

The number of accidents are of the order of 1 per 200 000 working hours or 0.01 per full time employee. The first criterion reveals a handicap, as for numbers of 10 or 100 accidents there is considerable Poisson scatter of 30% or 10% respectively. It is therefore tempting to count all injuries or all events which could have lead to injuries or finally all observations of faulty behaviour or technical deficiencies. The way to a safety culture is indeed to encourage and sustain a permanent search for such deficiencies and to respond with appropriate measures. But do these observations lend themselves to construct a representative index? The numbers associated with such observations are much larger of course than those of the accidents, but the reliability gained with respect to Poisson scatter is overwhelmed by the uncertainties associated with such observations. What is an injury? What is severe enough to rise attention? Are technical or behavioural deficiencies observed, reported, concealed? It may well be that a company with many observations of deficiencies is safer than a company, which does not even realize, that there are. These problems should not be underestimated and I definitely prefer a higher, but known Poisson scatter of well defined accidents to the unknown distortions associated with the other kind of events and observations.

Even with such a clear-cut index based on the number of accidents leading to temporary incapacity for work there are problems mainly associated with reporting or underreporting. A certain level of safety culture must be already reached to overcome these problems. Some distortion may arise from the pressure exerted by the index: The injured person may convince the doctor that he or she is fit to show up at the workplace and do some office work. This has certainly some influence on the data from DuPont.

4 A comparison of Swiss data and those of the DuPont companies

As our insurance compensates for medical cost and 80% of the wages from the third day of incapacity for work, our company has very reliable figures on professional and all other accidents of employees. There is no problem of underreporting and the data are often better than those collected by the companies for their own statistical purposes. The weakest point is the estimate of the number of full time employees. Table 1 shows a comparison for our Swiss nuclear power plants, for office work, for the largest chemistry plants and for DuPont chemistry and specialities world-wide. The data for the nuclear power plants contain 209 professional and 872 non professional accidents of the permanent staff during 1990 to 1996, the other Swiss data stem from 1996 and for DuPont I had the 1993 world-wide data for all plants.

Accidents per 1000 full time employees		
	at work	at leisure
Swiss nuclear power plants	9.1	33.4
Office work	7.5	38.2
Chemistry	13.9	46.7
DuPont, chemistry	0.5	8.7

This table shows why I am worried. A well developed safety culture is clearly reflected in the DuPont data, but scarcely in the data of the nuclear power plants. It seems that the world wide records for the industrial safety lost-time accident rate are in the same range as those from Swiss nuclear power plants. From the 0.64 accidents per 200 000 working hours reported [6] I arrive at about 6 accidents per 1000 full time employees. I may doubt if the world-wide safety culture is such that no underreporting occurs, which could explain the difference between 6 and our 9.1. In any case these figures are far from the benchmark for a good safety culture set by DuPont.

5 Conventional and radiological accidents: What they have in common

When I decided to look at conventional accident data in order to compare the safety culture of nuclear power plants to the safety culture of comparable industries, I expected that the power plants would rank considerably better. I wanted to compare the data also to the benchmark set by DuPont, which is reputed for an extremely strict safety management of a long tradition. In fact DuPont started to go this route some 150 years ago, when a plant producing explosives blew up. The management decided to start again, but under strict safety measures. In the new plant, the management was forced to reside on top of the building. It seems that DuPont realized at a very early stage, that the management must be vaccinated first with the idea, that safety is of vital importance. Safety is not achieved by bulky prescriptions or by bureaucratic external inspection bodies. It grows under the leadership of a conscious and rigorous management, rigorous with respect to safety oriented attitudes and few, but inflexible prescriptions. Of course, external inspection is also needed, but unless the management really wants it, it can not achieve much improvement in behaviour. It could even lead to a situation, where the management thinks of business and relies for safety on the external body, or even worse, draws back to a position of doing for safety as little as possible. It is the same for conventional and radiological safety.

Also the scenarios leading to accidents are very similar: Sometimes people do not know what they do or what they should do, but most of the time some negligence or "who cares" is somewhere involved in accidents. This is also the reason, why DuPont is very strict with respect to contractors. They have to work to the rules of DuPont, if they want to work for DuPont. This kind of management influences also the behaviour in leisure time. However, the success in preventing non professional accidents is less evident, I think because the rigid rules and the supervision is lacking. It is very important, that the managers of all ranks carry the responsibility for the safety of their men and machines. The managers of DuPont have to report for each accident at the main office overseas. You see where a consequent safety management leads. Of course many conventional accidents have no spectacular causes, many accidents happen just when walking around. But I think at DuPont you would be asked "why?" if you would dare to go up and down a staircase without using the handrail. This is straight forward, safety first, and no long definitions. The rules are kept simple, but the employees have to stick to it and they know that any idea or criticism aiming at more safety is welcome. You may object, that the radiological problems do not lend themselves to this kind of simplicity. But experience shows, that a valve left erroneously open or closed is typical for the things which happen and which could become crucial. Therefore I conclude that the behavioural deficiencies of the management and the staff, which sooner or later lead to an accident, are identical for conventional and radiological accidents.

