

Occupational Cancer in France: Epidemiology, Toxicology, Prevention, and Compensation

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This article is a description of the current situation in France with regard to occupational cancer: research, prevention, and occupation. Toxicologic experiments are carried out using *in vitro* and *in vivo* tests, particularly using transgenic mice. Several epidemiologic studies have been conducted over the last decades: population-based case-control studies; mortality studies and cancer incidence studies carried out in historical cohorts of workers employed in the industry; and case-control studies nested in occupational cohorts. French ethical aspects of toxicologic and epidemiologic studies are described. The results thus obtained are used to establish regulations for the prevention and the compensation of cancers attributable to occupational exposure. This French regulation for prevention of occupational cancer involves several partners: a) the states authorities, including labor inspectors, responsible for preparing and implementing the labor legislation and for supervising its application, particularly in the fields of occupational health and safety and working conditions; b) the Social Security Organisation for the analysis of present or potential occupational risks based on tests, visits in plants, complaints or requests from various sources, and statistics. These activities are performed within the framework of the general French policy for the prevention of occupational cancer. This organization includes the National Institute for Research and Safety, particularly involved in research in the various fields of occupational risks—animal toxicology, biologic monitoring, exposure measurements epidemiology, psychology, ergonomics, electronic systems and machineries, exposure to chemicals, noise, heat, vibration, and lighting; and c) companies where the regulation defines the role of the plant manager, the occupational physician, and the Health, Safety and Working Conditions Committee (comprising the manager, employees' representatives, the occupational physician, and the safety department) in dealing with any problem regarding safety, occupational hygiene, and working conditions. These organizations along with medical practitioners are involved with the compensation of occupational cancers. The regulation for compensation includes the tables of occupational cancer, the possibility of recognition of a cancer case when the requirements of the tables are not met, and the postprofessional follow-up of workers exposed to a carcinogenic agent. — *Environ Health Perspect* 107(Suppl 2):245–252 (1999). <http://ehpnet1.niehs.nih.gov/docs/1999/Suppl-2/245-252aubrun/abstract.html>

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The rapid worldwide industrialization that started about a century ago has been accelerating over the last decades. This leads to several technologies, occupations, and professions, spreading from industrialized to developing countries. Therefore, occupational cancer is one of the most important

fields in cancer research and public health because of the numerous practical and theoretical implications involving physicians, biologists, engineers, technicians, economics, industrials, unions, and social partners.

France is concerned about this problem, as it is one of the oldest and most

industrialized countries in the world. Several institutions or organizations are involved in the various topics resulting from occupational cancer detection and prevention including activities such as toxicology, epidemiology, regulation for compensation, and threshold limit values. Although these topics are not specific to French working conditions, some of the methods that deal with these problems depend on French legislation.

This article is an overview of the occupational cancer problem in France. The various topics discussed are a) research in epidemiology and in animal toxicology, b) the situation concerning exposures to known carcinogens, and c) the status of regulations on occupational exposure to carcinogens, occupational cancer deserving compensation, and prevention of occupational exposure. The roles of occupational physicians and medical practitioners in this field are also described.

Epidemiologic Studies

Organization

Epidemiologic studies focused on occupational cancer risks are currently being conducted in France. The principal investigators are from several organizations or institutes in France: the National Institute for Health and Medical Research (INSERM), the National Institute for Research and Safety (INRS), institutes of occupational medicine from universities, the Institute for Nuclear Protection and Safety, cancer registries, and the International Agency for Research on Cancer (IARC). Most of these studies are conducted with the collaboration of occupational physicians, industrial hygienists, medical practitioners, and other partners, depending on the type of study.

Most of these studies are performed following requests from industry, occupational physicians, unions, the French Social

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Abbreviations used: CHSCT, Health, Safety and Working Conditions Committee; CNAMTS, National Health Insurance Fund for Salaried Workers; CRAM, Regional Health Insurance Fund; EEC, European Economic Community; IARC, International Agency for Research on Cancer; INRS, National Institute for Research and Safety; INSEE, National Institute for Statistics and Economic Studies; INSERM, National Institute for Health and Medical Research.

Security Organisation, universities, or IARC. However, some studies specifically investigate clusters observed by occupational physicians or medical practitioners. These studies are case-control studies and cohort studies.

