Chapter 11
Ergotoxicological approach to the prevention of carcinogenic risk in the work environment

Brahim Mohammed-Brahim

Interest in understanding the chemical risk in complex work situations was first shown in the 1980s (Silva *et al.* 1980; Delvové 1984; Sznelwar 1992). Known as the 'ergotoxicological approach' (Villate 1985: 303), this approach struggled to gain ground among occupational health and safety experts with their prescriptive prevention model that was attractive on a formal level and comfortable in terms of responsibility. But things changed in the 1990s, with the asbestos scandal and the initial epidemiological data on the latent effects of pesticides encouraging us to revisit this approach (Mohammed-Brahim 1999).

1. The asbestos scandal in France: a textbook case

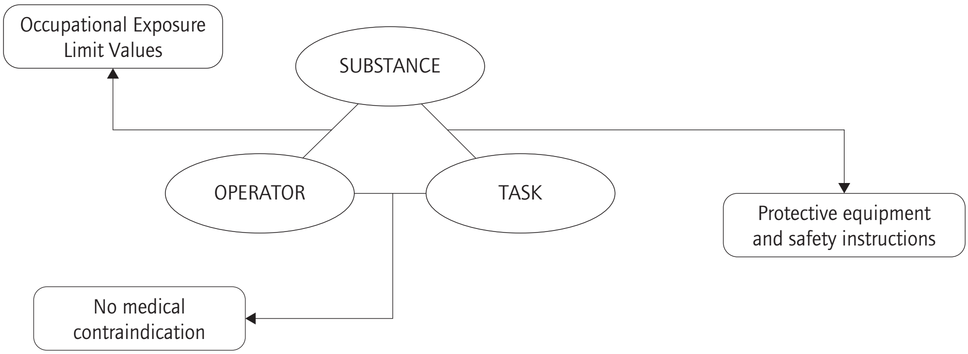
The links between occupational exposure to asbestos and the development of cancers were established quite early on (Doll 1955; Wagner *et al.* 1960). However, it was not until 1977 that the consensual option of 'controlled use' was adopted in France, inspired by the social partners, representatives of the State and public institutions, and scientists who came together from 1982 onwards within the Standing Committee on Asbestos. This was felt to be a framework capable of curbing any residual risk of unwanted exposure to asbestos. However, the measures adopted do nothing to prevent, and in fact will allow, an expected total of 68 000 to 100 000 cancers between 2009 and 2050 in France (HCSP 2014). Beyond the legal liability to be determined by the courts and the moral responsibility to be assessed by protagonists, we have started to analyse how the chemical risk could have been viewed in a way enabling such a harmful consensus.

2. The 'dominant' chemical risk prevention model or 'screen model'

The EU OSH Framework Directive of 12 June 1989 sets out the general principles of prevention, three of which directly relate to chemical risk prevention: eliminate or reduce the risk at source; confine, remove or overcome the risk; individually protect from the residual risk. Adapting work to the individual is mentioned only in reference to monotonous work and work at a predetermined work-rate, which should be alleviated (Article 6(2)(d)).

Achieving these aims requires the use of knowledge and practices stemming from industrial toxicology (Occupational Exposure Limit Values – OELs – 'normative screens' that must be achieved through a 'physical screen' made up of collective and personal protective equipment and safety instructions designed to keep actual exposure levels below these limits) and occupational medicine (no medical contraindication for exposure in the case of carcinogens, a 'regulatory screen' supposed to prevent the individual residual risk). These three approaches form a prevention model that we have called the 'screen model' (Mohammed-Brahim 2000). The 'dominance' of this model should be noted.

Figure 1 **'Screen' model of chemical risk prevention**



Source: Mohammed-Brahim (2000)

However, this model is flawed, whether with reference to:

— the OELs, which result more from a social compromise, reached in an unequal relationship between the social partners, than from any 'scientific objectivity';
— the protective equipment and instructions provided upstream of the work situation, where failure to comply is more an expression of the constraints on operators individually and/or collectively than any unfairly assumed negligence on their part;
— no medical contraindication, which replaces preventive medicine with 'predictive' medicine.

In addition, by limiting chemical risk prevention to the use of 'screens' to combat the dangers, the model in fact fails to consider and act on the technical, organisational and even human determinants of these dangers, losing any room for manoeuvre that may have been possible through an integrated approach to chemical risk prevention (Mohammed-Brahim and Garrigou 2009).

3. Ergotoxicology: an effective model of chemical risk prevention, in particular with regard to carcinogens

We hypothesise that the weakness of this model in properly and sustainably preventing chemical risks is linked to the lack of reference to working reality.

Work situations involving exposure to chemical risks are both complex and unique, particularly in terms of carcinogens.