6 Importance of conventional and radiological risks in nuclear power plants

It may be argued, that the management of nuclear power plants does not deal much with conventional accidents because the radiological ones are so much more important. This is only true in the sense of a catastrophe. And I cannot imagine a safety culture working perfectly for radiological hazards and having no substantial impact on conventional accidents. Furthermore, the conventional risk for the staff is not lower than the one taken by planned or unplanned irradiation. Taking into account the reduced expectation of life due to fatalities as well as the reduced quality of life during a temporary or permanent incapacity for work, one can arrive at a comparison between conventional and radiological risks [7], which is based on more cases than a comparison using only fatalities [8]. To show this [7] we used the days of incapacity for work, truncated at 30 days per accident, which is a useful index for individual companies. It can be easily converted back to the less sophisticated index used here, the number of accidents. It turns out that the risk which is manifested in 1 accident corresponds to the risk incurred by 300 mSv.

In the years 1990 to 1996, the permanent staff of the Swiss nuclear power plants accumulated a collective dose of 19 Sv in comparison to the 209 professional accidents mentioned above. The equation 1 accident = 300 mSv indicates that the conventional risk is about 3 times as high as the radiological risk for the staff of our nuclear power plants.

In this way of reasoning there is a very nice analogy between radiological and conventional risks: The observed radiation dose itself is not much harm, but it indicates the risk of a radiation induced cancer. Similarly, a conventional accident leading to the mostly observed one week incapacity for work is not so much harm, but it indicates the risk of accidents which sometimes are much more severe or lead to death. Therefore counting accidents or days of absence means for conventional accident prevention something like using a dosimeter for radiological protection. The main difference is the resolution, which is excellent for dosimetry and very poor when measuring accidents. The resolution for accidents corresponds to 300 mSv which would be utterly inadequate for personal dosimetry. Equally, it would not make sense to measure the personal accident risk by the number of accidents of that person. However for the collective risk of a plant, accident figures become as meaningful for the performance in conventional prevention as the measure of a collective dose. How can we give credit for the safe handling of radiological hazards when the handling of conventional hazards is unsatisfactory?

7 Trade off's between routine doses and prevention of accidents

Some irradiation of the staff is inevitable and planned. ALARA comes in at this point. The trade off starts, when some inspections necessary for the prevention of major accidents are associated with an inevitable and planned irradiation of the staff carrying out these inspections. When the performance of a plant is measured by the collective dose, there will be pressure to minimize this kind of inspections. How this will increase the risk for a major accident is hardly quantifiable. I do not know, if this problem of trade off's is rather theoretical. By intuition I would guess it is real. The public hysteria about low level doses is an additional handicap. For me it is clear, that the prevention of major radiological accidents is on the line of "safety first". We need a management acting according to this principle. I would like to see from the performance in conventional accident prevention, that the management and the staff has reached an extraordinary level of safety culture. For conventional accidents we can compare the performance in safety to the benchmark set by DuPont. For other indicators like collective dose, unplanned events or SCRAMS it seems to me rather difficult to define such a benchmark of a very high, but still realistic standard.

8 Conclusions

Behavioural aspects are very important in the chain of accidents, or better, in the continuous attempt to prevent accidents. The word "safety culture", which was created after Tschernobyl, describes all facets of the behaviour of the management and the staff. For a nuclear power plant I expect an extraordinarily well developed safety culture, which should be reflected also in the performance with respect to conventional accidents. However, the accident figures from nuclear power plants are only slightly superior to those of similar industries. They are far from the benchmark set by DuPont. I think an improvement is needed. This demand is corroborated by the fact, that the conventional risks for the staff of nuclear power plants is higher than the radiological risk. This conclusion is based on a equation for the collective risk: 300 mSv = 1 accident (with a temporary incapacity for work one or three days after the accident, depending on the definitions used). The conclusion is, that improvements in the safety culture are badly needed. A rigid regime of "safety first" must be established in the mentality of the management and staff.

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