Case-Control Studies

This section deals with population-based case-control studies only (1). Several independent case-control studies on occupational risk factors of cancer have been conducted in France (2). Almost half these studies have investigated occupational risk factors of lung or other respiratory cancers (2). The other sites of cancer most frequently studied were cancers of the hematopoietic system and urinary bladder (2).

Sources of Cases. Most of these studies included incident cases of cancer. The cases have been identified in hospitals and population cancer registries. Hospitals have been most frequently used as a source of case identification (public or private hospital, cancer treatment centers). Several sources may be used simultaneously as an attempt to obtain complete coverage of incident cases covering a given geographical area or the entire country.

No national cancer registry is available in France (3). However, well-established cancer registries cover the population of about 10 districts (administrative areas), representing approximately 10% of the total French population. Some of these registries include only digestive tumors or hematopoietic cancers (3). For a given study, the local clinicians and pathologists who systematically report all cancer cases to the registry may be asked to report the new cases of the specific site of cancer to the study investigator at the time of diagnosis. Some studies have already been conducted in this way by cancer registries or with their collaboration (2). This procedure for recruiting the cases in population-based case-control studies may become more frequent in the future.

Source of Controls. When cases are recruited among hospitalized patients, hospital-based controls are also used. The controls may be other cancer patients or noncancer patients. The advantages and the limitations of this procedure for selecting controls are not specific to France (1). Controls may be selected among different groups of diagnoses to control for possible selection biases (1).

No population register is available in France for epidemiologic studies, but

theoretically other sources may be used to select general population controls:

- Electoral rolls include all persons of French nationality, with a high degree of completeness except in the younger age groups. As these lists include the date of birth and address of each person, they can be used directly for selecting controls according to age and to trace the selected persons. They can be obtained in each municipality or in the main city of each area.
- Census data are available at the National Institute for Statistics and Economical Studies (INSEE). The data consist of a list of dwellings, and they cannot be used to identify the controls with requested characteristics. The use of census data implies that the occupants of the dwelling are contacted to see whether an eligible control is present.
- Telephone directories can also be used to identify general population controls. The telephone coverage is very large in France, but approximately 20% of the population is not listed in telephone directories, implying possible selection biases. Theoretically, this problem could be solved using a random-digit dialing procedure, but this method has rarely been used in France.

Data Collection. There are no large databases in France that include information on occupation or on occupational exposures. However, large job exposure matrices that would fit to the French context are being elaborated and might be used more frequently in the future for population-based case-control studies (4). Questionnaires completed during face-to-face interviews are the most frequent method of data collection. Although the early studies addressed cancer risk in relation to occupational title only, most of the recent studies include detailed data on occupational history and an evaluation of different exposures by industrial hygienists (4). Therefore, detailed occupational exposures could be investigated in the most recent studies.

Cohort Studies

Because there is no cancer registry at the national level in France (3), most cohort studies are mortality studies (5,6). Because of the latency time of cancer, historical cohorts are usually investigated. Complementary nested case-control studies are performed when data on job histories or smoking habits are not available for all workers of the study cohorts (1,7). In

addition, some cancer incidence studies can be conducted in plants located in districts having a cancer registry (3). Over the last two decades, cohort mortality studies have been conducted in several industrial sectors—particularly mining, coal transformation, the steel industry, metallurgy, and the chemical industry (2).

Individual Data Collection. Administrative data and job histories are provided by personnel departments of plants.

The vital status of workers included in a historical occupational cohort can be assessed through *a*) the administrative registries of birth places for people born in France; *b*) the national file of the INSEE, which provides date and place of death for people who died in France, regardless of the place of birth; *c*) the national registry of Nantes, which contains information on French people born in a foreign country; and *d*) the file of retired workers that may exist in some study plants.

Causes of deaths are ascertained from the national file of death certificates, which is managed by the INSERM (8). Because this file was set up in 1968, most follow-up periods begin in 1968. Before this date, causes of deaths have to be collected from medical practitioners.

Data on lifestyle such as smoking habits can be collected from medical records of each plant for present and past workers.

Occupational Exposure Assessment. Exposure measurements can be performed by the INRS, the Regional Health Insurance Funds (CRAMs), or some universities. They provide information on current exposure. Past exposure can be assessed using available past measurements and through the development of job exposure matrices specific to the industrial process of interest (9,10).

