

# Studies & Research

2013/2014





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Professor Didier Baptiste  
Scientific Director of INRS

## Editorial by the scientific Director

Every year, INRS proposes this roundup of the studies and research that it is conducting in favour of preventing occupational accidents and diseases. In order to take occupational safety and health forward, INRS's scientific and technical teams develop knowledge calling upon a variety of skills in engineering, toxicology, ergonomics, etc. that cover all occupational risks, be they chemical, physical, psychosocial, mechanical, etc. Partnerships are also initiated with bodies (universities, CNRS, counterpart institutes) involved in the field of occupational safety and health both in France and abroad. Those partnerships are backed up by a dynamic policy of offering places for doctoral researchers. From the findings of all of that work, solutions and methods are then transposed into actions on training, information, and assistance that are disseminated widely among companies. At INRS, this marked complementary interplay between acquiring knowledge and making tools available is essential in responding to the needs out in the field, and in particular in reaching out to OSH experts.

In 2013, our studies and research have contributed to developing new knowledge for identifying or characterising emerging risks that have deferred effects, or multi-factorial effects, etc.

For instance, the growth in the use of nanomaterials in various industrial sectors is a topic on which INRS has been focusing efforts for several years now, with the aim of providing answers to questions about the health risks for workers, and the means of preventing those risks. Even though the initial results of studies have shown that conventional protection systems used for aerosols (fume cupboards, respiratory protective equipment) make it possible to reduce exposure satisfactorily, the major technological innovation potential and the growth in applications mean that manufactured nanomaterials remain a research priority for INRS for the next five years. On 4 October 2013, in the presence of personalities from the scientific and socioeconomic world, INRS inaugurated its nano research centre (Pôle de recherche nano). It has in particular a whole range of resources for conducting studies on toxicity by inhalation, suspected to be the main contamination route in the working environment. Characterising nanoaerosols present at work stations is an important focus for that research centre. Instrumentation adapted to conducting such measurements is developing rapidly and requires fine characterisation of the performance of such new apparatus. Pôle Nano also

makes it possible to do work on collective protective equipment and on the effectiveness of respiratory personal protective equipment. Six studies are on-going on these subjects in 2014. INRS thus intends to contribute to taking knowledge in this field forward and to sharing it, e.g. through the European project NanoReg 2013-2017, on which about sixty bodies from 16 countries are working. A second large-scale collaboration, the project Nanogenotox (with 16 institutes from 11 European states) ended in February 2013 with a conference organised in Paris, the results of which will be incorporated into the OECD database for helping to assess the dangerousness of nanomaterials.

INRS is also taking part in the project NanoCen, for contributing to standardising activities relating to nanotechnologies and nanomaterials.

In this scientific report, you will find other focuses of attention, such as research devoted to chemical risks, such research accounting for over 30% of our activities. INRS also develops devices and methods for combating mechanical risks, for acting upstream in workplace design, for reducing psychosocial risks, for progressing with prevention of disorders of the limbs and of the back, etc., of which, I hope, the following pages will give you a better picture.

Finally, this 2013-2014 report is marked by a slightly revamped graphical design serving contents that are, as always, hinged around the topics of our strategic plan, and our issues and stakes in research for occupational safety and health.

I hope you enjoy the read.



## The Scientific Executive

The Scientific Executive's remit is to lead and co-ordinate the study and research activities of INRS, and to analyse the trends and developments that might have impacts on the occupational health and safety environment. It develops European and international scientific partnerships.

**Contact:** [ds@inrs.fr](mailto:ds@inrs.fr)





## The INRS Scientific Commission

INRS has an independent scientific commission which appraises its scientific and technical work. This Scientific Commission is responsible for assessing the relevance and the validity of the studies and research the Institute conducts. It comprises individuals who are highly skilled and acknowledged experts in the disciplinary areas of INRS. The members of the Scientific Commission accompany each new operation and monitor its progress through to closure, in close collaboration with the Institute's specialists. Its members are voted in by the Board of Directors for a term of four years. The Chairperson and the Vice-Chairpersons of the Scientific Commission give their opinions to the Board.

### Chairperson

<b>Dominique CHOUDAT</b>	Groupe Hospitalier Cochin. Service de Pathologies Professionnelles Université Paris-Descartes, Paris (75).
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### Vice-Chairpersons

<b>Denis BOULAUD</b>	Institut de Radioprotection et de Sûreté Nucléaire (IRSN). Direction Environnement et Intervention, Le Vesinet (78).
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### Other members

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<b>Christine CHAUVIN-BLOTTIAUX</b>	Université Bretagne-Sud. Centre de Recherche en Psychologie, Cognition et Communication (CRPCC), Lorient (56).
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<b>Alain DEGIOVANNI</b>	École Nationale Supérieure d'Électricité et de Mécanique (ENSEM). Laboratoire d'Énergétique et de Mécanique Théorique et Appliquée (LEMETA), Vandœuvre-lès-Nancy (54).
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<b>Daniel EILSTEIN</b>	Institut de Veille Sanitaire (InVS), Saint-Maurice (94).
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<b>Nadine GABAS</b>	École Nationale Supérieure des Ingénieurs en Arts Chimiques et Technologiques (ENSIACET), Toulouse (31).
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<b>Pascal GUENEL</b>	Institut National de la Santé et de la Recherche Médicale (INSERM). Centre de Recherche en Épidémiologie et Santé des Populations (CESP), Villejuif (94).
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<b>Pascal UGHETTO</b>	Université Paris-Est. Laboratoire Territoires, Techniques et Sociétés (LATTS). Marne-la-Vallée (77).
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<b>David VERNEZ</b>	Institut Universitaire Romand de Santé au Travail. Lausanne (Switzerland).
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<b>Elisabete WEIDERPASS VAINIO</b>	Cancer Registry of Norway. Institute of Population Based Cancer Research. Oslo (Norway).
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## Follow-up Groups

To cover the range of disciplines present at INRS, the Scientific Commission has recourse to subcommissions, termed follow-up groups. There are six of them, and each group is linked, by area of competence, to a particular scientific and technical division (see the following presentation) of the INRS Lorraine Centre. For each study, these groups examine the aims, the approach followed, the results, and the anticipated or achieved outcomes. Their members meet at INRS every year for two days to analyse the study reports, to exchange with the researchers and to draft their assessment report.

### Members of the Occupational Epidemiology Follow-up Group

Alain BERGERET	Institut Universitaire de Médecine du Travail. Institut Pierre-Mazel Université Claude-Bernard. Lyon (69).
Dominique CHOUDAT	Groupe Hospitalier Cochin. Service de Pathologies Professionnelles Université Paris-Descartes. Paris (75).
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### Members of the Working Life Follow-up Group

Emmanuel ABORD DE CHATILLON	Institut d'Administration des Entreprises de l'Université Pierre-Mendès-France. Grenoble (38).
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Xavier CUNY	Honorary Professor at CNAM. Paris (75).
Alexis D'ESCATHA	AP-HP. Unité de Pathologie Professionnelle, de Santé au Travail et d'Insertion. Garches (92).
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Jean-Claude MOISDON	École des Mines. Paris (75).
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### Members of the Work Equipment Engineering Follow-up Group

Michel BERENGIER	Institut Français des Sciences et Technologies des Transports, de l'Aménagement et des Réseaux (IFSTTAR). Centre de Nantes. Bouguenais (44).
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Élodie FALCONNET	Centre Technique des Industries Mécaniques (CETIM). Senlis (60).
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### Members of the Toxicology and Biometrology Follow-up Group

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Robert GARNIER	Hôpital Fernand-Widal. Centre Anti-Poison. Paris (75).
Pascal GAUDUCHON	Groupe Régional d'Études sur le Cancer (GRECAN). Centre F. Baclesse. Caen (14).
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## Studies and Research Activities of INRS Divisions

In 2013, studies and research actions accounted for 42% of INRS activities. In 6 divisions and 23 laboratories at the Lorraine Centre, these activities are conducted by researchers, engineers, physicians, technicians, chemists, toxicologists, ergonomists, etc. These divisions total about 300 people.

### ■ Pollutants Metrology

This division works mainly on assessing occupational exposure to chemicals. It develops sampling and analysis methods, and disseminates them through the Metropol database. It conducts campaigns for measuring exposure to toxic substances in companies at risk, the data that is collected then being fed into the Colchic database.

#### > Laboratories

- Organic Analytical Chemistry
- Chemical Risk Characterisation
- Aerosol Inorganic Analysis and Characterisation Laboratory
- Aerosol Metrology

### ■ Process Engineering

This division studies exposure to chemicals or heat and promotes prevention solutions. It seeks the most appropriate solution by analysing the process causing the occupational exposure problem and by emphasizing emission reduction at source.

#### > Laboratories

- Chemical Risk Assessment
- Technological Applications for Risk Assessment
- Aerodynamics Engineering
- Pollutant and Air Cleaning Process

### ■ Toxicology and Biometrology

This division does applied research in toxicology, in the field of assessment of risks related to exposure to pollutants in the occupational environment. The two focuses for the research work are firstly biological monitoring of exposure and of the consequences of exposure in humans in working situations, and secondly measurement of the toxic effects on experimental systems.

#### > Laboratories

- Biometrology
- Atmospheres Generation and Toxicological Analytical Chemistry
- Carcinogenesis, Mutagenesis and Reprotoxicity
- Awareness Raising, Allergies and Clinical Biology
- Cutaneous Penetration, Kinetics and Metabolism
- Ototoxicity and Neurotoxicity

## ■ Work Equipment Engineering

The division is in charge of assessing and reducing physical risks related to work equipment, such as machinery (stationary or portable machines, tools, plant, etc.), safety components, premises (workshops, offices, etc.), and personal or collective protective equipment.

Physical risks are related to accident risks and to physical stressors such as noise, vibration, heat, optical or electromagnetic radiation, etc. This division aims to improve safety devices and equipment used in working life.

