A comparison of the carcinogenic risk assessment and management of asbestos and ionising radiation

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Objectives

The study[1] sets out to explain the similarities and differences in the ways in which carcinogenic risks associated with occupational exposure to asbestos and ionising radiation are assessed and managed [1]. The analysis will focus on five areas: conceptual approach, regulations, risk perception, safety culture and actual practice in the workplace. The aim is to analyse the reasons for the differences which have been detected.

1. Similarities and differences as regards conceptual approach

1.1. Similarities

Both epidemiological and animal studies have clearly and incontrovertibly demonstrated the carcinogenic properties of ionising radiation and asbestos fibres at levels of exposure which show excess incidence of cancer.

In both cases, epidemiological studies demonstrated the link between relatively high levels of exposure and an excess incidence of cancer, in either absolute or relative models (exposure-risk relationships).
The model which linked cumulative exposure to asbestos to the excess risk of death from lung cancer was based on 11 cohort studies [2]. The relation between the concentration of airborne fibres and the excess risk of death from mesothelioma is based on a multi-stage model of carcinogenesis in humans. This model, adjusted for 3 cohorts, provides the absolute excess risk of death from mesothelioma and not the relative excess risk, as in the case of lung cancer [2].

In both cases, experts considered that it is possible to make the cautious assumption that an excess risk of cancer is associated with low levels of exposure. This is the assumption made by the International Commission on Radiological Protection in its recommended protection system [3] which constitutes the basis for European [4] and French regulations. In the case of asbestos, the use of exposure-risk relationships in the context of low concentrations was deemed possible in 1997 by an expert group set by the French National Institute for Health and Medical Research (INSERM). Indeed, the expert group was of the opinion that this linear no-threshold extrapolation to low doses was "the most plausible uncertain estimate in view of current knowledge" [2].

Thus, for the sake of risk-management and in an effort to simplify matters, the experts in both fields adopted linear no-threshold exposure-risk relationships obtained by extrapolating the results of epidemiological studies related to higher levels of exposure down to lower levels of exposure.

1.2. Differences

In the case of asbestos, the scope of validity of the exposure-risk relationships concerning lung cancer and mesothelioma is limited. They do not apply to discontinuous occupational exposure which takes the form of high levels of exposure over short periods (known as sporadic exposure). In such cases not enough reliable data are available to reconstruct the doses actually inhaled by workers. While data regarding concentrations may be available, data on effective exposure duration are not. The exposure-risk relationship may for example be supra-linear if a low average dose administered in sporadic exposure peaks was associated with a higher risk than an identical average dose administered evenly over time [2].

[1] The study was carried out in collaboration with T. Schneider, S. Lepicard (CEPN), S. Gadbois et G. Hériard-Dubreuil (Mutadis)

1.3. Assessment

In both cases, prevention specialists (Professional Body for Risk Prevention in the Building Industry, the Regional Health Insurance Office, the Labour Inspectorate, the Occupational Health Physicists, etc.) manage risks within the framework of the cautious no-threshold assumption. Given that at all levels of exposure, no matter how low, it is possible to make a connection with an excess risk of cancer, zero risk is possible only if there is no exposure. Generally speaking, this type of objective cannot be attained in an industrial environment and specialists therefore have to deal with the problem of "acceptable" residual risk. In the remainder of this paper, we shall see how they manage to achieve this in the two fields being studied.

2. Similarities and differences as regards regulations and institutions

2.1. Differences as regards regulations

As far as ionising radiation is concerned, the assumption that there is no threshold below which no risk exists has led the International Commission on Radiological Protection to devise a system based on three principles:

- justification of the activities resulting in exposure (the advantages of the activity must compensate for the radiological risks it engenders),
- optimisation of radiological protection (the individual dose level and the number of persons exposed must be kept as low as is reasonably achievable with economic and social factors being taken into account). This principle is also designated by its acronym: ALARA (as low as reasonably achievable),
- limiting doses (dose limits are applied to the exposure of individuals to ensure that no-one is exposed to risks that are considered unacceptable).