Statistical Analysis. Standard mortality ratios are calculated as recommended in the literature (5,6). The reference death rates are published by the INSERM, at the national or regional level (95 French districts). They provide the numbers of causes of deaths according to sex, 5-year age groups, and year of death since 1968. Data from the INSEE provide the corresponding numbers of subjects for the calculation of death rates.

Ethics in Epidemiologic Studies

The conduct of epidemiologic studies in France has to meet the requirements of legislative or regulatory guidelines that are intended to protect the study subjects

(11–14). These guidelines cover three broad areas:

- The automated treatment of nominative information (11,12), which deals with the automated treatment of nominative information. It is necessary to obtain the agreement of the Advisory Committee for the Treatment of Information and of the National Commission for Computerizing and Liberties before the study begins.
- The medical secrecy based on a 2,500-year-old principle: the respect of the individual and his privacy. The law on the treatment of nominative data (12) provides for the relaxation of medical secrecy under certain conditions, particularly the written consent of the individual concerned, if the information is to be used for research purposes.
- The laws on the protection of individuals participating in biomedical research (13,14), which define the conditions under which trials, studies, or experiments intended to improve biologic or medical knowledge can be organized and carried out with human beings.

Animal Experimentation

Methods

Although the etiology of human cancer remains for the most part unknown, many chemical agents or processes were found to be carcinogenic in experimental studies or in epidemiologic research and were classified as human potential carcinogens (15). These agents must be included in consideration of suitable preventive measures, as well as those agents for which adequate proof of carcinogenicity in animals exists without epidemiologic evidence (16). *In vitro* or *in vivo* experimental methods have been elaborated to address the need for prevention, as the results of decisive human epidemiological studies are often delayed. From a regulation point of view, the choice of tests depends on the quantity of the chemical agent and of the specific effects on health (17,18). Short-term studies, including mutagenesis tests (19), and long-term carcinogenesis studies (20,21) constitute the methodologic corpus of this assessment.

Mechanistic studies include research on the understanding of the production and the target effects of free radicals, the cellular effects of proliferation and apoptosis, the formation of DNA adducts, the direct or indirect mutagenic effect on DNA, the change of gene expression, and the analysis of the physicochemical properties of

susceptible particle surfaces to explain their differences in biologic activity.

Only two types of tests can be used in *in vitro* carcinogenesis testing (22–25): the morphologic transformation of mammalian cells in culture (26,27) and the inhibition of metabolic cooperation (28). Current research works use the survey of methodologic parameters to improve their predictiveness.

For *in vivo* assessment, methods in molecular biology led to the creation and use of transgenic animal models from 1984 (29,30). Two types of models have been developed. First, transgenic models of mutagenicity permit the identification and characterization of mutagenic agents for germ cells and somatic cells. This model is devoted to measuring mutations induced by the exposure of a substance with tissue or organ specificity after an acute, subchronic, or even chronic exposure. Second, transgenic animal models for oncogenes or tumor-suppressor genes have been created to study genetic or epigenetic events that occur after an exposure in conjunction with the mutation to produce cancer. Still very recent and in constant evolution, these transgenic animal models open perspectives of mechanistic understanding and quantification of target mutations.

In conclusion, characterization of the potential effects of carcinogenic agents is a major issue in France in terms of public health and the cost for society. The research works that permit an understanding of the mechanisms of action of the chemical agents, fibers, and particles driving toward a process of carcinogenesis are therefore important. Such research should lead to new models, resulting in a reduction of experimental animal use, a faster, more reliable detection of potential carcinogens, and a better extrapolation to man of the results of experimental studies in animals. This last point will permit a more accurate assessment of the implications of the exposure to carcinogenic agents for human health.

Ethical Aspects

Before entering production, any new chemical product must undergo a series of toxicologic tests, particularly tests to verify whether the substance is a potential carcinogen. *In vitro* experiments cannot involve the entire set of biologic phenomena, and it would be unethical to extend the results to humans without examining *in vivo* models. As a consequence and

because such experiments are irreplaceable (31), it is our responsibility to respect the animal subjects and consider their capacities for suffering and remembering. The ethical principles imposed by current legislation are based on the “three Rs” of Russel and Burch (32): replace, reduce, and refine (33–35).