### > Laboratories

- Personal Protective Equipment
- Machinery
- Design Engineering of Safe Systems
- Safety of Automated Systems
- Modelling of Preventive Mechanical Systems
- Occupational Noise Reduction

## ■ Working Life

This division's objectives are to fit the working situation (task, tool, workstation, organisation, and environment) to the needs of the human operator (physical, physiological, mental, and social needs). The optimisation criteria for achieving this matching are operator safety, physical and mental health, and also efficiency, comfort, and work satisfaction, satisfying these criteria contributes to improving the safety and reliability of production and service systems.

### > Laboratories

- Ergonomics and Psychology Applied to Prevention
- Management and Organisation for Occupational Safety and Health
- Physiology - Movement -Work

## ■ Occupational Epidemiology

This division conducts epidemiological studies aimed at highlighting deteriorations in health due to occupational exposures. The studies carried out examine respiratory pathologies, peripheral nervous system perturbations, neuro-behavioural disorders, stress-related pathologies, and occupational cancers. They are made public and contribute to prevention-related decisions.



## Interview with



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Philippe Piéri,  
CNRS Centre-East  
Regional Delegate

Karl Tombre,  
Vice-President in charge  
of socioeconomic partnerships  
and international affairs  
at the University of Lorraine

The research work done by CNRS in France covers all fields, and, at the University of Lorraine, uses many different scientific skills. Of that research, which pieces can contribute to occupational risk prevention, which is what INRS does?

■ **M. Piéri:** CNRS is steered scientifically by 10 national theme-based institutes (9 of which are present in Lorraine). Across France, they cover all research fields: humanities and social sciences, biology, nuclear and particle physics, information science, engineering and systems, physics, mathematics, chemistry, Earth and universe sciences, and ecology and the environment. A large number of topics that INRS addresses nationally for preventing occupational accidents or occupational diseases resonate with this multi-disciplinary potential. We only need to scan through the 22 topics of your strategic plan to see this. By way of example, the research conducted at the CNRS “Institut de Physique” contains a focus devoted to nanoscience and nanotechnologies (nano-scale physics, new materials, self-organisation, etc.). This topic is also one of the priorities of your Institute which has recently designed a laboratory dedicated to assessing the risks of nanomaterials.

■ **M. Tombre:** As regards the University of Lorraine, which shares 20 research laboratories with CNRS, and as regards possible theme-based contributions lying within INRS’s sphere of action, the example of work conducted on the impact of the ageing of the population on economic and social sectors seems to me to be interesting to emphasize. What is true at the level of French society could apply to the working population. Aware of the challenges that companies, associations or local authorities have to take up in terms of industrial upheavals or societal transformations, the University of Lorraine develops innovation and has research teams with skills in chemistry, biology, physics, mechanics, etc.

CNRS, the University of Lorraine, and INRS have been working together for several years now. How will the framework agreement recently signed between our organisations develop our relations in terms of Studies & Research?

■ **M. Piéri:** In Lorraine, the CNRS has 33 operational research structures in which over 1,000 people are involved (researchers, engineers, and technicians). At regional level, their activity is coordinated firstly with higher education establishments - including the University of Lorraine with whom we share 20 joint research units - and secondly with public scientific establishments such as Inra (French National Institute for Agricultural Research), Inria (French National Institute for Research in Computer Science and Automation), Inserm (French National Institute for Medical and Health Research), the University’s Teaching Hospital, etc. Today, this rapprochement covers 98% of publically funded research in Lorraine. It offers an overall, consistent view of scientific and technological progress, with the aim of sharing knowledge and of joining forces. The framework agreement and the specific agreements resulting from it are part of this federative rationale.

■ **M. Tombre:** Indeed, our partnership enjoys a history of working together on topics relating to modelling pollution, acoustics and filtration – adsorption of pollutants. This agreement between the teams from INRS, from CNRS, and from the University of Lorraine will enable us to develop that work. As regards scientific action, one of the characteristics of the University of Lorraine is that it has 10 scientific centres, at which not only fundamental research is done but also research more directly related to socioeconomic issues. The University of Lorraine also enjoys close ties with industry, via its 10 engineering schools. These skills offer plenty of advantages for INRS whose purpose is to make methodological know-how and practical solutions available. This partnership agreement should put the spotlight on and offer greater visibility to our respective contributions, and make it possible, in Lorraine, to build gateways and bridges not only for research but also for technological innovations, and for higher education and training.

**What forms will the collaborations between our structures take? How will they participate in developing certain aspects of research & development or of training?**

■ **M. Piéri:** This collaboration with INRS will translate in practice by project teams being set up, generating inventive activity and the conditions under which the acquired knowledge can be shared. This partnership makes provisions for joint research, and for participation in European projects, in symposia, or in any action that aims to develop scientific and technical culture. And then we must not forget the equipment aspect and the mutual use of infrastructures. These collaborations foster sharing of facilities, which rationalises the use of resources and means. Finally, our organisations will come together on a steering committee that will meet once a year. In addition to the aspects relating to the state of progress of the work that will be raised at such meetings, that steering committee symbolises the will to consult one another and to work together.

■ **M. Tombre:** As regards education - and beyond the supervision of doctoral researchers that is encouraged by your Institute - the national system for referencing publically funded universities pays particular attention to developments in vocational courses. In this context, new training courses in occupational risk prevention could be deployed in the medium term in initial higher education syllabuses in Lorraine, based on INRS's expertise. Other actions relating to entrepreneurship could be implemented and transposed in order to raise the awareness among students more broadly of the issues of occupational safety and health. Finally, beyond our borders, the will to take part jointly in European calls for tenders is also a shared concern. Such pooling of our knowledge and know-how will work in favour of transferring knowledge to applications so that students (tomorrow's employees and managers), teachers, researchers and institutional or economic partners can appropriate it.



The Centre National de la Recherche Scientifique (France's National Scientific Research Centre, CNRS) is a publically funded research body, governed by the French Ministry for Higher Education and Research. With its 34,000 researchers, engineers, and technicians, CNRS is organised into 10 institutes that orchestrate its scientific policy, and 19 delegations that represent it in the regions of France. 1,053 laboratories are distributed across France, 95% of which are run in partnership. In Lorraine, CNRS comprises 33 operational research structures including 20 joint research units co-governed with the University of Lorraine.

The University of Lorraine is an establishment that groups together the following:

- > for training, component parts (faculties, schools, institutes) that are structured around 8 collegiums in the fields of science, health, technologies, engineering sciences, humanities and social sciences, law, economics, management, arts, letters and languages,
- > for research, 61 laboratories, including 33 with "équipe d'accueil" status receiving doctoral researchers, 28 joint research units (UMRs, "unités mixtes de recherche") co-governed with CNRS, Inra, Inria, and Inserm, 1 service and research unit, and 7 research federations.

In 2013, 52,478 students did initial training given by more than 3,700 teaching staff and teaching researchers.



## 2013 “Studies and Research” Annual Report

The studies & research activities conducted in 2013 break down mainly into 17 topics from among the 22 topics identified in INRS’s strategic plan for 2013-2017. These topics are defined on the basis of various types of entry: the type of risk in question (biological, chemical, etc.), the sector in which the risks appear (waste and recycling, road accident risks, etc.) or the type of effect in question (allergies, occupational cancers, musculoskeletal disorders, etc.).

A special case is the topic “Manufactured nanomaterials”, which, while being a subset of chemical risks, is the subject of specific developments.

In 2013, as in the preceding years, the topic “Chemical risks” predominates (31% of the studies & research activity). Then come the themes of “Manufactured nanomaterials” (9%), “Noise, vibration, electromagnetic fields, and optics” (8%), followed by “Multiple exposures: chemicals and noise” (6%).

The latter topic is a newly created one in the strategic plan. It covers, in particular, studies relating firstly to the combined noxious effects of exposures to noise and to solvents, previously coming under the topic “Noise, vibration, electromagnetic fields, and optics” and secondly to combinations of toxic chemicals, such studies previously lying within the topic of “Chemical Risks”.

In the following pages, the 26 studies that were completed by the end of 2013 are presented, as are the titles of the 87 studies in progress in 2014. Summaries of these completed studies are given by main topic to which they are related.

# Accidentology, and perception & acceptability of occupational risks

In 2012, the occupational accident rate reached a level of 35 occupational accidents with sick leave per 1000 employees. Employees aged under 30 represented 33.6% of the victims, with a rate of 55 occupational accidents per 1000, and they form a population who are particularly affected. Furthermore, employees of all ages with length of service of less than one year show an accident rate close to that of the under-30s, and constitute another strategic target for the actions of INRS.

One of the priorities of INRS in terms of accidentology is to incorporate safety as far upstream of working situations as possible, through systems for managing occupational safety and health, and through development of a prevention culture out in the companies.

The INRS studies & research activities on this topic follow two focuses:

- > Establishing new methods of understanding and of assessing accident risks.
- > Developing strategies for reducing the overly high accident rate of newly hired staff.

## Safety at work: case of accidents with movement disturbance (AMD)

**Sylvie LECLERCQ**

Working Life Division

### ■ Presentation of motives and aims

Slips, trips and other movement disturbances make up one third of work accidents involving time off work. This transversal study forms an ongoing part of the work initiated within the framework of the topic "Same level falls: case of balance disturbance in a work situation". The work carried out in the laboratory and in the field examined locomotion control in situations likely to lead to the occurrence of so-called same level accidents. Additionally, it involved characterizing recurring scenarios concerning this type of accident.

### ■ Approach

This transversal study included three areas of research falling within the scope of different disciplines, for which several methodologies were employed:

- > experimental study of disturbed locomotion conducted by means of a movement recording system.
- > psychoergonomic study of work situations likely to result in the occurrence of these accidents which exploited self-confrontation interviews based on video recordings of work situation activity.
- > extraction of recurring AMD scenarios using a probabilistic approach making use of accident cases represented by a logical combination of the facts having contributed to the occurrence of the movement disturbance.