In this system, which constitutes the basis of the regulations in force in member countries of the European Union in particular, dose limits are at the boundary between "unacceptable" and "tolerable" risk levels; the optimisation principle makes it possible to determine "acceptable" dose levels (i.e. those which are ALARA). The main objective is therefore not to comply with dose limits, but to keep exposures ALARA [3].

In the case of asbestos, there is no difference between dose limit and "acceptable" dose level. The limit exposure value is designed to reduce the residual carcinogenic risk to a very low level[2]. Prevention specialists often consider achieving compliance with the limit exposure value as a very ambitious objective. The use of a very low limit value for exposure to asbestos must be considered in the light of how the regulations have changed over the last twenty years. In the past, the asbestos regulations called for "controlled use" based on risk management and regular lowering of the limit exposure values; for example, as far back as 1978, it was forbidden to use sprayed-on fireproofing containing more than 1% asbestos in buildings of all types. As far as fibre concentrations in the workplace were concerned, 2 fibres/cm^3 were tolerated ; this was gradually lowered to 1 fibre/cm^3 and 0.5 fibre/cm^3 in 1987 (the two values co-existed to make allowance for the alleged differences in carcinogenic potential depending on the types of asbestos fibre), dropping to 0.6 fibre/cm^3 and 0.3 fibre/cm^3 in 1992.
The European directive of 1st September 1993 contained a list of carcinogenic substances, including asbestos, for which the substitution principle applied. This European directive was incorporated into French law under the ministerial order of 20th April 1994, when asbestos was officially recognised as a carcinogenic substance. Despite this order, the idea of controlled use continued to hold sway and the decree of 7th February 1996 even reduced the concentration to 0.1 fibres/cm^3 in one hour, without there being any obligation to replace asbestos by another material. The limit was modified before the conclusions of the expert group set by the French Institute for Health and Medical Research were published in 1996 ([2]. Application orders were issued in May 1996 in the wake of the decree of 7th February 1996.

On 2nd July 1996, the report published by the French Institute for Health and Medical Research indicated that asbestos was indeed a carcinogenic substance and that the risks it engendered were not entirely under control, thereby opening the way to its being withdrawn from use. The decision to do so was taken by the French minister for labour the following day. This represented an unprecedented political and legal turnaround: within

[2] The exposure limit value for asbestos in France is not based on exposure-risk relationships. The status of the limit exposure value addresses preccupations of different natures:
a) 0.1 f/ml is the lowest concentration which, over a 50-year period, leads to a statistically significant excess risk in one of the available epidemiological studies. It is therefore a lowest observed effect level.
b) 0.1 f/ml constitutes the practical sensitivity value of the measurement apparatus used in the occupational environment.

the space of twenty-four hours, the attitude that *“risks [could] be better brought under control by lowering exposure levels”* was replaced by one advocating total ban.

Finally, one of the particularities of the regulations covering asbestos-related activities must be mentioned: they have to be applied in the fields of both public health and labour, and contain new obligations as regards not only results, but also the means by which they are to be achieved.

2.2. Similarities and differences as regards institutions

2.2.1. Radiological risk management in large nuclear facilities (Diagram 1)

Radiological risk management by the licensees of large nuclear facilities (covered by the regulations governing major nuclear installations) is based first on the assessment of occupational exposure. This assessment is highly analytical, particularly where external exposure is concerned. The primary outcome of the assessment is the setting of dosimetric objectives at the end of the work planning stage (individual and collective exposures). A system for collating data is used to monitor the changes in exposure level while work programmes are being carried out (operational dosimetry); the results (dose rates at the workstations, work time resulting in exposure and individual doses for each task) are then analysed to provide experience feedback which is used to predict and “optimise” exposure levels for future work programmes.

Risk management is also based on the assessment of alternative prevention actions, leading the licensee to indicate to the authorities the protection solution it considers as “optimal” (radiological protection optimisation process).