French legislation is designed to conform to the European and French texts on this issue, particularly with Council Directive no. 86/609/EEC of 24/11/1986 (36) and the French Decree no. 87-848 of 19/10/1987 (37,38).

Currently there are no regulatory texts on the creation of ethics committees because the system chosen by France is based on an authorization delivered to responsible and competent individuals (conforming to article 7-1 of the Council Directive no. 86/609/EEC) (32). Because of the application of this set of directives, the number of animals used in experiments has decreased 25% over the last 10 years without causing a reduction in research activity (39,40).

Exposure to Some Carcinogens of the IARC Classification

Exposure to Fibers, Silica, and Wood Dust

Fibers. ASBESTOS. Individualization of asbestos-related disease has been made since 1975. Specific preventive rules concerning asbestos have been promulgated since 1976, with progressive interdiction of materials containing asbestos, and elaboration of health and safety procedures in order to control exposure. All regulations were in agreement with directives from the European Union. Exposed workers are included in a special medical survey conducted during and after exposure and based on biannual chest X-ray and spirometry. As in other countries, however, those rules have been difficult to apply in small plants and among end users. A complete banishment (with an exception list) of new manufactured products containing asbestos was applied in France in 1997. However, exposure resulting from in-place asbestos will still be a major problem for some decades. New threshold limit values were proposed for 1997: 0.1 fibers/ml/hr. A recent analysis of the French situation was conducted at the request of our national health research institute, INSERM. It was estimated that, in 1996, more than 700 patients with mesothelioma and 1250 patients with lung cancer related to occupational exposure

would die (41). Those figures represent the consequences of exposure before 1976 because of the long latency period of respiratory cancers. During 1995, only 554 new cases of all asbestos-related diseases were compensated, including 171 asbestos, 272 nonmalignant pleural diseases, 77 mesothelioma (mainly pleural), and 21 lung cancers (42). But it was not possible to predict the expected number of cases resulting from more recent exposure because of insufficient data on the number of exposed subjects and the levels of exposure in the last 20 years. It is estimated that between 1 and 10% of active workers have been exposed, at least occasionally, during the last 20 years. Figures such as those presented by Peto et al. (43) for England are also possible. The French cancer registries have estimated an increasing incidence of mesothelioma of 25% each 3 years from 1985 to 1995 (44). This is in accordance with the French ongoing multicenter mesothelioma case-control study, in which more than 70% of cases had occupational asbestos exposures, essentially among end users such as those in building industries (4,45).

OTHER FIBERS. Mineral and synthetic fibers, especially mineral wools, are also widely used in France. Most of the data on fibers have been obtained in experimental models, either in chronic oncogenic experiments or in biopersistence *in vivo* experiments. International meetings have recently presented new data that suggest that fine and long biopersistent fibers such as ceramic fibers were associated with a significant risk of mesothelioma, fibrosis, and lung cancer in rodents. Moreover, those data are of utmost importance in producing new fibers with fewer potential biologic effects. No specific data are available for France, as French plants were not involved in the European follow-up until recently. Since 1995, the French Ministry of Labour has recommended a threshold limit value of 1.5 f/ml (1 fiber in 1997) for mineral wools and 1 f/ml (0.6 f/ml in 1997) for ceramic fibers.

Silica. Silica exposure in the occupational environment is extremely frequent (46). Mines and quarries are exposed workplaces that employed nearly half a million persons in France after War World II. Today this population is restricted to less than 30,000 workers. Specific health and safety regulations are involved in this sector, including a threshold limit value for occupational exposure to free silica at 0.25 mg/m³ for a pure crystalline silica aerosol. A special medical survey is conducted during and

after the period of activity, based on chest X-ray (lecture according to International Labour Organisation classification) and spirometry. Silicosis is an occupational disease that can include some nonmalignant complications. Lung cancer occurring within a silicosis is not presently compensated. In 1994, 28,000 workers still alive were compensated, with only 331 new cases for 1994. Iron mines workers had only 438 workers compensated in 1994. Siderosis is also compensated with more than 1,000 prevalent cases and 36 new cases in 1994 (47). Lung cancer can be compensated as a complication of siderosis in France.