## ■ Main results

The experimental work substantiated the hypothesis according to which the resources set aside for carrying out a task can, in some cases, be lacking in terms of movement control.

The psychoergonomic study showed that the operating procedure which determines the movements made in a work situation is chosen by operators from among a range of potential movements, the twin aim being to complete the task while ensuring the safety of their movements.

AMDs were modelled and, on the basis of this model, the specific accident factors present in a hospital setting were grouped and classified under relevant generic factors. Eight serious AMD scenarios were also identified from 143 accounts of serious accidents occurring in the civil engineering and construction sector and in the metallurgy sector. Specific features emerged in terms of generic factors or scenario according to the sector of activity.

The consideration given within the context of this study also led to:

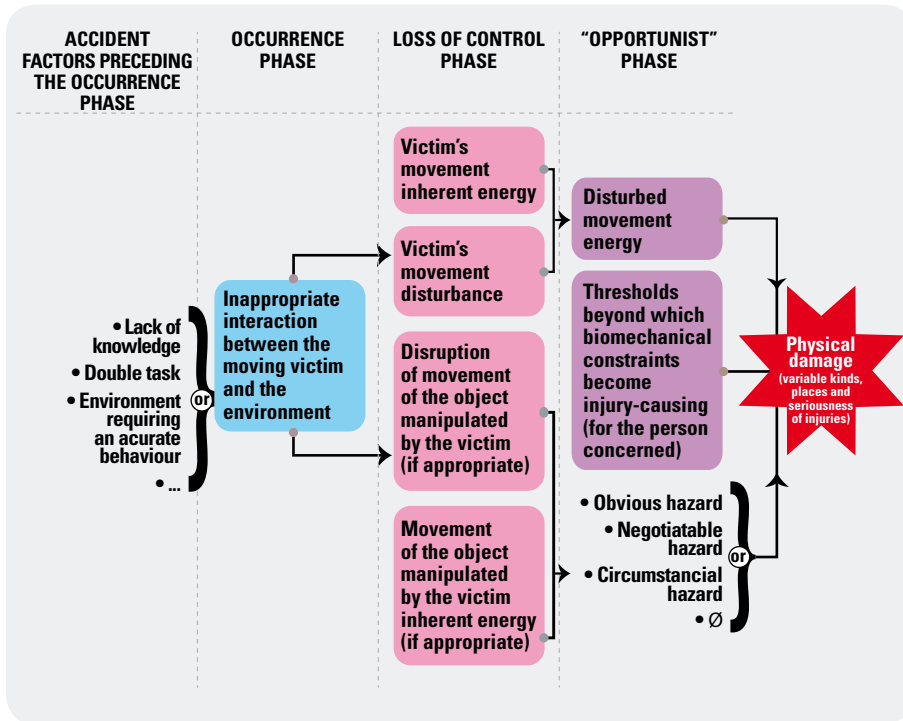
- > the operational definition of a set of accidents, coherent from the diversity of outward signs of risk point of view and the prevention point of view. This definition was matched with a terminological change: the use of the expression "accident with movement disturbance (AMD)" is aimed at changing the representations associated with this risk,
- > modelling AMDs,
- > formalising their closeness to other occupational risks that show up in work movements with a view to drawing prevention conclusions.

## ■ Discussion

The results are useful for encouraging a shift in view towards a set of accidents that conform more to the real diversity of AMDs, many of which are serious and which stem from the operation of a socio-technical system, making prevention no easy matter. Three points determining the structuring of future research within the context of preventing AMDs are discussed: the need to centre on several levels of work activity analysis, the interest of studying the controls made by employees to allow them to carry out their activity while guaranteeing their safety in relation to AMD risk, and, finally, the gap between a work situation resulting in an accident and one with no accident.



### Occupational accidents with movement disturbance model



As part of this topic, one study is underway in 2014

- Assessment of the impact of initial occupational safety and health training on the occurrence of work accidents among the under 30s

> Stéphanie BOINI and Michel GRZEBYK - Epidemiology in Enterprise Division

And other studies exploring this subject are mentioned under the following topics: "Psychosocial Risks", "Musculoskeletal disorders of the limbs and of the back", "Ageing, Staying in Work and Preventing Occupational Exclusion", and "Occupational Road Risk".



# Occupational allergies

The number of allergenic substances is high and constantly rising. Nearly 30% of the population would appear to be affected today, as against 10% in 1980. There are deemed to be more than 350 of them in the working world. Encountered in a multitude of different sectors (cleaning, baking & pastry, hairdressing, the waste sector, healthcare professions, the timber & wood-working industries, paints & painting, building & civil engineering, metallurgy, the agri-food industry, and farming), they cause disabling occupational pathologies such as occupational asthma and allergic dermatitis.

In the context of this topic, the studies & research activities are attached to the following focuses:

- > Developing tools for measuring exposure and effects so as to identify the risk substances better.
- > Identifying the determining factors that contribute to exposures to the allergy risk.

Although the essential prevention mode is not to expose workers to allergens, e.g. by substituting one substance for another, it very often happens that knowledge on the substitute substance is lacking in particular as to whether or not it is allergenic. In addition, every year, new molecules appear in industry. It is therefore of primary importance to have the capacity to test the allergenic potential of a chemical before it is used.

The immunological mechanisms involved in allergies are increasingly well understood but it is essential to transfer that knowledge to the working world and to have analysis techniques that are reliable, sensitive and specific, and easy to use.

## Development of an *in vitro* test to identify chemical sensitizers

**Fabrice BATAIS**

Toxicology and Biometry Division

**Related topic: Chemical Risks - knowledge of the exposures and tools for assessing the exposures**

### ■ Presentation of motives and aims

Occupational allergies caused by employee exposure to chemicals are an important occupational health issue. Currently, over 350 industrial substances have been identified as occupational allergens. The frequency of these pathologies and the consequences they may have on the health of workers requires identification of these substances so that they can be replaced by alternative products and/or labelled appropriately. Besides, European legislation relative to protecting animals used for scientific purposes (Directive n° 2010/63/EU) and the REACH system encourages limiting the use of laboratory animals for assessing chemicals. It is thus necessary to develop *in vitro* tests to substitute reglementary *in vivo* tests. The aim of this study was to develop a predictive *in vitro* test of the potential sensitisation of chemicals by using a cellular model developed during a previous study. To do this, 20 chemical substances were tested. The effect of these substances on the cellular model developed was assessed by previously selected activation markers and new markers tested in this study.



## ■ Approach

Dendritic cells derived from mouse bone marrow were exposed to 20 reference chemicals: 16 sensitizers and 4 non-sensitizers. Cell activation under the effect of these substances was assessed by measuring the increase in the expression of membrane markers as well as the increase in cytokine production. The results were compared to the LLNA test, a reference and reglementary *in vivo* test for testing sensitizing effect.

## ■ Main results

The results obtained show that the irritants and non-sensitizers tested did not activate the cells studied. All these substances were classified as “non-sensitizing” by the model developed in this study. Of the 16 sensitizers studied, nine substances are referenced as cutaneous sensitizers according to the LLNA classification. The cellular model developed during this study discriminated eight of the nine cutaneous sensitizers tested and classified these substances as a function of their sensitizing ability. Of the seven respiratory sensitizers studied, three caused strong cell activation.

## ■ Discussion

This study showed that the model based on dendritic cells derived from mouse bone marrow are of real interest for seeking a test to substitute the *in vivo* model for assessing sensitizing ability. In effect, it fulfils certain prerequisites required when developing *in vitro* models. In this regard, it is capable of discriminating sensitizers from non-sensitizers. It also allows for the classification of cutaneous sensitizers according to their sensitization potential in the same way as the LLNA test. Additionally, it is in agreement with certain clinical observations, notably for benzocaine, benzalkonium chloride and SDS, in contrast to the LLNA test. Nevertheless, this model does not distinguish between a cutaneous sensitizer and a respiratory sensitizer. The development of new models of co-culture between different cellular types could possibly achieve this objective.



Within this topic,  
four studies are in progress in 2014

- **Inflammation of the upper airways and microbiological exposure of composting plant workers: a longitudinal study**  
> Valérie DEMANGE and Michel GRZEBYK - Epidemiology in Enterprise Division
- **Severity and control of asthmas in relation to work**  
> Valérie DEMANGE and Anca RADAUCEANU - Epidemiology in Enterprise Division
- **Nickel and its compounds: review and characterisation of exposure**  
> Barbara SAVARY - Pollutant Metrology Division
- **Development of an *in vitro* co-culture model to assess the sensitizing potential of industrial substances**  
> Fabrice BATAIS and Isabelle SPONNE - Toxicology and Biometrology Division

And other studies exploring this subject are mentioned under the topics “Chemical Risks” and “Biological Risks”.

# Noise, vibration, electromagnetic fields, and optics

Noise and vibration have been the subject of recent regulatory changes and have been recognised as factors in severity of working conditions. Millions of employees are subjected to them. Electromagnetic waves affect 100,000 workers while the boom in new optical radiation applications would apparently be affecting millions of employees. Four European directives on these types of harm set action values and exposure limit values beyond which firms are required to reinforce prevention. For several years now, INRS has been developing knowledge so as to facilitate implementation of these preventive regulations.

## Noise

On this topic, the research work being conducted by INRS aims to improve methods of performing diagnostic surveys for and of locating sources of noise, and to study new acoustic materials and hearing protectors. Another focus for work is understanding and perception of messages in open-space or open-plan workplaces and the influence on worker hearing comfort or discomfort.

### Improving the intelligibility of useful signals in noise: application to open-plan offices

**Patrick CHEVRET**

Work Equipment Engineering Division

#### ■ Presentation of motives and aims

The number of employees working in open-plan offices is high and constantly increasing, notably as this flexible and economic arrangement rationalises the working area and facilitates both communication and teamwork. However, it is now accepted that the auditory discomfort linked to overheard conversations can have an impact on activity (loss of concentration, errors in executing tasks) or on employee health (general tiredness, auditory fatigue, discomfort or stress factors). The present study was intended to evaluate intelligibility in open-plan offices by means of dedicated indicators and to establish any relationship that may exist between auditory discomfort and the intelligibility of the noise experienced in these areas. On this latter point, a partnership with the Lyon Acoustics and Vibration Laboratory of INSA was entered into, with joint support of a thesis conducted at INRS.