The originality of the system resides in the fact that the previous stages are submitted to expert appraisal organisations (the Institute for Nuclear Safety and Protection and the Office for Protection against Ionising Radiation) on behalf of the authorities concerned (the Nuclear Installations Safety Directorate and the General Directorate for Health). One of the main features of this expert appraisal processes is the technical dialogue which takes place between specialists and licensee. In particular, a debate may be held on the prevention solution put forward by the licensee, with reference to the studies provided by the latter to justify and support its proposal.

2.2.2. Risk management in small companies charged with asbestos removal or nuclear activities (Diagram 2)

In small companies, be they involved in nuclear activities or charged with asbestos removal (particularly sprayed-on fireproofing), the risk assessment stage and preventive actions are carried out quite differently by the licensee. The extent of the assessment varies according to the level and nature of the risks encountered and also depends on the “safety culture” of the licensee (see Section 4). In the case of companies charged with removing asbestos, a “removal plan” has to be drawn up by the licensee (see Section 5.1). Before work begins, the licensee has to make a list of all the risks which will be encountered, making allowance for the layout of the workplace, the characteristics of the walls and equipment from which asbestos has to be removed, the chances of personnel falling or being electrocuted etc.

Generally speaking, it must be emphasised that the possibility of critically discussing the licensees choices are much more limited than in the case of major nuclear installations. It is true that the French regulations governing asbestos removal work are very prescriptive and leave little room for manoeuvre. Similarly, the removal plan is sent to prevention specialists for their opinion and analysis of this plan helps to improve the quality of the preventive measures taken. But this analysis is not always made since the risk prevention organisations lack staff. Before works begins, or sometimes when it is in progress, the Regional Health Insurance Office and the Labour inspectorate can demand that prevention devices and operating procedures be improved, but inspections such as this are not systematic, given the number of worksites involved.

There is therefore far less opportunity to discuss the licensee’s plans than there is with major nuclear installations, where provision is made for a formal stage involving expert appraisal on behalf of the authorities.