Apart from extractive industries, silica exposure is frequent, mainly in building industries that include tunneling, ceramic production, abrasive production, and glass manufacture. It is possible to give a precise number of workers involved based on identification by occupational physicians of subjects included in the special silica medical survey. Probably more than 1% of active workers are involved. Organization of preventive strategies is slightly different from that of extractive industries, with a threshold limit value of 0.1 mg/m³ for quartz. The medical survey is also based on annual chest X-ray and spirometry during and after exposure. The main sample of compensation exists in extraction industries; in 1993, 226 new cases of silicosis were compensated. There was a significant decrease from the 1980s (around 600 cases), but values have been stable since 1988 (42). This must be considered in the evaluation of a potential carcinogen risk.

Wood Dusts. Sinonasal cancers are well related to occupational exposure to wood dust, as recently reported in an important case-control study conducted in France from 1986 to 1988 (48). It was reported that risk was higher for hard wood and adenocarcinoma; all but 2 of the 82 male cases with adenocarcinoma were exposed. A 2-fold increase in risk was observed for squamous cell carcinoma. Moreover, another analysis of the same population has suggested an interaction with other chemicals such as formaldehyde, glues, and adhesives. As exposure to all those products is highly correlated, the exact model of this interaction could not be correctly described (49).

However, it is still difficult to assess precisely the number of exposed workers. Cases of sinonasal cancer among woodworkers are compensated as occupational diseases and the number of compensated cases during the past decade ranged

between 20 and 40 each year (42). Finally, recommendations were proposed to limit exposure to less than 3 mg/m³ of inhalable dusts in 1993 and less than 1 mg/m³ in 1997. Obligatory integration of ventilation/aspiration systems within the tool machines will certainly greatly contribute to reducing the level of exposure.

Exposure to Metals Listed by IARC

In France, the reference to IARC lists of carcinogens, in terms of metals and compounds and workplace regulations, is mitigated by the fundamental European Directive 90/394/EEC on *Carcinogens at the Workplace*, defining carcinogens through European Directive 67/548/EEC and its annex I (50,51). The latter is a list of precisely defined carcinogenic substances [carcinogens category 1 (proven for humans) and category 2 (probable for humans)]. This leads to a significant difference between IARC and EEC lists through the introduction of the speciation concept. IARC lists (15) in its overall evaluation a metal and its compounds, whereas European Directive 67/548 lists some precise metal compounds and possibly the metal itself (51). All metals and compounds listed as carcinogens are indeed carcinogenic, most of them only by inhalation. (Risk phrase R 49 is "may cause cancer by inhalation.")

Prevention of occupational cancers in relation to metals and related compounds must take into consideration the unique characteristic that metals, as elements, are ubiquitous in the workplace atmosphere or ambient air and can be quantified as a background exposure. This leads to the question in the course of the regulatory risk assessment process of the definition of a *de minimis* level, or action level above which the prevention should really apply.

In addition to designation of a metal or some of its compounds as carcinogenic at the workplace, certain processes can be also classified/designated as potentially carcinogenic for humans. This is the case of some nickel-refining steps (listed as such in Annex I to European Directive 90/394) (50) or aluminium production, underground hematite mining with exposure to radon, or iron and steel founding, where sometimes the quoted metal is not directly concerned as the causal agent. For instance, in the case of aluminium production and iron and steel founding, the causal agents are polyaromatic hydrocarbons.

Another characteristic of metals in terms of possible carcinogenicity is that

often, if not in most of the situations, they are present at the workplace in a nondispersible form (i.e., massive form) that eliminates naturally all possibilities of significant exposures by inhalation.

Some Occupation-Related Cancer in the Chemical Industry

The prevention of occupation-related cancers in the chemical industry is based essentially on the principles outlined in European Directive 90/394/EEC (50). The evaluation of the real danger is the key element to this approach, a strategy founded on well-understood methods used in industrial health and safety:

- Hazard evaluation, i.e., the presence of either carcinogens as defined in Annex 1 of the EEC Directive 67/548/EEC (51) (categories 1 and 2) or intermediates (short duration) used in a fabrication process and defined as being carcinogenic according to the same criteria;
- Risk evaluation, i.e., demonstrating the possibility of exposure to carcinogens. This evaluation is based on a study of the process in question and any possible contacts with such substances, including measurements of their atmospheric concentrations and biologic monitoring when possible (i.e., when the measurement of a compound or one of its representative metabolites can be performed with sufficient specificity and sensitivity); and
- Risk management, i.e., after an initial analysis at the workplace, a sampling strategy is developed using a study of the probability of exceeding the reference values (either published limit values or values specific to the enterprise at hand when no published limits are available). In the case of substances still in a preindustrial research/development stage, it is necessary to use a strategy that uses confinement grading techniques. These techniques are based on the results of a rapid toxicologic screening test using alternative methods, on the foreseeable duration and intensity of the exposure, and on the physical and chemical properties of the chemical involved. Medical and biologic monitoring (search for reversible adverse effects) are conducted simultaneously.