### ■ Approach

From a bibliographic study carried out on the mechanisms that can influence the intelligibility of noise in open areas, it emerged that temporal ambient noise fluctuations are a key factor of intelligibility, but that the existing models are limited to stationary ambient noise, which is only one particular case of ambient sound. An operational system to measure intelligibility, based on this assumption of the stationary nature of noise, was nevertheless developed before being tested in enterprise. In addition, perceptive tests for the development of new intelligibility indicators were conceived to account for fluctuations in ambient noise. Finally, in the doctorate thesis, other tests sought to link different intelligibility indicators with auditory discomfort, both measured and experienced, in an open-plan office.

### ■ Main results

It was demonstrated that ambient noise modulations linked to the population density of the work area play a significant role in intelligibility. From this observation, a new intelligibility indicator was developed and was validated by the laboratory tests. In parallel, the results of the other tests conducted within the framework of the doctorate thesis showed that intelligibility is a descriptor insufficiently linked to performance and the discomfort experienced, and that it must therefore not be used alone to assess situations of sound discomfort directly.

### ■ Discussion

Even if the new indicator developed constitutes progress in assessing auditory discomfort in open-plan offices, the fact that its link with the discomfort experienced could not be significantly demonstrated does raise the question of its improvement as well as its subjective assessment. Concerning the first point, the main avenue to explore is linked to the spatial distribution of the sound sources in the open-plan office, a distribution that depends mainly on the position of the people around the discomforted employee. Regarding the subjective assessment of the auditory discomfort, if further progress is to be made, it should examine the consequences of long-duration exposure as the tests conducted in the laboratory, limited in time, only allowed to measure a weak immediate discomfort. To do this would require the implementation of an approach relying on both long-duration laboratory tests and field surveys.



## Personal protection against noise: a review of in-situ methods to measure the real and personal efficiency of hearing protectors

Nicolas TROMPETTE, Alain KUSY

Work Equipment Engineering Division

### ■ Presentation of motives and aims

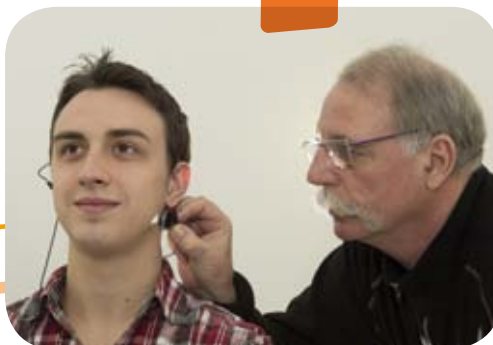
It is now accepted that the acoustic attenuation measured in laboratories and affixed by manufacturers on hearing protection devices (HPD) is overestimated. Employers choosing hearing protection for their employees on the basis of these manufacturers' data can therefore put the hearing of those exposed in peril. To respond to this problem, manufacturers are beginning to propose different measurement systems and methods allowing for an *in situ* estimation of the real individual attenuation provided by HPD. The aim of the study was to assess the performance and limits of these new systems.

### ■ Approach

The methodology consisted in identifying the main methods used to individually assess the efficiency of hearing protection and the systems available on the market based on these methods. Four currently available systems were acquired and analysed. Assessing their efficiency consisted in comparing the results of these systems to reference measurements obtained from both the standardised method used for certification purposes and another standardized method used to assess sound exposure in the field, including protective devices. The comparison, on eight protection devices and with the assistance of 20 subjects, was firstly made as a mean value to check the validity of the results, then individually to evaluate the accuracy.

### ■ Main results

Out of four systems dedicated to determining the in-situ personal acoustic damping of HPD, namely SVANTEK SV102, E-A-Rfit, CAPA and VeriPRO, only the first three were validated. These systems employ three different methods: F-MIRE (for in-situ measurement in the ear canal) for the first two, audiometry for the third, and sound balancing for the fourth. The mean attenuation obtained with the E-A-Rfit, SVANTEK and CAPA systems were very closely correlated with the reference values and can therefore be considered as valid. Individual comparisons lead to satisfactory uncertainties for the SVANTEK system dedicated to earmuffs. By contrast, for the two other systems, namely E-A-Rfit and CAPA dedicated to earplugs, high discrepancies were observed. These two systems declare an uncertainty of 7 dB whereas the results of this study show an uncertainty of about 10 dB.



Therefore, these methods would appear well suited to this type of measurement as long as a large uncertainty is considered. Lastly, the VeriPRO system, which uses the method of sound balance between the two ears, is unusable in its present state.

## ■ Discussion

Three of the four systems tested are validated and can be used to check the in-situ, personal attenuation provided by hearing protectors. These systems can now be recommended to prevention specialists for assessing the individual hearing protection of employees. The results of the study will be exploited mainly by publications and presentations to different audiences (ministry of labour, standardisation specialists, scientists, prevention specialists in companies, and occupational physicians). It is also planned in future work to improve the precision of these methods when applied to earplugs.



Within this topic of "noise",  
three studies are in progress in 2014

### ■ **Characterisation of the acoustic properties of complex panels and influence on noise in industrial premises**

> Jacques CHATILLON - Work Equipment Engineering Division

### ■ **Acoustic holography techniques to characterize noisy industrial machinery**

> Armand NEJADE - Work Equipment Engineering Division

### ■ **Perception of useful acoustic signals in noise**

> Jean-Pierre ARZ - Work Equipment Engineering Division





## Vibration

Exposure to vibration can, in the long-term, cause not only musculoskeletal but also vascular and neurological occupational diseases. In order to contribute to preventing them, INRS is developing tools for assisting in measurement-free assessment (calculator, database, etc.).

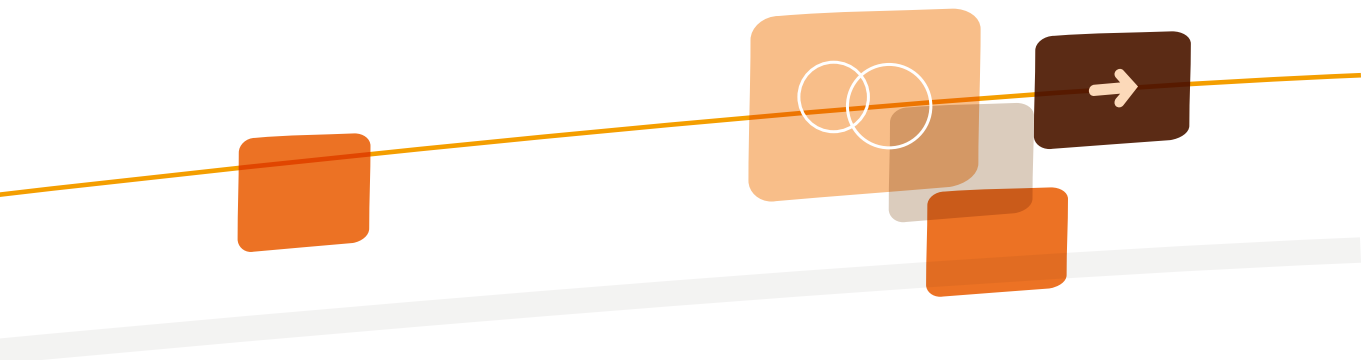
In order to deepen knowledge in the field of hand-arm vibration, INRS is developing actions for modelling and for experimental characterising of propagation of vibration emitted by handheld machinery.

As regards overall body vibration, exposure to which led to 488 cases of chronic low back disorder (a recognised occupational disease) in 2012, work on taking account of co-factors (efforts, posture) is focusing on developing knowledge about this co-exposure at the driver stations of vibrating mobile plant or vehicles.



Within this topic of “vibration”, four studies are in progress in 2014

- **Experimental modelling and characterisation of mechanical vibration propagation in the upper limbs when using machinery**  
 > Christophe NOËL - Work Equipment Engineering Division
- **Development of a tool for implementing the “Vibration” decree for operators of hand-held vibrating machinery**  
 > Éric CARUEL and Patrice DONATI - Work Equipment Engineering Division
- **Mapping static and dynamic postures among seated operators of vibrating mobile plant**  
 > Maël AMARI - Work Equipment Engineering Division
- **Modelling vascular remodelling phenomena subsequent to vibratory exposure of the hand-arm system**  
 > Pierre LEMERLE - Work Equipment Engineering Division





# Electromagnetic fields and optical radiation

As regards electromagnetic fields, populations are exposed due to occupational and domestic applications using the properties of electromagnetic waves and fields. We need to assess the real exposures, to characterise the sources, to identify the prevention means, to develop technical solutions for reducing the exposures, and to raise awareness in users.

In the field of optical radiation, studies are continuing to define a methodology for assessing risks *in situ* and for assessing protective means. Others aim to accompany implementation of the decree on protecting workers from the risks due to artificial optical radiation.

## Proposal of a measurement method of the optical radiation applied to the workplace

**Annick BARLIER-SALSI**

Work Equipment Engineering Division

### ■ Presentation of motives and aims

So as to have available a simple methodology to measure optical radiation *in situ*, within the framework of European Directive 2006/25/EC and Decree N° 2010-750 of the 2nd of July 2010, INRS conducted a study between 2006 and 2008 which highlighted that CCD spectroradiometers (measurements between 200 and 1100 nm) had high errors due to stray light. Among the methods proposed in the bibliography to reduce the error attributable to stray light, that developed by the NIST (National Institute of Standards and Technology) is now most often referenced in the literature. It consists in constructing a correction matrix based on the lines (about 80) emitted by tuneable lasers. However, the hardware required to employ this method is considerable, and the associated costs are high. The main aim of this study was therefore to reproduce this methodology by producing lines from a monochromator available to the INRS laboratory. However, the initial results resulted in our experimenting with another simplified solution based on nine low-power lasers. A second phase of the study was intended to assess the performance of an infrared photodiode spectroradiometer with a view to proposing a methodology to measure the entire ultraviolet, visible and infrared spectrum.