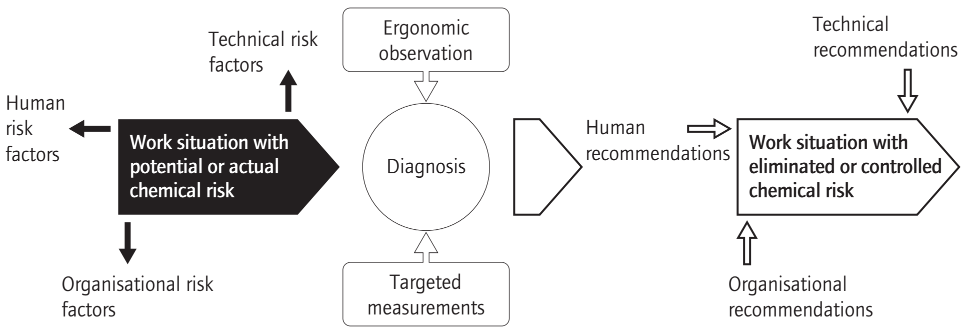
They are complex, in this case, for several reasons:

— scientific uncertainty (the generally multi-causal origin and non-specific nature of cancers, length of latency, absence of an a priori threshold value), which always makes recognition of an exposure-effect relationship controversial and which further delays the introduction of regulations prohibiting and/or limiting use and/or laying down protection measures;
— multiple exposures within the same job and over a career, making it harder to characterise the risk using the reading grid and prevention framework prescribed by the ‘dominant’ model;
— not always clear perception of the risk by operators in the absence of an effect felt during exposure and/or a definite representation (absence of specific pictogram, no pictogram in the absence of classification of the substance or preparation).

Similarly, they are unique when we take account of their variability (repeated or sustained incidents, work in degraded mode, non-standard hours, added physical workload and/or heat) and the specific careers of each individual (non-evaluated effects of previous exposures, medical history, addictions).

Ergotoxicology offers a prevention model combining technical, organisational and human measures capable of acting on the determinants of the exposure situation identified through an analysis of the work and knowledge stemming from toxicology. This model involves the following process (Mohammed-Brahim 2014):

Figure 2 **Breakdown of the ergotoxicological approach**



Source: Mohammed-Brahim (2014)

These determinants may therefore be:

— **technical**: specific to the substance(s) (physical, chemical and toxicological properties), linked to the physical environment (heat, noise, architectural configuration), process requirements (alteration of the physical state, intermediate synthetic products, manual interventions) or intrinsically unsuitable protection that may prevent or constrain necessary or useful acts;

- **organisational**: working hours and rates influencing the duration and repetitiveness of exposures, quality requirements incompatible with protection requirements, regulatory constraint, remoteness of decision-making centres, commercial policy;
- **human**: sociodemographic characteristics specific to the business and associated with the typology of the employment pool, training, professional experience, contractual status.

It is clear that these determinants can exist:

- both at 'micro' levels, directly linked to the configuration of the situation observed, relatively deterministic, often accessible to observation and offering possibilities for action that are more perceptible, acceptable or achievable in the short term;
- and at 'macro' levels, remote from the observables of the work situation, accessible through reports, sometimes involving actors remote from the operators, possibly impacting situations other than the one observed, and offering fewer possibilities for action, at least in the short term, in terms of their construction, implementation and impact.

Access to these determinants is made possible by the ergonomic observation of exposure situations and reports by operators. Videos together with targeted environmental measurements support the self-confrontations among operators and with the expert so that diagnoses can be formulated and validated.

The subsequent combination of actions on these various levels and qualities of determinants, only minimally or not at all in some cases and with much more room for manoeuvre in others, their construction and validation with local operators and their supervisors and the subsequent negotiations with the decision-makers, allows a situation to be constructed in which risk is controlled (or even eliminated), shared, accepted and sustainable.

4. An approach used in the field

This approach, tested over several years, will be illustrated here by two experiments involving the issues mentioned at the start of this paper: asbestos and pesticides.

4.1 Use at asbestos removal sites

Two years after the 1997 Regulation was adopted in France, we were tasked to investigate its implementation in practice. Two sites were therefore monitored and subjected to an end-to-end analysis, from the examination of the calls for tender to final acceptance. The following are some of the significant elements of the diagnosis and recommendations.

Reasoned trade-offs

In order to reduce dust, the Regulation recommends firstly wetting the surfaces to be treated. However, spraying pressurised water vapour or surfactant will also wet the plastic sheeting protecting the floor, causing people to slip. This water also makes the waste much heavier, requiring much more manual handling during its removal. This example, among others, illustrates the trade-off processes of the operators involved, in this case between a real-time risk and a delayed risk against which respiratory protection is deemed to protect them.