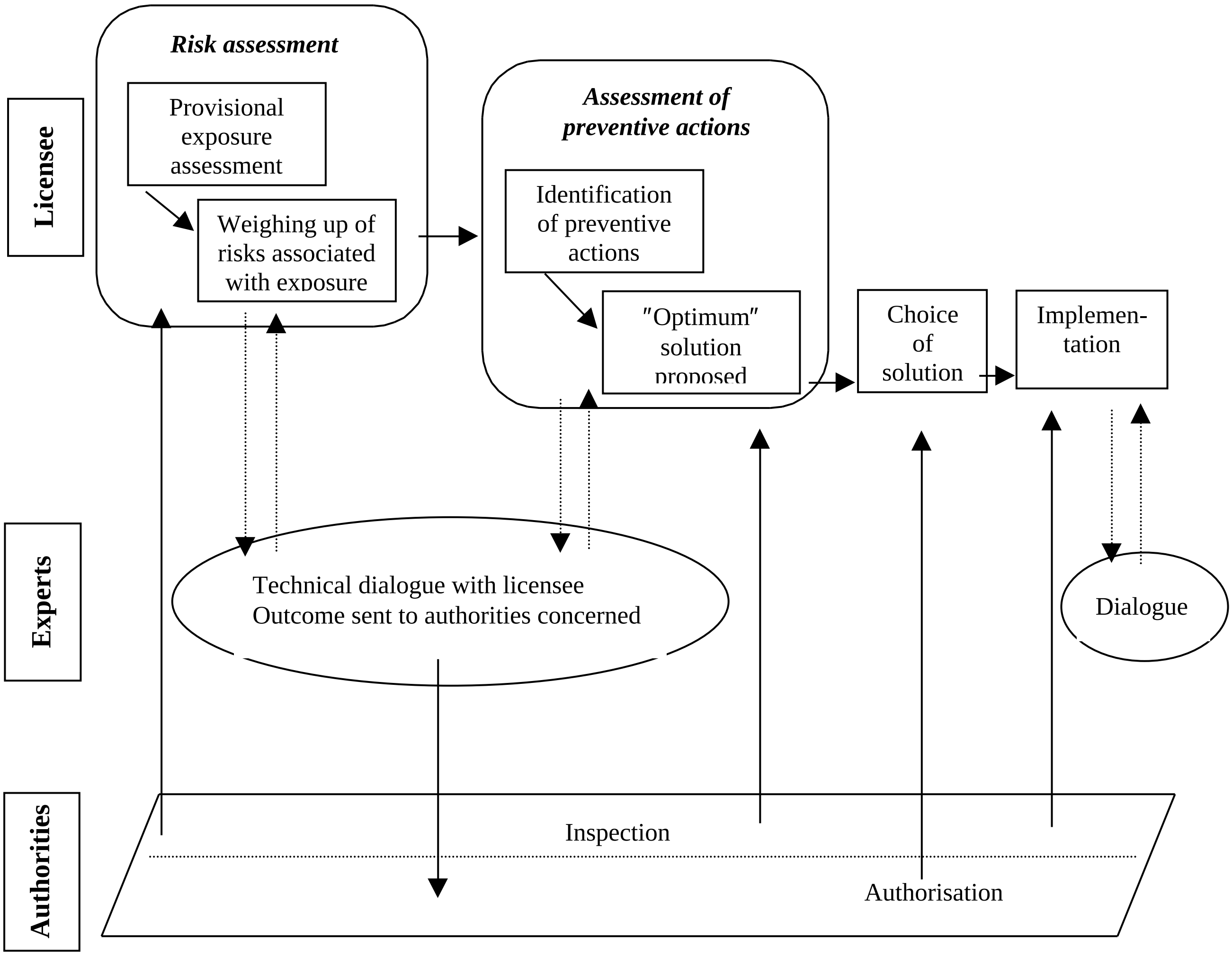

Diagram 1 – Radiological risk management in major nuclear installations

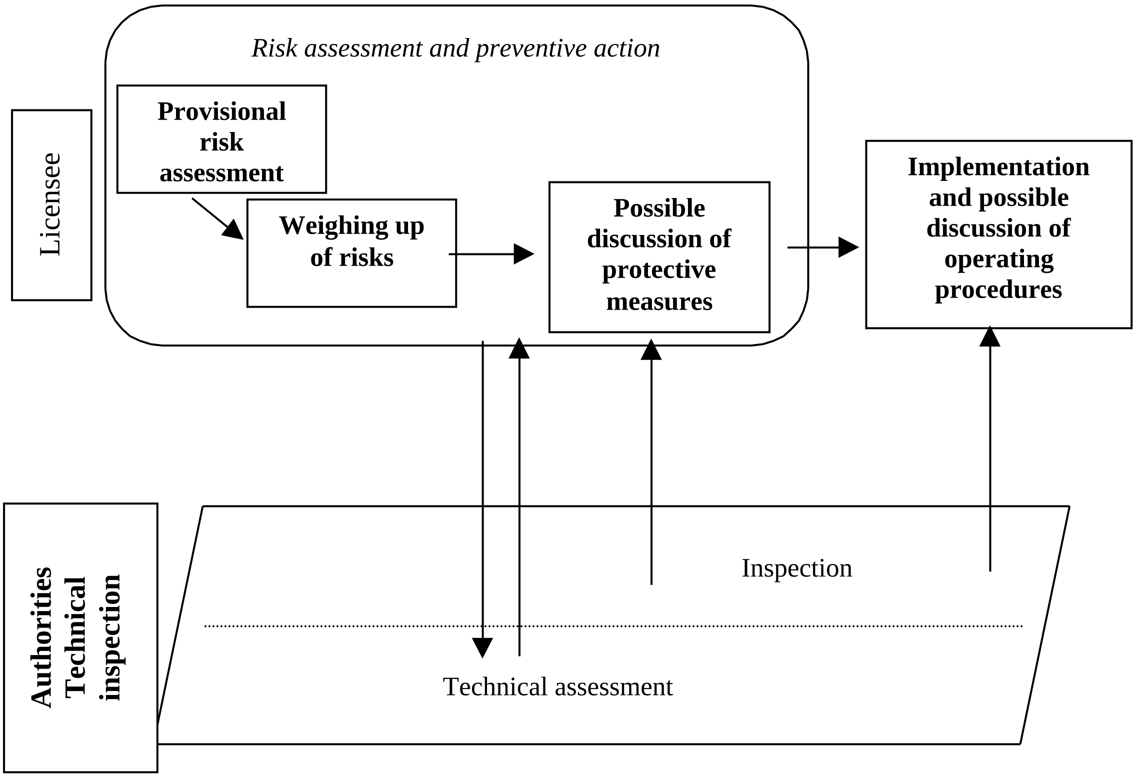

Diagram 2 – Risk management in the asbestos industry and small nuclear facilities

3. Similarities and differences as regards risk perception

Ionising radiation and asbestos-related risks have one thing in common: they are not physically visible. Intermediate measurement apparatus is required. While external exposure to ionising radiation can be measured instantly and on a continuous basis, the same cannot be said of internal exposure, which is similar in many ways to exposure to asbestos. When samples are taken from workplaces likely to contain asbestos, the fibres have to be counted under a scanning microscope; the result is known 48 hours after the measurement has been taken, so sometimes the potential exposure of workers does not become apparent until after the work has been completed.

As far as internal exposure to ionising radiation is concerned, whole body gamma counting can be used to determine the extent of internal contamination. In incident situations, the degree of contamination can be determined rapidly and the appropriate treatment dispensed. There are no similar means of investigation for asbestos, where uncertainty as to the consequences of exposure lingers on during the cancer latency period, which can be very lengthy. Thus it is that mesothelioma, which may occur 30 or 40 years after exposure, is detected only a few months before death, there being no effective treatment.

Finally, public perception of asbestos-related risks and those associated with ionising radiation are radically different. Through the years, ionising radiation has always been considered dangerous and dose limits have been steadily declining as more light is shed on its effects and associated risks. Public perception of asbestos has changed drastically in recent times (see Section 2.1). For many years, the risks associated with asbestos were underestimated and workers often used it without taking any special precautions. In the case of sprayed-on fireproofing remediation, the same workers who applied the sprayed-on fireproofing without wearing masks are now being told to wear masks to remove it; this gives rise to a number of problems regarding the implementation of risk prevention policies.

4. Safety culture

The effectiveness of a preventive approach and the social and technical context in which it is applied cannot be considered independently. This was outlined in Section 2.2 in the context of risk management bodies. Another important factor is the level of safety culture of licensees and "risk prevention specialists"[3].