### ■ Approach

First, the correction matrix of the two CCD spectroradiometers was constructed from a monochromator, and from nine lasers, the missing lines being obtained by interpolation/extrapolation. The measurements on the variable characteristic spectrum sources were corrected by the matrix and then compared to the measurements recorded with the scanning spectroradiometer belonging to the laboratory, which was taken as the reference. The performance of the infrared spectroradiometer was also assessed by comparing it to the reference spectroradiometer.



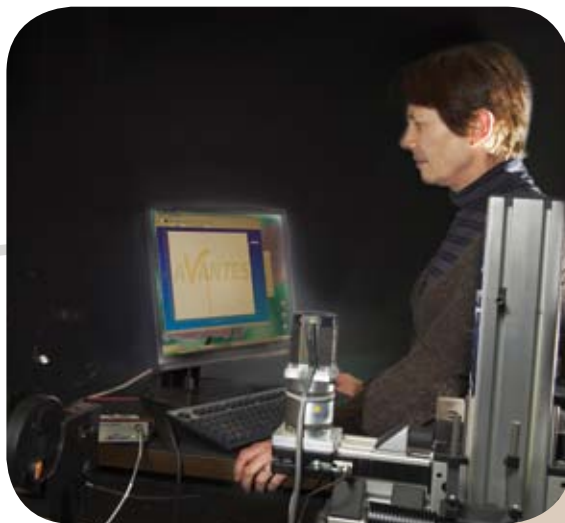


## ■ Main results

The correction matrix constructed from the monochromator was unsatisfactory owing to a lack of output signal. By contrast, that constructed on the basis of lasers allowed for the correction of stray light, in particular, as well as a closer match with the signal measured by the reference spectroradiometer. One of the spectroradiometers had better correction behaviour than the other due to its better sensitivity in ultraviolet. Concerning the infrared spectroradiometers, the maximum errors recorded compared to the reference measurements were below 10%.

## ■ Discussion

This study highlighted that it was possible to reduce the stray light of spectroradiometers by a factor of between 10 and 100 by using only nine lasers to construct the correction matrix. The results are in the same range of values as those obtained by NIST. Spectroradiometers used *in situ* should, however, be very sensitive in ultraviolet. An interface taking correction of the measurement acquisition signal into account will be developed so that the Physical Measurement Centres have an easy-to-use tool available whose results can be used directly in CatRayon for risk assessment.



As part of this topic,  
two other studies are underway in 2014

- **Assistance in implementing the “Electromagnetic Fields” European directive for operators of radiating machinery**  
> Philippe DEMARET and Patrice DONATI - Work Equipment Engineering Division
- **Tool to accompany the implementation of Decree 2010-750 of the 2<sup>nd</sup> of July 2010 relative to “protecting workers against risks due to artificial optical radiation”**  
> Annick BARLIER-SALSI - Work Equipment Engineering Division

# Design of work equipment, workplaces, and working situations

Beyond compliance with regulatory requirements, the “integrated prevention” approach enables designers, company managers, and OSH players to anticipate occupational risks and to keep them better under control, while also reconciling the technical, organisational, and economic demands of their projects. The issue at stake is to apply safe design principles, upstream in equipment projects (for machines, tools, etc.) or for workplaces (buildings, workshops, etc.).

This approach is one of the eight good practices in occupational risk prevention and it is written into the Code du Travail (French Labour Code). It therefore includes all sectors of activity (industry, building, services, etc.), regardless of the risks. The INRS studies concern both the methodological approach and also the design tools. Other work is studying software tools or “digital manikins” for enabling designers to simulate various scenarios for a future working situation, and to check compliance with physical ergonomics principles (anthropometry, postures, efforts, stability, etc.).

## Methodology to assist in the drawing up of a technical specification based on the concept of work situation

**Bruno DAILLE-LEFEVRE**

Work Equipment Engineering Division

### ■ Presentation of motives and aims

This study was conducted in partnership with the Technical Centre for the Mechanical Industries (CETIM). The intention was to develop and then disseminate a methodological tool in SMEs that integrates all the data necessary to apply safe design principles into the purchasing or design specification of an item of work equipment (special machine, individual workstation, assembly line, etc.). These data should go beyond the references of the standards and, in particular, must encompass the uses and constraints of “probable future” work situations.

### ■ Approach

A bibliographic analysis completed by an analysis of the practises of machinery designers showed that industrialists generally have recourse to the functional needs analysis (FNA) to lay down the specifications of work equipment that they wish to acquire.

The proposed approach is based on coupling this FNA with the "MOSTRA" work situation model, previously developed by INRS regarding the issue of integrating prevention into design. This approach requires that each function must be safe. The challenge therefore consists in defining a questionnaire based method structured so as to identify the criteria of use associated with each function.

The theoretical development of this approach was completed by application phases in real situations in industrial concerns to assess its relevance and acceptability.

### ■ Main results

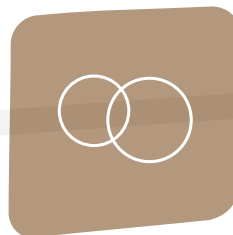
The theoretical approach retained and its being put it into practice allowed the structuring of an approach based on a description of the use of the machine in each technical function. To do this, it was proposed to question each of them in the following way: **Why** this function? **What** does this function act on? **Who** or what is involved in executing this function? **How** is this function executed? **Where** does this function take place? **When** does this function happen?

Two cases of applications, one with a "designer" of special machinery, the other with a "final user", showed both the applicability of the method proposed by the SMEs and the interest, from the occupational risk prevention point of view, of including criteria linked to use in the technical functions.

### ■ Discussion

As has been shown, the proposed approach allows those directly involved (designers and users) to go beyond the technical specification alone so as to achieve a description of work situations and thus identify, very early on, potentially hazardous situations. However, this approach must be replaced in the broader context of acquiring an item of work equipment. Indeed, to ensure that the technical solutions actually retained by the designer are in compliance with the specification, they must also contain elements relative to the project validation process, in particular the definition of intermediate project reviews (procedures, criteria, scenarios of use).

Result exploitation projects are already underway, both from the scientific (proposal of a chapter in a written work examining the integration of usage in design, Lambda Mu 18 congress) and practical points of view. A brochure and a training course developed in conjunction with CETIM will explain and focus on this methodology in SMEs.



## Development and validation of digital human models algorithms for assessing biomechanical risk factors in design

**Jonathan SAVIN**

Work Equipment Engineering Division

### ■ Presentation of motives and aims

Digital human models (DHM) are of genuine interest for integrating prevention at the initial stages of designing work equipment. They are, in effect, computer tools that simulate the future activity of operators and assess it from the biomechanical point of view (workstation sizing, verification of fields of view and restricted areas, estimation of risks likely to cause damage to the locomotor system, etc.). However, their implementation is complex and, in certain cases, can result in underestimating the future exertions of operators. The aim of this study was therefore to develop control algorithms allowing animation of these DHMs with a view to achieving a reliable ergonomic assessment of future activity, and to validate these developments by means of biomechanical data stemming from experimental situations requiring human subjects.



### ■ Approach

This study served as the framework for an academic thesis supported jointly by INRS and the French Atomic and Alternative Energy Commission (CEA). The approach retained was based on calculation and simulation techniques employed in robotics: control laws inspired by human behaviour were developed to animate a DHM autonomously, generically and realistically in terms of postures, trajectories, speeds and exertions from as simple a description of future activity as possible. The quantitative validation of the work was based on a comparative analysis of the simulations obtained with this controller with experimental data relative to fitting inserts, a repetitive industrial activity previously studied by INRS from the biomechanical point of view.



## ■ Main results

The DHM controller developed models the feed-forward, feed-back and learning abilities of the human motor control. The ergonomic assessments of the simulations obtained with this controller, established in accordance with the recommendations of Standard EN 1005-5, were coherent with those of the activity of human subjects. For the example in question, the profiles of the simulated trajectories and speeds were very close to the range of the trajectories and speeds of the subjects. The control laws appeared to be robust and generic in the case of a change in activity or anthropometry of a subject, and the simulation time was virtually real time.

## ■ Discussion

The work carried out achieved the aims of the study, namely the autonomous and realistic animation of a DHM to assess the biomechanical factors of a future work situation. While the robustness and genericity of the algorithms developed turned out to be satisfactory for an insert fitting task, these results should be confirmed for more complex tasks.

Some perspectives for making progress were also identified, particularly as regards the variability of human movement: to date, this has not been taken into account DHMs, whereas they would appear to play a protective role for the locomotor system. A transversal study bringing together INRS engineers, ergonomists and doctors will examine this issue, and is set to start in 2014.

Finally, this study was the subject of a doctorate thesis as well as international publications and presentations. Exploitation of the results among prevention specialists is also planned for 2014 (an article in the journal HST and a technical day).



Within this topic,  
two studies are in progress in 2014

### ■ Development of a detailed and safe design methodology for work equipment

> Jacques MARSOT, Bruno DAILLE-LEFEVRE, Aurélien LUX - Work Equipment Engineering Division

### ■ Movement variability: characterisation during assembly activities and potential for integration into Computer Aided Design software

> Jonathan SAVIN - Work Equipment Engineering Division, Clarisse GAUDEZ and Martine GILLES - Working Life Division

# Waste and recycling

Changes in European regulations and, more recently, the “Grenelle de l’environnement” Talks have encouraged the development, growth, and industrialisation of the recycling and transformation sectors.

An analysis of the data from the CNAM-TS (French National Health Insurance Fund for Salaried Employees) has highlighted a high growth in numbers of staff over the last ten years in the various trades of collecting, sorting, and treating household refuse and of recycling. According to that data, the workers in the sector are more exposed than in the other activities coming under the general social security scheme.