Surprising exposures

The work area was sealed off using a double layer of joined plastic sheeting, with only the inner layer being fixed to the walls and floor. Negative pressurisation caused aspiration towards the inside of the second layer. To prevent this problem, operators came up with the idea of gluing the two layers together in places. The glue was sprayed, with the operator being sandwiched between the two layers. However, the glue contained dichloromethane, a substance classified as a group 2B carcinogen by the IARC due to its suspected responsibility for pancreatic cancers. Exposure could be significant due to the confinement and physical workload.

A second finding involved the presence of mineral oils in the air breathed in by the operators, at a rate more than five times the level permitted by standard EN 132. These mineral oils came from the compressors supplying the protection masks with air. Depending on their level of refinement, these oils appear in the list of mixtures classified as group 1 carcinogens by the IARC. Given the number of people likely to be exposed to this source (sandblasting operations in the building, for example), the competent authorities (INRS, Ministry of Employment) were quickly alerted.

Finally, despite the air supply, our measurements revealed the presence of asbestos fibres inside the masks, in some cases exceeding the permitted levels. This was explained by variations in internal pressure due to the differing rates of breathing associated with the physical workload, and by breaks in the seal due to intentional or unintentional disconnections in order to untangle the supply pipes connected to the same supply terminal.

Adverse organisational factors

The Regulation limits the period of work in a confined area to two hours thirty minutes, and even less than that for heavy workloads. However, not only was this period systematically maximised, but recuperation time outside the area was minimised. As a result, the time spent by operators in the work area during a working day could total seven hours thirty minutes. Workload measurements carried out revealed the physical cost of this organisation.

A single chamber was provided for accessing the sealed-off area, both for operators and for removing waste, which led to contamination given that regular cleaning was prevented by time pressure.

Most of the staff were on fixed-term contracts and came from cleaning companies rather than the building sector, particularly the nuclear sector. The staff were therefore inexperienced, with precarious contracts, subject to successive uncontrolled exposures and mostly without any medical monitoring.

Feedback enabling advances in prevention

Leaving aside the failure to comply with the wetting instruction, a formal reading of the work situations would have indicated an almost total observance of the regulatory provisions. However, the ergotoxicological approach revealed deviations leading to exposures that would otherwise not have been suspected, and enabled their understanding and the collective construction of a range of prevention measures.

Feedback allowed urgent decisions to be made, particularly the ban on fixed-term contracts and the monitoring of breathing air supply equipment. This assessment resulted in a document that has been extensively distributed among occupational health and safety experts (Garrigou *et al.* 1998) and a manual for use by occupational doctors (Mohammed Brahim *et al.* 1998). It largely inspired the update of the Regulation, particularly the 2012 decrees.

4.2 Assessment of exposures to pesticides in the seed industry

Stemming from a meeting between a pesticide supplier, the seed industry representatives and the prevention body, this assessment was intended to diagnose exposures to pesticides and their determinants during seed coating operations and to design prevention measures. This occurred in a context of heavy social, media and political pressure (Mohammed-Brahim 2009).

The assessment involved nine companies representative of the variability of the industry (size, type of seed, technology). We will only mention here the most illuminating situations.

Analysis of the activity and targeted measurements

Observing the activity allowed the hypothesis to be made that equipment cleaning was the situation involving the greatest exposure, as confirmed by the respiratory and cutaneous measurements. Depending on the operation, the level was 5 to 20 times higher than that found in other activities. Respiratory exposure seemed to be negligible in all cases. The cutaneous route was the main route of exposure, with 80 % to 100 % occurring through the hands alone.

Personal protective equipment (PPE) – dry suits, full filtering masks and gloves – was required by the occupational health and safety expert.

However, during peak periods, cleaning was repeated up to 10 times, i.e. after each change of seed or preparation. It took around 12 minutes to put on and remove the PPE, i.e. a total of two hours out of the working day. No organisation would be prepared to accept this within working time. In addition, the sheer physical weight of the equipment and the heat in the height of summer were difficult to sustain.

Cleaning or protecting: what is the room for manoeuvre and what are the compromises?

In this case, compromises were built around the evidence that effective protection of the hands alone (gloves, rinsing) reduced exposure to an acceptable level:

— for occupational health and safety experts on the one hand, enabling them to improve their representation in light of our findings;
— for employees on the other hand, as regards managing this personal protective equipment (putting it on, working with it and removing it without damaging it; training seasonal workers, in particular, through practical and taught courses).

At a 'macro' level, work was carried out to reduce the number of cleaning operations:

— with professionals, by questioning the actual need for these operations and by reorganising their implementation;
— with the agricultural adviser and sales force, by limiting the range of preparations used.