Generally speaking, the licensees of major nuclear installations have been obliged to gradually develop a general safety culture, in order to control the radiological risks associated with operation of their facilities. This safety culture is developed through staff training and the thorough planning of operations which are the subject of operating procedures, most of which are extremely directive. During the course of their work, workers in these facilities are required to handle and operate equipment which is often highly sophisticated. Likewise, the risk prevention specialists working in these branches of industry receive special training and belong to a handful of organisations with considerable resources. Finally, there are international bodies responsible for disseminating experience feedback acquired in the fields of nuclear safety and radiological protection and producing radiological protection doctrine.

The context is drastically different when it comes to removing asbestos. Further to the ban on the production and processing of asbestos in France, friable asbestos treatment sites now constitute the sector of activity where, in view of the high potential risks involved, the most professional approach has been adopted to management of the asbestos risk. But most of the workers in this field started their working life in building and public works. Transposing knowledge of safety matters between this field and that of asbestos processing gives rise to problems as regards:

- initial worker training,
- the use of sophisticated equipment such as vacuum devices which represent a technological breakthrough compared to the equipment usually used in the building industry,
- worksite preparation, especially since the worksites are always changing and are never the same,
- work directives.

As for risk the prevention organisations, numerous bodies exist, some of which are not asbestos specialists, and for which asbestos-related risk assessment is an extra workload, even though no additional means are available. The fact that at national level there is no real coordination between risk prevention organisations as regards the asbestos issue means that requirements vary from region to region within France, or even within the one region depending on the bodies involved. Finally, with the exception of a certification process of the asbestos treatment companies, there is no international supervisory body.