Through its studies & research activities, INRS is contributing to designing and organising the sectors (collection, sorting, dismantling, depolluting, treating, recycling & transforming) by including the health and safety component, in particular by analysing certain organisational processes, characterising the methods in emerging and/or existing sectors, and assessing levels of exposure of workers on the ground.

INRS is also focusing on developing solutions for preventing risks for and effects on worker health, such solutions being adapted in particular to the specificities of the waste recycling & transformation sector, of the building & civil engineering trade, and of the polluted soil treatment sector.

## Assessing chemical and biological exposures during non-hazardous waste product exploitation and maintenance operations in thermal treatment plants

**Ronan LEVILLY**

Process Engineering Division

**Related topic: Chemical Risks - prevention solutions**

### ■ Presentation of motives and aims

Few studies have examined workers operating in thermal treatment plants for non-hazardous waste products. However, the number of treatment plants in France currently stands at 129, representing a total of 3,500 employees.

The study aimed at achieving a twin objective:

- > to conduct an assessment of exposures to the chemical and biological agents present in these plants,
- > to guide professionals in implementing good chemical and biological risk prevention practices in these treatment plants.



## ■ Approach

The methodology applied was organized in accordance with the following steps:

- > review of the typologies of treatment plants to allow the definition and choice of pilot sites for the study (five typologies retained),
- > determination of the chemical and biological substances representative of the activity of incinerating household and equivalent waste products (on average 40 chemical and biological substances sought during the metrological campaigns),
- > identification of the different families of personnel [five homogeneous exposure groups (HEG)] and areas of interest (10),
- > implementation of a sampling strategy employing a job-exposure matrix,
- > assessment of the mean levels of exposure to the substances identified as a function of work periods.

## ■ Main results

The results obtained came from a total of 5,500 measurements taken over the course of 13 measurement campaigns (9 weeks in normal operation and 4 weeks in heavy technical shutdown).

### > In normal operation

The maintenance and operations personnel (particularly the process controller) were the most exposed employees during normal operation. The area with the highest exposure level was the unloading zone. The substances with the highest exposure levels were inhalable dust, calcium aerosols, hexavalent chromium and bio-aerosols (uniquely for the operations and workers in contact with process elements soiled by household waste).

### > In the heavy technical shutdown period

The maintenance personnel involved (backed-up by operations personnel or personnel from sub-contractors) were exposed. The exposure levels recorded were very high and at times exceeded the occupational exposure limit levels, raising the question of the appropriateness of the Personal Protective Equipment (PPE) provided.

These exposures concerned a number of substances including dust (alveolar and inhalable), calcium aerosols, metal aerosols (lead, iron, copper) and hexavalent chromium, whose limit value is to be lowered in July 2014.





## ■ Discussion

Improving the working conditions in the incineration sector must focus on the day-to-day tasks taking place in the unloading area, but more particularly on maintenance operations during technical shutdowns. However, the configuration of the installations concerned does not always allow recourse to collective protection solutions. The difficulties linked to working areas (manholes, cramped spaces, co-activities, etc.) are equally important elements to take into account when choosing prevention solutions. The chemical and biological risk prevention guide drafted on the basis of this work will endeavour to propose avenues of improvement.



As part of this topic,  
four other studies are underway in 2014

- **EEEW: chemical risk reduction in existing and emerging branches**  
> Marie-Thérèse LECLER, François ZIMMERMANN - Process Engineering Division
- **Preventing chemical and biological risks in biogas plants**  
> Philippe FERRARI - Process Engineering Division
- **Overview of employee exposure in contaminated soil cleaning activities**  
> Pascal POIROT - Process Engineering Division
- **Photovoltaic panel recycling and treatment branch - Preparatory study**  
> Ronan LEVILLY - Process Engineering Division

And other studies exploring this subject are mentioned under the topics "Occupational allergies" and "Biological Risks".

# Multiple exposures: chemicals and noise

Multiple exposures (interactions of various chemical agents or noise) are very prevalent in industrial environments.

Exposure to several different chemicals at the same work station has been established in 99% of interventions out in the firms. In addition, multiple exposures involving chemicals relate to 89% of the identified chemical agents (Colchic database), i.e. 623 out of 700.

The work done by INRS is aimed at:

- > identifying the risks run by employees exposed to combinations of harmful/pollutant factors (association of noise and of chemicals) and assessing their potential effects,
- > developing new tools capable of taking multiple exposures into account (databases, physiological and pharmacokinetic models, biomonitoring, protective equipment, screening, epidemiology, etc.),
- > assessing the relevance of the present Occupational Exposure Limits (OEL), in particular when doses are small.

## Objective hearing test to prevent the risks of occupational hearing loss: an alternative to liminar pure tone audiometry

**Pierre CAMPO, Thomas VENET**

Toxicology and Biometrology Division

**Related topic: Chemical Risks - knowledge of the hazards**

### ■ Presentation of motives and aims

Hearing can be adversely affected by noise and by certain aromatic solvents used in industry. The aims of this study were to understand the impact of these solvents on the peripheral auditory receptor and on the central auditory system which controls the reflex of the middle and inner ears. This step was intended to allow the development of a new tool to test the hearing of multi-exposed employees.

### ■ Approach

This relies, in both animals and humans, on measuring distortion-product otoacoustic emissions (DPOAEs) in one ear, associated with a stimulus in the other ear. The DPOAEs are obtained by a probe placed in front of the eardrum which generates two pure sounds:  $f_1$  and  $f_2$ , with a ratio  $f_1/f_2=1.2$ . The probe also includes a microphone which records the "distortions" emits by the cochlea through the tympano ossicular chain. Regarding contralateral stimulation, the parameters are set to stimulate the reflexes of the middle and inner ears. A computer programme produces  $f_1$  &  $f_2$ , records the DPOAEs, and triggers the reflexes. The procedure is non-invasive and objective since it does not require the participation of the subjects undergoing test.



### ■ Main results

DPOAEs are sensitive enough to measure the amplitudes of the middle and inner ear reflexes in rats and human. Aromatic solvents poison the outer hair cells and disrupt the middle-ear reflex. By contrast, the inner-ear reflex would appear to be insensitive to these chemicals. These results were the subject of a university and medical thesis, both of which were supported in 2013. The objective and rapid measurements thus allow the evaluation of the hearing performance of employees. On the basis of this statement, a new procedure for measuring the auditory reflex was designed and patented: EchoScan Audio. The first studies in enterprises demonstrated the high sensitivity of the reflex triggering thresholds in revealing auditory fatigue.

### ■ Discussion

This study has shown that the Echoscan Audio procedure can assess peripheral auditory fatigue in humans working in a moderately noisy environment for one single day. It has also shown, in animals, its ability to detect disruptions of the middle- and inner-ear reflexes caused by aromatic solvents. We have yet to find host enterprises to test its performance on humans working in polluted atmospheres. The procedure is capable of measuring objective data on site in a less constraining acoustic environment than that required for carrying out pure tone audiometry. An industrial partnership has now been entered into to allow the production of a measurement system and Echoscan Audio, which is the subject of information activities undertaken in conjunction with the external communications unit of INRS among risk prevention partners.





As part of this topic,  
five other studies are underway in 2014

- **Comparison of the harmfulness of a pulsed noise and a steady noise with the same acoustic energy during co-exposure to styrene**  
> Pierre CAMPO - Toxicology and Biometry Division
- **Toluene/butanone interaction in the rat: metabolic and ototoxicity aspects**  
> Frédéric COSNIER - Toxicology and Biometry Division
- **Modifications to the amplitude of the middle ear reflex after solvent inhalation. Physiological consequences of noise exposures**  
> Pierre CAMPO, Thomas VENET - Toxicology and Biometry Division
- **Assessment of the use of measurements of exposure to chemicals in the French Colchic and Scola data bases for the prevention of occupational diseases**  
> Gautier MATER - Toxicology and Biometry Division
- **Modification of the metabolism of styrene by co-exposure with 2-butanone (MEK)**  
> Benoît COSSEC - Toxicology and Biometry Division

And other studies exploring this subject are mentioned under the topic  
"Chemical Risks".



# Manufactured nanomaterials

Nanotechnologies are enjoying a considerable boom, because of the innovations they enable in numerous sectors of activity: chemicals, energy, building, cosmetics, automobile, electronics, etc.

But the enthusiasm aroused by manufactured nanomaterials is tempered by issues relating to the potential risks of biological effects on workers. The European Agency for Safety and Health at Work considers nanomaterials to be one of the ten main emerging health risks at the workplace.

Prevention of risks requires, as it does for any chemical substance, identifying the sources of exposure, assessing the exposures, and characterising the risk in relation to the potential hazards, the end purpose being to reduce the risk by providing prevention solutions. In this context, significant importance should be given to protecting workers and to managing the risks. Collective or personal protective means exist, but additional checks are necessary in order to confirm the performance of such equipment.

INRS action on manufactured nanomaterials has three objectives:

- > making knowledge on hazards available to the working world,
- > designing tools for identifying, characterising, and measuring occupational exposures, and
- > proposing risk prevention approaches and tools for firms and laboratories who produce or handle these materials.

## *In vitro* and *in vivo* genotoxicity of nanomaterials: the European joint action project "Nanogenotox"

**Yves GUICHARD, Laurent GATE, Christian DARNE**

Toxicology and Biometry Division

**Related topic: Chemical Risks - knowledge of the hazards**

### ■ Presentation of motives and aims

The study "*In vitro* and *in vivo* genotoxicity of nanomaterials: European joint action project" forms part of the European Nanogenotox project, the aim of which falls within the scope of assessing the hazards and risks linked to exposure to manufactured nanomaterials. For INRS, this project directly responded to prevention needs regarding employees potentially exposed to nanomaterials. Its main aim was to establish a robust *in vitro* method to assess the genotoxic potential of manufactured nanomaterials by employing animal experimentation. The project took place over three months (March 2010 – February 2013) with the participation of seventeen research institutes from eleven Member States coordinated by the French Agency for Food, Environmental and Occupational Health & Safety (ANSES).