5. Yes, assessing the work more clearly identifies the chemical risk, at the same time as improving prevention by basing it on the actual work situation

This confirmation is being echoed by an increasing number of occupational health and safety experts and companies in the context of training measures and proposed interventions.

Still relatively unknown, the ergotoxicological approach is also being echoed in regulatory developments, as evidenced in France by the changes made by the 2003 Decree on chemical risk prevention (extension of the definition of dangerous chemicals and of the scope to all exposure situations, reference to real work), and more recently the Decree on asbestos exposure risks (separate assessment for each 'work process', individual sampling in situations of significant exposure, reference to the rest time after each shift, etc.).

Occupational health programmes are reinforcing the idea that ergotoxicology represents an alternative approach offering a new dawn in chemical risk prevention in the work environment.

The DRT Circular of 24 May 2006 explaining Decree No 2003-1254 of 23 December 2003 on chemical risk prevention states that 'the analysis of the forms of exposure ... shall be based ... on an analysis of the work situations, workplaces and conditions under which activities involving chemical agents are carried out; this **analysis of actual work** must necessarily be based on the knowledge that employees have of their own activity and workplaces'.

The 2005-2009 Occupational Health Plan sets, as one of its occupational health research objectives, 'renewing the approach methods' for toxicology in particular and 'developing new approaches'. In its annex on the creation of multidisciplinary scientific centres, it talks in particular of 'ergotoxicological approaches'.

References

Council of the European Communities (1989) Council Directive of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work (89/391/EEC), Official Journal of the European Communities, L 183, 29 June 1989.

Devolvé N. (1984) Ergonomie et toxicologie, Le Travail Humain, 47 (3), 227-235.

Doll R. (1955) Mortality from lung cancer in asbestos workers, British Journal of Industrial Medicine, 12 (2), 81-86.

Garrigou A., Mohammed-Brahim B. and Daniellou F. (1998) Etude ergonomique sur les chantiers de déflocage d'amiante : rapport final, Université Bordeaux 2, OPPBTP, DRT/CT3.

HCSP (2014) Repérage de l'amiante, mesures d'empoussièrement et révision du seuil de déclenchement des travaux de retrait ou de confinement de matériaux contenant de l'amiante : synthèses et recommandations, Paris, Haut Conseil de la Santé Publique.

Mohammed-Brahim B., Daniellou F. and Garrigou A. (1998) Amiante, chantier de retrait secteur 2 : guide pour le médecin du travail, Bordeaux, AHI.

Mohammed-Brahim B. (1999) Ambiances chimiques de travail : l'ergotoxicologie ou la transition d'une prévention formelle à une prévention opérationnelle, Performances Humaines et Techniques, 99, 27-34.

Mohammed-Brahim B. (2000) Concept and methods in ergotoxicology, in Karwowski W. (ed.) International encyclopedia of ergonomics and human factors, London, Taylor and Francis, 698-701.

Mohammed-Brahim B., Garrigou A., Daniellou F. and Brochard P. (2000) Temps de travail en et hors zone : la combinaison de tous les dangers sur les chantiers de retrait de l'amiante en place, Archives des Maladies Professionnelles et de Médecin du Travail, 62 (3), 210-211.

Mohammed-Brahim B. (2009) Intérêt d'une approche ergotoxicologique dans la prévention du risque cancérogène en milieu de travail, Seminar "Prévenons les Cancers Professionnels", INRS, Paris, 18-20 November 2009.

Mohammed-Brahim B. and Garrigou A. (2009) Une approche critique du modèle dominant de prévention du risque chimique : l'apport de l'ergotoxicologie, Activités, 6 (1), 31-49. DOI: 10.4000/activites.2086

Mohammed-Brahim B. (2015) L'ergotoxicologie ou comment aborder le risque chimique du point de vue de l'activité du travail. http://www.prevention-ergonomics.com/fr/conference03F.html

Silva M.R.C *et al.* (1980) Optimização ergonômica nos tratos culturais na lavoura de cana-de-açúcar, Rio de Janeiro, Fundaçao Getulio Vargas, Instituto de seleçao e orientaçao profissional, Centro Brasileiro de Ergonomia e Cibernitica.
Sznelwar L. (1992) Analyse ergonomique de l'exposition de travailleurs agricoles aux pesticides : essai ergotoxicologique, PhD thesis in ergonomics, Paris, Laboratoire d'ergonomie du CNAM.
Villate R. (1985) Toxicologie et ergonomie, in Cassou B. *et al.* (eds.) Les risques du travail : pour ne pas perdre sa vie à la gagner, Paris, la Découverte, 301-303.
Wagner J.C., Sleggs C.A. and Marchand P. (1960) Diffuse pleural mesothelioma and asbestos exposure in the North Western Cape Province, British Journal of Industrial Medicine, 17 (4), 260-271.