It should be noted that the situation described here in the context of asbestos is very similar to that prevailing in small companies working in the nuclear field (irradiators, welding companies etc.).

5. Similarities and differences as regards practice

5.1. Differences between prevention of external exposure to ionising radiation in major nuclear facilities and prevention of exposure to asbestos

In certain major nuclear installations, such as nuclear power plants, exposure to ionising radiation is essentially due to external irradiation by gamma radiation and, to a lesser extent, neutrons.

In these installations, the workstations are clearly determined and it is possible to calculate the expected dose rates, making it easier to predict the level of exposure. Numerous tools have been developed for doing so: measuring systems or dose rate modelling, software permitting analytical forecasts of the dose rates per task, per work organisation modes and procedures, experience feedback databases.

Once exposure levels have been assessed, several possible protection actions are reviewed by the licensee in order to select those which are consistent with the available resources and which ensure that the risks are distributed in what is felt to be an even-handed manner between individuals. In this perspective, licensees sometimes base their actions on economic tools which allow them to determine the investment to be made in

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[3] Administrative authorities involved: Nuclear Installations Safety Directorate, Office for Protection against Ionising Radiation, Regional Directorates for Industry, Research and the Environment, Labour Inspectorate, and advisory bodies and risk prevention specialists in industry: Regional Health Insurance Office, Professional Body for Risk Prevention in the Building Industry, Committee for Hygiene, Safety and Working Conditions, Occupational Health Service etc.

terms of radiological protection, taking the “optimum model” as a basis; this puts the expenditure devoted to radiological protection and the benefits for health (expressed in monetary terms) expected from the investment into perspective. However, more often than not a qualitative approach is adopted but the main thing is to compare radiological protection actions, making allowance for the doses prevented and other considerations such as costs, technical feasibility, effects on nuclear safety, facility availability etc.

As regards the removal of asbestos, the inherent risks in buildings that need to be treated depend upon a number of factors including the type and condition of structures containing asbestos, the volume and layout of areas where work is to be carried out, as well as the type of work to be performed on the structures. The risks reside not only in the asbestos material but also in the way in which it is treated, the environment in which it is treated and in the interaction between these different factors. In this context, systems providing collective protection of, for example, clothes changing airlocks which are installed on each site, are temporary installations and depend on the particularities of the workplace. In contrast to the approach adopted for external exposure to ionising radiation, provisional assessment is a complex task which cannot be carried out using models alone (this is the case of ventilation). The way in which work progresses depends on the number of contingencies which may occur (delivery of supplies, waste removal, power outages etc.). These contingencies could have serious repercussions for the rate at which the work progresses but could also affect working conditions.

Very few dust measurements are available before work begins and provide only a limited amount of information on the risks. It is generally through an overall qualitative assessment, based on knowledge of work procedures, associated dust levels and experience with earlier treatment operations, that the risks are assessed [5]. There is no doubt that the risks can be attributed to asbestos, but other dangers existing specifically on building sites must also be reckoned with: falls, electrocution etc.

The choice of protection depends on the “removal plan” drawn up by the contractor commissioned to carry out the work; it must include details of the technical and human resources to be deployed on the site and the characteristics of the protection equipment. In particular, besides a predictive risk-assessment, French regulations require a containment system to be installed at the work site with a 3 or 5-compartment air-lock as well as the use of supplied-air personal protective equipment that is virtually air-tight. The design of the personal protective equipment used for sprayed-on fireproofing remediation work exhibits certain shortcomings. It would appear that it has been imported from other branches of industry, such as the chemical or nuclear industry, without any thought being given to the special nature of sprayed-on fireproofing remediation work. This type of activity is somewhat special in that it requires sustained physical effort by the workers who have to scrape ceilings with their arms in the air for two and a half hours. During this physical activity a high amount of oxygen is required at a high breathing frequency. Early masks were not designed with this special requirement in mind, since they were more suitable for monitoring activities; when a sudden supply of oxygen was required that was higher than the flow rate supplied by the mask, the pressure inside the mask could drop below the external pressure, which was contrary to the operating principle of the equipment [6]. Furthermore, prevention in the form of an air supply implies that the air supplied be free of impurities, thereby excluding the type of equipment normally used in the building industry. The study by Garrigou *et al*. [7] showed that non-dedicated site compressors were used to compress breathable air, meaning that oil found its way into the air breathed by the workers, posing serious risks to their health.