Risk evaluation and risk management are both supported by information from workers and managers. Their active cooperation is always encouraged because an efficient prevention system needs the participation of the actors (i.e., involved

people). Some examples may illustrate this prevention in the field of risk assessment, risk management, and health surveillance.

- Benzene: occupational exposure to benzene is regulated using blood cell counts. In earlier prevention efforts, nonmandatory biologic monitoring was developed in cooperation with the INRS, with *trans-trans*-muconic acid in urine as provisional biomonitoring.
- Aromatic amines: the French regulation includes nonspecific research of free amines in urine by colorimetric method; dosage of transaminases (alanine-aminotransferase and aspartate-aminotransferase) for suspected hepatotoxic substances; and cytologic examination and research of blood in urine. With the accuracy of analytic methods and on a voluntary basis, we promote identification and dosage of the amine itself and its identified metabolites as early indicators of exposure, especially in the case of skin penetration.
- Vinyl chloride: existing regulation is based on an exposure limit in the workplace. This evaluation is completed with a clinical surveillance twice a year. From a consensus conference, transaminases, alkaline phosphates, blood cell count (once a year), and hepatic vessels echography (every 2 years) were added. In a prospective study, carcinogenic biomarkers are being investigated.
- Bischloromethylether: based on air monitoring, this surveillance is completed by some occupational physicians who have developed lung cell microscopic studies.

Prevention of Occupational Cancer

The French Framework

Following the historical development of the French legislation, several organizations are involved in the prevention of occupational cancer, including state authorities, the Social Security Organisation, companies, and trade or private organizations.

State Authorities. The Labour Ministry prepares and implements the labor legislation, and supervises its application, particularly in the fields of occupational health and safety and working conditions. In so doing, the main activities of this ministry are *a*) to prepare the work of the Superior Council for the Prevention of Occupational Risks to draw up regulations and to develop preventive policies; *b*) to supervise the National

Agency for the Improvement of Working Conditions, to help companies, trade organizations trade unions, and educational organizations improve working conditions. Consequently, this agency is involved in collecting and providing relevant information, producing guides and analytic and teaching aids, and undertaking or sponsoring studies or pilot projects; and *c*) coordinating and promoting the activities of the Labour Inspectorate. The labor inspectors are responsible for enforcing the relevant legislation and regulations. They perform investigations following serious accidents. They also provide information and advice to employers and employees. In addition, the labor inspectors must work with the labor medical inspectors to ensure that the legislation relating to occupational hygiene and health protection at work is properly observed, and to supervise the activities of occupational physicians.

The Social Security Organisation. The Social Security Organisation includes the National Health Insurance Fund for Salaried Workers (CNAMTS), the CRAMs, and the INRS (52,53).

The activities of the CRAMs involve analysis of present or potential occupational risks based on visits, tests, complaints, or requests from various sources, and statistics. These activities are performed within the framework of the general prevention policy developed in conjunction with the CNAMTS.

The INRS is involved in research in the various fields of occupational risks (animal toxicology, biologic monitoring, exposure measurements, epidemiology, psychology, ergonomics, physiology, electronic systems and machineries, and exposure to chemicals, noise, heat, vibration, lighting), and training, information and assistance to CRAMs, occupational physicians, and the Health, Safety and Working Conditions Committee (CHSCT).

This organization also includes the National Technical Committees and the Regional Technical Committees (managers and employers, representatives). These committees are specific to different economic sectors.

Companies. The plant manager has the authority and resources to determine work procedures and to choose equipment that ensures safety in the workplace. He may be assisted by a safety department.

The occupational physician is in charge of clinical examinations for workers and advising the manager, employees,

and their representatives on any problem relating to occupational hygiene and working conditions.