## ■ Approach

Three types of nanomaterials were selected in this project: four synthetic amorphous silica materials, four titanium dioxides and six carbon nanotubes. The methodology was based on four main steps:

- > Physico-chemical characterisation of the nanomaterials and development of a method of dispersion in biological media.
- > *In vitro* genotoxicity: primarily assessed by the comet assay and the micronucleus assay in different cellular models representative of the exposure routes (inhalation and oral). Two cellular models (pulmonary and intestinal) were retained for the inter-laboratory trials.
- > *In vivo* genotoxicity: assessed in rats exposed by intratracheal instillation and by gavage. The comet assay was conducted on different organs (lung, liver, kidney, spleen, blood and bone marrow, the micronucleus assay in bone marrow and, for the gavage study, in colon level).
- > Toxicocinetiks: by using the oral and intravenous routes in rats to assess the target organs.

The participation of INRS in this project concerned the second and third steps: the *in vitro* (in human alveolar cells) and *in vivo* genotoxicity of the silica samples as well as the *in vitro* inter-laboratory trials on different nanomaterials.

## ■ Main results

For the entire project, the main results were:

- > Genotoxic effects were detected *in vitro* with most of the nanomaterials tested but remained at low levels.
- > The inter-laboratory trials show a high variability in the results of the *in vitro* genotoxicity test (comet assay and micronucleus assay).
- > The *in vivo* genotoxicity tests were negative (or sometimes ambiguous) for the majority of the nanomaterials. Moreover, our laboratory showed pulmonary inflammation effects for the four silica nanomaterials tested.

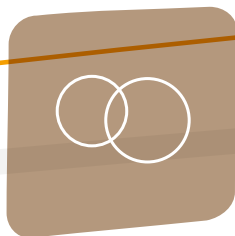
## ■ Discussion

This project should be considered as a first step in the introduction of a robust method to assess the genotoxicity of nanomaterials. Additional work would be necessary to allow the *in vitro* tests to be considered as a reliable alternative to animal experimentation. The project has contributed to the setting-up of an exchange network among European laboratories to improve and share their knowledge of nanomaterials.



As part of this topic,  
eight studies are underway in 2014

- **A common European approach to the regulatory testing of manufactured nanomaterials (NanoReg)**
  - > Laurent GATE - Toxicology and Biometry Division, Olivier WITSCHGER  
Pollutant Metrology Division, Emmanuel BELUT - Process Engineering Division
- **Standardisation of activities concerning nanotechnologies and nanomaterials (NanoCen)**
  - > Olivier WITSCHGER and Sébastien BAU - Pollutant Metrology Division
- **Impact of sources and of the environment on nanoparticulate pollutant confinement by means of collective protection systems**
  - > Emmanuel BELUT - Process Engineering Division
- **Performance of filtering and isolating breathing apparatus in relation to nanoparticles**
  - > Sandrine CHAZELET - Process Engineering Division
- **Performance of real-time metrology applied to nanoparticle aerosols**
  - > Sébastien BAU and Olivier WITSCHGER - Pollutant Metrology Division
- **Assessing the chemical risk linked to exposure to nanometric titanium dioxide**
  - > Bertrand HONNERT - Pollutant Metrology Division
- **Studies of the *in vitro* genotoxic effects of nanostructured silica particles from different manufacturing processes**
  - > Yves GUICHARD and Christian DARNE - Toxicology and Biometry Division
- **Study of the effect of clustering on the respiratory toxicological and toxicokinetic properties of inhaled titanium dioxide in the rat**
  - > Christian DARNE and Yves GUICHARD - Toxicology and Biometry Division



# Organisation, health and safety at work

In recent years, many national or international programmes of action have highlighted the organisational dimensions of occupational safety and health. Taking an overall look at the occupational risks and at their corresponding costs, they urge stakeholders to use integrated prevention approaches emphasizing the importance of work design and organisation choices. In this way, organisation is considered as an essential resource for preserving health.

The INRS studies are focusing particularly on three organisational dimensions that interact on health and safety: company organisation, production organisation, and prevention organisation. These dimensions of work organisation go from tool, system and work process design to human resources management and issues of occupational safety and health. Two lines of research are being taken:

- > Developing new organisation modes, new workforce management modes, and new information and communications systems, whether it be for Lean Management, for subcontracting, or for New Information and Communications Technologies in networked companies.
- > Changing roles and responsibilities in new trades, new sectors, and new forms of work design or of division of labour, including the work of designers and of the management on site.



As part of this topic,  
three studies are underway in 2014

■ **Prevention in transport and logistics: technological and organizational changes in networking enterprises**

> Virginie GOVAERE and Liën WIOLAND - Working Life Division

■ **Lean practices in enterprises and occupational health**

> Evelyne MORVAN, Bertrand DELECROIX, Edwige QUILLEROU-GRIVOT - Working Life Division

■ **Prevention in design and cooperation between interested parties from different professional worlds. Case of a national project to broaden the scope of exploitable waste product treatment**

> Bertrand DELECROIX, Evelyne MORVAN - Working Life Division

And other studies exploring this subject are mentioned under the following topics: "Psychosocial Risks", and "Ageing, Staying in Work and Preventing Occupational Exclusion".



# Prevention of occupational cancers

In France, the share attributable to occupational risks has been estimated at in the range 4% to 8.5% of all human cancers, but this share can be higher depending on the type of cancer or on the regions in question. Although there is no specific technical prevention for preventing carcinogenic agents, preventing the risk of occupational cancer should be addressed in a particular way:

- > Specific legislation exists that lays down rules for substitution, work organisation, training and information, that legislation being different, for example, from the legislation that applies to hazardous chemicals.
- > A specific time scale applies, since the effects of carcinogens are generally not immediate, occupational cancer prevention actions are long-term or even very long term actions. That is why, we need to act today to prevent these diseases in the period from 2020 to 2050.

The studies related to this issue have three focuses:

- > Improving prevention of all types of occupational cancers, and in particular assessing the opportuneness of using early-effect markers following exposure to carcinogens.
- > Initiating and accompanying companies in preventing the asbestos risk.
- > Studying the perception of carcinogenic risks.



As part of this topic,  
one study is underway in 2014

- **Rated protection factors of breathing apparatus used in asbestos removal worksites**  
> Sandrine CHAZELET and Eric SILVENTE - Process Engineering Division

And other studies exploring this subject are mentioned under the topic  
"Chemical Risks".



# Reproduction and work

The surrounding environment in the broad sense of the term can have an impact on human fertility. In the working world, toxic factors can induce effects that are harmful to reproduction, in particular via molecules having endocrine disruption action.

The INRS research programmes are contributing to identifying certain hazards having potential impacts on pregnancy, by improving the state of experimentally acquired toxicological knowledge about chemicals, and in particular about phthalates.

Other studies are focusing on identifying risk situations and on gathering data about relationships between occupational exposure of the mother and pathology in the child.

## Study of the reprotoxic mode of action of phthalates: case of di-n-hexyl phthalate

**Anne-Marie SAILLEFAIT**

Toxicology and Biometrology Division

**Related topic: Chemical Risks - knowledge of the hazards**

### ■ Presentation of motives and aims

Phthalates are plasticizers that form part of the composition of numerous PVC objects. Their toxic properties are linked to their chemical structure, and only some (phthalates belonging to categories C4-C6) have raised concern about their possible impact on gestation. In the rat, *in utero* exposure to these phthalates, including di-n-hexyle phthalate (DnHP), results in numerous anomalies of the reproductive system in male descendants, notably severe malformations (cryptorchidism, hypospadias), testicular atrophy and reduced spermatozoid production. The main aim of this study was to identify the mechanisms responsible for the testicular effects of DnHP in the rat after exposures during the foetal stage.



## ■ Approach

The first phase of the study was given over to developing methods to analyse hormonal and molecular markers allowing an evaluation of the early effects of endocrine disruptors. DnHP was then administered to gestating rats during the critical period of sexual differentiation. A wide range of doses was tested. The testes of the foetus were collected at the end of gestation for analysis. In conjunction with the measurements of the expression of the key genes of steroid synthesis by Q-PCR (Quantitative real time polymerase chain reaction), the production of testosterone by the foetal testis was quantitatively analysed by LC-MS/MS (Liquid chromatography coupled to tandem mass spectrometry).

## ■ Main results

This study has shown that DnHP causes a dose related (with a linear progression) reduction in the production of testosterone by the foetal testis, correlated with a decrease in the expression of several genes involved in its synthesis. DnHP turns out to be slightly more toxic than the top-ranking substance of this chemical family, diethylhexyl phthalate (DEHP). The dose threshold with no effect based on these hormonal and molecular modifications was 5 mg/kg/day, whereas it was 125 mg/kg/day based on conventional morphological or gravimetric examinations.

## ■ Discussion

The results demonstrate that exposures to DnHP during gestation have a direct and specific anti-androgenic action on the development of rat testis. They have led to lowering the no-effect dose levels for DnHP, and prove that the foetal period is particularly sensitive to phthalates, and more generally to endocrine disruptors.

This study has also confirmed the ability of certain specific markers to detect effects on the foetal testis, whereas no obvious morphological damage has yet been observed with conventional toxicological parameters. This underlines the interest of combining standard and molecular tools to refine dose-effect relationships and to better understand the origin of the toxic effects observed. These data will be useful within the context of giving consideration to implementation strategies intended to improve hazard identification and risk assessment of chemical substances, and more particularly endocrine disruptors.