Because of the difficulties involved in measuring occupational exposure, risk control during operations will primarily focus on the protection system put in place. Thus the prevention experts will focus their attention on the factors influencing the collective and individual protection levels laid down in the removal plan, notably [7]: work organisation, electrical installations, detailed characteristics of each room, containment characteristics, airlock characteristics, atmospheric checks, breathing apparatus, masks, tools and operating procedures (wet or dry conditions etc.).

As far as the organisation of sprayed-on fireproofing remediation work is concerned, workers should work for two and a half hour periods. In reality, depending on how far the work is behind schedule, the duration or number of periods worked in one day will often be far in excess of the requirements of good practice. Furthermore, it has been observed that workers generally smoke heavily during their rest periods, which is prohibited in controlled areas of major nuclear installations.

5.2. Differences between prevention of internal exposure to ionising radiation in major nuclear facilities and prevention of exposure to asbestos

If we now consider radiological protection in nuclear fuel cycle facilities, such as fuel fabrication plants, serious problems are encountered when assessing and measuring exposure through the inhalation of radionuclides, just as they were for exposure to asbestos.

In order to model exposure levels, it is first necessary to assess the concentrations present in the ambient air in workshops during the working day. Depending upon the workstation considered, however, the concentration will to a large extent depend on the type of operation carried out (or even on the procedures followed by those who carry them out), resulting in concentration peaks that it is impossible to simply assess through predictive models. This situation is very similar to that encountered on asbestos removal sites.

When selecting prevention methods, the use of an ALARA approach for this type of exposure requires the identification of the main sources of contamination and the most penalising types of work operation. In practice, however, this identification generally can only be made with recourse to both experience feedback and a specific programme of measurement of the concentrations inhaled that are sufficiently representative of the actual exposure conditions. It is then possible to measure the expected efficiency of the protective actions envisaged by using measurements taken before work started and by modelling internal exposure. But it should be noted the prevention of chronic internal exposure in the nuclear environment is largely based on the use of collective systems, whereas in the case of asbestos removal, personal protection equipment is more commonly found.

Conclusion

The comparison made here highlights several factors at the root of the different ways in which risks due to asbestos and ionising radiation are managed.
Public perception of nuclear risks has undoubtedly been the driving force behind the stringent measures taken to avert radiological risks in major nuclear installations. Large amounts of money are usually made available to them and they are regularly inspected by specialist bodies whose role is to monitor nuclear safety and radiological protection. From the time they are designed to the point at which they are decommissioned, these installations are also regularly reviewed by expert appraisal organisations capable of discussing, and sometimes shedding doubt on, the solutions proposed by licensees. In major nuclear installations, the ALARA approach combined with detailed technical dialogue makes it possible to set in place preventive measures which constitute a reasonable compromise in several areas: reduced exposure, available technical resources, environment in which they are deployed and, implicitly, the technical and financial capabilities of licensees. As it develops further, this “iterative, analytic-deliberative process” [8] gathering the licensee, the competent authorities and their technical support bodies could, in the long term, also involve representatives of the personnel at risk.

But these remarks only apply to major nuclear installations and radiological risk management in small nuclear companies is very similar to the type of management in force in small asbestos removal companies. They have in common a lack of safety culture and the fact that specialist prevention organisations are required to simultaneously manage a multitude of risks in a large number of companies which are not always in a position to invest in safety to the degree required.