The main organization involving employees in the management of prevention is the CHSCT in factories having more than 50 employees. This committee is chaired by the manager and comprises employee representatives, the occupational physician, and the safety department.

Trade or Private Organizations.

Organizations specific to certain economic sectors provide relevant information or technical advice on the prevention of occupational risk and perform regular measurements on exposure in workplaces (e.g., chemical exposure, noise, lighting).

General Rules

Specific Provisions. Following the European Directive 90/394/EEC (50) of June 1990, Decree no. 92-1261 (54) concerning the prevention of chemical hazards, specific provisions were included in the French Labour Code on the prevention of occupational cancer risks. These provisions apply to all substances or preparations defined as carcinogenic category 1 (proven for humans) and category 2 (probable for humans) through the European Directive 67/548/EEC and its annex I (50,51). Such products shall be labeled carcinogens. In addition, a government order defined the following processes as producing carcinogenic agents: manufacture of auramine; work involving exposure to polycyclic aromatic hydrocarbons present in coal soot, tar, pitch, fumes, or dust; work involving exposure to dusts, fumes, and sprays produced during the roasting and electro-refining of cupro-nickel mattes; and the strong acid process in the manufacture of isopropyl alcohol.

In all plants where such products or processes are used, Decree no. 92-1261 (54) requires the employer to implement technical and medical prevention measures and to provide adequate information and training.

Technical Measures. In addition to specific provisions, technical measures must be applied: *a*) the employer shall regularly assess the nature, level, and duration of exposure, taking all exposure routes (inhalation, ingestion, percutaneous penetration) into account; *b*) the employer shall reduce to a minimum the use of carcinogenic agents, in particular by replacing them with less dangerous products or processes; *c*) the employer

shall reduce to a minimum the duration of exposure and the number of exposed workers; and *d*) the employer shall provide the necessary protective equipment and keep it in good condition.

Medical Examination. Before being employed in a workplace where exposure to carcinogens is likely to occur, each worker must undergo an ad hoc medical examination by the occupational physician of the plant. This examination shall be performed every 6 months. For each worker, a medical record shall be set up and archived, indicating a description of the work, the duration of exposure, and the results of clinical and biologic examinations. This record is to be archived for at least 40 years after the end of exposure. If the worker moves to another company, the medical record relating to occupational exposure is transmitted to the occupational physician.

Training and Information. The employer shall organize appropriate safety training for workers exposed to cancer risks with the advice of occupational physicians and CHSCT. The employer shall also inform the workers, the occupational physician, the members of the CHSCT, and the competent health and safety inspectors of the hazards associated with the products used, the work organization, the incidents that have occurred, and the safety measures that have been implemented. In particular, the employer shall ensure that all products are adequately labeled.

Restriction and Prohibition of Use. Decree no. 89-593 (55) following European Directive 88/364/EEC (56) prohibited the production and use (except for research, scientific analysis, or disposal purposes) of preparations containing more than 0.1 % (weight percentage) of four carcinogenic substances (55).

Other provisions prohibit the appointment of different categories of workers (workers under a fixed-term contract of employment, temporary workers, young workers) for certain jobs (e.g., asbestos work).

When workers have to carry out tasks on the premises of another company and when those tasks involve possible exposure to carcinogenic agents, both employers must jointly draw up a written prevention plan before work starts.

Special Regulation Applicable to Certain Products. This concerns the use of X-rays, arsenic, benzene, asbestos, vinyl chloride, and ionizing radiations. All such products require particular technical measures,

work organization measures, ambient air monitoring, medical surveillance, training, and information.

Compensation for Occupational Cancer

One of the aims of the Social Security system set up in 1945 was to protect employees and their families against all risks likely to impair or deprive them of their abilities at work. Thereafter, compensation for industrial accidents and occupational diseases became a part of the system (57). The Social Security funds are responsible for the management of industrial accidents and occupational diseases. Furthermore, the employers are responsible for financing these damages through a tariff system using contribution rates varying according to the number and seriousness of accidents or diseases.

Methods for Identifying Occupational Cancers

The primary method used to identify occupational cancers is the procedure in the Tables of Occupational Diseases (Tableaux de Maladies Professionnelles) (58-60). A patient with cancer can be identified and compensated for occupational disease if the following conditions are fulfilled:

- The disease is formally listed in the table.
- The subject has participated in one of the occupational activities mentioned in the table. (The lists of activities given in tables may not be exhaustive.)
- There is a delay in compensation, i.e., time elapsed between the end of the exposure of interest and the date of the diagnosis of the disease. (This delay can be up to 50 years for certain types of cancer.)