Based on the different situations shown here above, a discussion should take place on the conditions that will make efficient a prevention policy in the field of the exposure to toxic agents or substances. These conditions refer to the foundations of prevention policies.
The limits of exposure models that only take into account the simple cause/ effect relation (an asbestos fibre and the lungs), have been widely discussed; it is then important to analyse the complex and permanent interactions between the various determinants of the exposure, on which one has to act simultaneously [7].
Three levels are identified, that can determine the exposure conditions of a worker faced with a risk :

- A general level dealing with the production of the legal obligations;
- A the level of organisations and companies ;
- A microscopic level dealing with work situations and workers.

Production of the legal obligations level

It was previously emphasised to what extent, when passing from the controlled use of asbestos to total ban, the drafting of new regulations and their setting up represent important stakes for prevention. It is pertinent to note that law makers, just as institutional prevention specialists that are going to enforce these regulations, are involved themselves in a learning process even though they are supposed to be experts. To recognize that they are “learners” too lead us to discuss the “transitional” status of regulations. Therefore the latter can only be incomplete, perfectible ; they cannot foresee all possible cases and thus cannot be applied as such without the prevention specialists transposing them to each specific situation. For example, when supplied-air personal protection equipment presents risks of accidental exposure (due to a tear in the fabric, loss of face mask fit) or other risks (falls), the licensee and the prevention specialists may discuss the advisability of using personal protection equipment which offers less protection but gives workers greater freedom of movement. Similarly, the risk of electrocution may prompt the prevention specialists and the licensee to decide against using sprayed liquids to capture airborne fibres and thus reduce the level of airborne dust in the ambient air. This transposition stage, even though not yet recognised is a key element in the prevention specialist activity.

At the organisations and companies level

In the context described above, the companies charged with asbestos treatment can be seen as insuring a "public safety" function. The industrial sector of asbestos treatment appears then as a striking example of risk transfer from the public to the workers. The public has recently been made aware of the risks related to asbestos and this is shown with the strong requests for asbestos removal from buildings open to the public (in particular schools and universities). This situation leads to asbestos removal decisions that are not always justified if one considers the levels of contamination that have actually been measured. Besides, the high costs of asbestos removal very often encourage to choose the cheapest contractor, even if the lower cost is indirectly obtained by cutting down the protection of the asbestos treatment workers. To what extent such a logic, if carried out to its extreme, would not lead to "sacrify" the involved workforce for the sake of public health and well-being ?. More generally, the dismantling of hazardous facilities, after closing down, may rise the same concern.

Besides the conditions under which the markets are concluded with the contractors doing the asbestos removal, the organisation of the tasks, the preparation of the interventions as well as the choice of the protective equipment (collective or individual) have to be questioned. These different dimensions are highly inter-related and will be essential to determine exposure conditions.

At the work situations level

A long time ago, ergonomics have shown that workers set up complex strategies according to the various normal events and incidents occurring during the course of their activity. The operational modes, including safety, are only working tools and they cannot foresee everything. The exposure conditions are strongly determined by the varying events and incidents. The analysis of the activity requires to specify the model of man at work which is used as a basis for preventive action. Various dimensions can be emphasised :

- The biological dimension at work relating to physical stress, effort, fatigue ; good examples are the relationship between the physical work and efficiency, as well as the comfort when wearing work equipment ;
- The cognitive dimension, that takes into account the research and the treatment of the information as well as the individual decision making (detection of risk situations ; use of formal information, such as operational modes, dials, screens, etc., or non-formal information related to the process, decision making in emergencies, etc.).
- The psychical dimension which reveals the identity of each individual within work situations. This dimension helps in highlighting paradoxical risk taking behaviours, defences that can be set up in order to protect oneself, at the psychical level, against these risks, as they are perceived ;
- The social dimension that takes into account the worker as a member interacting with others in a work team. In the latter are developed values, representations, skills, including carefulness.

In a work situation, the exposure conditions to a toxic substance or agent will be largely determined by the interactions between these three levels. However, prevention specialists tend to focus solely on the biological models linking exposure and risks. Resisting this tendency opens the road to interdisciplinary approaches that allow putting together the three above-mentioned levels, in view of defining more efficient prevention policies. To go ahead with these issues, understanding the activities carried out by the prevention specialists appears to be necessary.

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