Any French physician, occupational physician, or medical practitioner, with the agreement of the patient, has to report cancer cases that meet these requirements.

An additional procedure is planned for the recognition of cancer cases when all requirements of the table are not met completely, through the expertise of the Regional Committee for the Recognition of Occupational Diseases (61).

Postprofessional Follow-Up

In addition to these regulations, the post-professional follow-up procedure was set up in 1993 (54). This consists of health surveillance of workers after their occupational exposures to carcinogenic risk or

processes (61). This follow-up is made by physicians, occupational physicians, or medical practitioners for all workers who provide a certificate of exposure written by the manager and the occupational physician of the activity of interest.

Occupational Cancers Deserving Compensation

The tables concerning lung cancer are related to exposure to asbestos, arsenic dusts and vapors, bischloromethylether, coal tars and oils, coal tar pitch, soot, chromic acid, chromates, roasting of nickel matte, ionizing radiation, and iron oxide dust in iron ore mining (lung cancer with siderosis) (58–60).

The tables concerning other cancer are (58–60) bladder (exposure to *N*-nitrosobutylamine, aromatic amines, coal tars and oils, coal tar pitch, and soot), nose and sinuses (exposure to wood dust and to roasting of nickel matte), pleural mesothelioma (exposure to asbestos), leukemia (exposure to ionizing radiation and benzene exposure), sarcoma (exposure to ionizing radiation), angiosarcoma of the liver (exposure to vinyl chloride), and skin (exposure to coal tars and oils, coal tar pitch, soot, and mineral oils).

Number of Compensated Cancer Cases

Despite the great number of the above-mentioned occupational cancer tables, the number of compensated cases remains low compared to the size of the French population. The number of compensated cancer cases has been rising from about 50 compensated cases per year in the 1970s to about 150 to 200 cases during the 1990s (62,63). About 50% of compensated cases in the 1990s are due to asbestos (84 mesothelioma and 33 lung cancer in 1994) (64). According to the published estimates suggesting that about 4% of all cancer cases could be attributable to occupational exposure (65), the number of occupational cancer cases deserving compensation would be approximately 7,000 each year in France (62,63).

This suggests an underestimation of cancer cases attributable to occupational exposures. Several factors may be responsible for this underestimation: *a*) the relative importance of lifestyle and occupational factors is difficult to assess at an individual level (e.g., smoking and occupation for lung cancer), *b*) interactions between occupational factors, *c*) time elapsed between first exposure and cancer diagnosis, *d*) past

exposure difficult to assess, mainly because of industrial processes no longer performed, and *e*) lack of knowledge by medical practitioners on occupational exposure for diagnoses after retirement.

Roles of Occupational Physicians and Medical Practitioners

Occupational physicians and medical practitioners have important roles in both prevention and compensation of occupational cancer. Although detailed descriptions are given in previous sections of this article, some activities of occupational physicians and medical practitioners must be emphasized:

- The occupational physician is the manager's adviser. He contributes to the assessment of the carcinogenic hazards in the company (15) and to the research for alternative noncarcinogenic products or processes. When a carcinogenic agent has to be used, he provides advice to decrease the number of exposed workers, exposure levels, and duration.
- The occupational physician is involved in providing information and training to workers about cancer prevention, with emphasis on the efficiency of collective protection as opposed to individual protection; the synergy between occupational and nonoccupational carcinogens (e.g., smoking and asbestos exposure); and the selection, appropriate use, and maintenance of personal protective equipment.
- Regarding compensation, the occupational physician has a role for the detection of occupational cancer that may occur after retirement. First, he has to draw up the certificate of exposure with the manager. Second, he has to supply the future retiree with relevant advice and data that could be useful for the medical practitioner who will follow him after the worker retires.
- Thus, the medical practitioner will use this information for the surveillance of such workers.

In addition, regarding research and the detection of new risks of occupational cancer, occupational physicians and medical practitioners may observe similar cancer diagnoses, during short periods of time, that could be considered clusters. Such results could generate hypotheses for further formal epidemiologic and toxicologic studies that may detect occupational cancer risk.

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