As part of this topic,  
three studies are underway in 2014

- **Biological assessment of occupational exposure to di-(isononyl) phthalate (DINP)**  
> René GAUDIN - Toxicology and Biometrology Division
- **Assessing the prenatal toxicity of pyrethrinoid insecticides in the rat - testicular effects**  
> Anne-Marie SAILLENFAIT - Toxicology and Biometrology Division
- **Investigating endocrine disruptor type effects during exposure to DINP in industry**  
> Jean-Bernard HENROTIN - Epidemiology in Enterprise Division



# Biological risks

The Sumer 2010 survey identifies 4 million people carrying out occupational activities that might expose them to biological agents (bacteria, microscopic fungi, cellular cultures, endoparasites, viruses, and prions) that can give rise to toxic, immunoallergic, and carcinogenic risks and not merely to infectious risks.

The occupational sectors include personal care services, reception jobs, healthcare professions, and trades involving contact with animals, the environment sector, water treatment, and waste treatment, etc.

In the absence of Occupational Exposure Limit Values (OELVs), the INRS research work is focused in particular on:

- > developing approaches for assessing the immunoallergic and toxic risks related to exposure to airborne agents of biological origin,
- > developing methods and strategies for measuring (sampling and analysing) bioaerosols, such methods and strategies being transferable to stakeholders in prevention of such risks,
- > acquiring methods for assessing the quality of interior air,
- > studying means for reducing exposure to bioaerosols.



As part of this topic,  
three studies are underway in 2014

- **Comparative study of sampling methods to measure exposure to bioaerosols composed of stress-sensitive biological agents**  
> Xavier SIMON and Philippe DUQUENNE - Pollutant Metrology Division
- **Development and assessment of a method to measure (1,3)-B-D-glucans in workplace air**  
> Philippe DUQUENNE and Xavier SIMON - Pollutant Metrology Division
- **Processes for cleaning workplace air contaminated by microorganisms: preparatory study of technical separation/disinfecting solutions**  
> Denis BEMER - Process Engineering Division, Philippe DUQUENNE and Xavier SIMON - Pollutant Metrology Division

And other studies exploring this subject are mentioned under the topics "Occupational allergies" and "Waste and Recycling".

# Chemical risks

Omnipresent in the workplace, certain chemicals sometimes still go unnoticed. And yet, nearly 33.5% of employees declare that they have been exposed to at least one chemical (SUMER 2010 survey), and a large number of sectors of activity are potentially concerned by exposure to chemicals.

Regulations include specific provisions for hazardous chemical agents, and for carcinogenic processes, while the international context is changing with the phased implementation of REACH.

Chemical risks have been studied at INRS since it was founded. However, the work needs to be continued: with studies on new substances including substitute products, metrology, bio-indicators, influence on health, epidemiological studies, improving and developing processes, developing prevention techniques, etc.

It should be noted that some work cuts across several different fields of research and that a certain number of actions are also raised in other topics: nanoparticles, cancers, risks for reproduction, allergies, waste and recycling, noise and vibration.

## Focus 1: making knowledge on hazards available to the working world

The work for highlighting and for quantifying the hazards related to exposure to chemicals, whether they be toxic, mutagenic, carcinogenic, reprotoxic, allergenic, or neurotoxic, are studied from two angles: experimental toxicology studies, on animals (*in vivo*) and on cells in culture (*in vitro*), and epidemiological studies. The studies for developing methods in these two disciplines appear under this sub-topic.

## Modelling the percutaneous absorption of industrial toxins: taking into account the amphiphilic character of substances and skin thickness

**Jean-Paul PAYAN, Dominique BEYDON**

Toxicology and Biometrology Division

### ■ Presentation of motives and aims

In the world of work, the cutaneous route is the second penetration route possible during exposure to toxic compounds. *In vivo* and *ex vivo* experimental methods to determine absorption flux are both time consuming and costly, and in certain cases unusable for ethical reasons. Besides, alternative methods such as quantitative structure-activity relationships have been proposed. However, for widely used industrial products, including 2-butoxyethanol (2-BE), N-methylpyrrolidone, N-vinylpyrrolidone and dimethylformamide, the percutaneous absorption fluxes have been very poorly estimated from the algorithms available.

This study had two main aims:

- > explain the divergence of the percutaneous absorption fluxes of amphiphilic industrial toxins in aqueous solutions compared to Fick's first law,
- > correlate the *in vivo* and ex vivo absorption fluxes by taking into account the skin thickness of the samples used.

### ■ Approach

To achieve the first objective, the determination of the physico-chemical properties of aqueous solutions containing amphiphilic molecules of interest, the modelling of their transfer flux, the determination of their absorption fluxes as well as their effect on skin samples were carried out.

For the second objective, samples of rat skin were cut to different thicknesses. The absorption fluxes of the lipophilic and amphiphilic molecules were determined ex vivo with rat skin in exposure conditions (quantity deposited, concentration, exposure time) identical to the *in vivo* exposure conditions.

### ■ Main results and discussion

The four molecules studied had an adverse effect on the physical integrity of the rat skin samples. The increase in permeability does not explain the variation in absorption fluxes observed as a function of the concentration of these aqueous solution solutes. The octanol/water partition coefficient varied moderately in the range of non-miscibility concentrations of the ternary mixtures studied. However, the non-miscibility range is very narrow for certain molecules such as 2-butoxyethanol. Besides, this parameter cannot be used to explain the variation in absorption fluxes as a function of solution concentration. On the other hand, it was shown that the variation in the chemical activity of the aqueous solutions of 2-butoxyethanol, contrary to their concentration, could allow normalization of the absorption flux of each molecule.



For the second objective, it was shown that the *in vivo* absorption flux of lipophilic molecules (bisphenol A, pyrene, benzo(a)pyrene, naphthalene) can be estimated with close approximation by measuring the change in the ex vivo absorption flux of these molecules as a function skin sample thickness. This new methodological approach would appear to be promising for estimating *in vivo* percutaneous absorption fluxes from ex-vivo experimental data.



As part of this focus,  
six other studies are underway in 2014

- **Measure, method to estimate relative survival**  
> Michel GRZEBYK and Guy HEDELIN - Epidemiology in Enterprise Division
- **Bladder cancer and oil mists: prospective cohort study in professional populations from the steelmaking industry of Nord - Pas-de-Calais**  
> Eve BOURGKARD and Michel GRZEBYK - Epidemiology in Enterprise Division
- **Ex-vivo percutaneous absorption of solid lipophilic toxins: use of the artificial sebum**  
> Dominique BEYDON - Toxicology and Biometry Division
- **Taking into account the characteristics of skin samples to better estimate percutaneous absorption fluxes**  
> Fabrice MARQUET and Jean-Paul PAYAN - Toxicology and Biometry Division
- **Development of a co-culture model to study the genotoxic properties of particles**  
> Laurent GATE and Christian DARNE - Toxicology and Biometry Division
- **Determination of the parameters to allow quantitative analysis of intra-erythrocyte chromium-*in vitro* study**  
> Jérôme DEVOY - Toxicology and Biometry Division

And other studies exploring this subject are mentioned under the topic  
“Manufactured Nanomaterials”.





## Focus 2: making knowledge available on the state of exposures and on the state of tools for evaluating exposures

Measuring occupational exposure to chemicals draws on two complementary disciplines: atmospheric metrology for the purpose of providing methods of sampling and analysing various chemical substances, and biometrology so as to measure exposure-revealing bioindicators in human fluids. For both of these approaches, studies for developing finalised field studies and methods are being conducted. From an overall viewpoint, the sector-based studies make it possible to estimate the extent of a particular type of exposure and the number of employees exposed. Then, by using exposure measurement databases (Colchic-Scola) and measurement campaigns, it is possible to appraise the levels of the exposures.

### Dustiness of powders in conventional aerosol fractions

**Richard WROBEL, Peter GÖRNER**

Pollutant Metrology Division

#### ■ Presentation of motives and aims

The dustiness of a powder or its potential to generate an aerosol can be considered as a property of the powder to cause a dust emission when being handled. Characterising this property first allows a classification of different powders as a function of aerosol generation risk during handling and, secondly, an estimation of the quantity of dust emitted as a function of energy input. The main aim of this study was to respond to a need for a stabilized method to measure the dustiness indexes of powders in conventional aerosol fractions in the interest of health risk prevention.

#### ■ Approach

The study comprised setting up the installation necessary for the dustiness tests, fitting its instrumentation and qualifying the operating parameters. The operating procedures for preparing samples and measuring both the bulk density and the water content of powders were also developed. Experiments were conducted to perfect the dustiness measurement method. The detection and quantification limits as well as the repeatability and reproducibility of the tests were assessed. Finally, the dustiness was studied as a function of the mechanical properties of the powders.

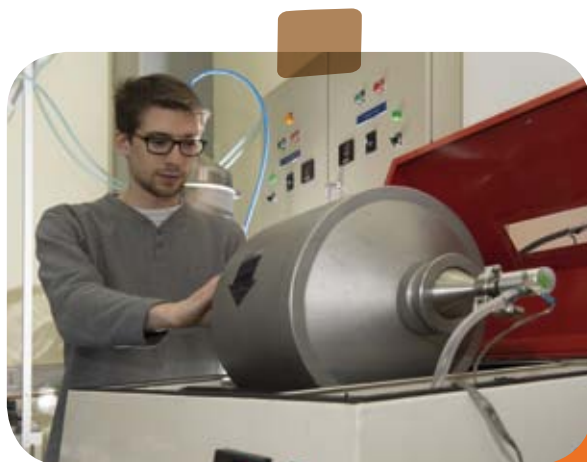
#### ■ Main results

The dustiness indexes of some forty industrial powders were determined. The alveolar, thoracic and inhalable indexes were classified in four dustiness categories: very low, low, moderate and high. The results constitute the start of a future dustiness database to offer potential users guidance in choosing them, handling them and ensuring employee protection. The method is now operational and available to prevention specialists and industry to allow them to participate in assessing chemical risk, reducing the dustiness of powders or replacing them with less dust emitting materials.



## ■ Discussion

In response to the concerns of advisory occupational health engineers, it was necessary to propose a stabilised method to measure the dustiness indexes of the powders handled in industry. To be capable of application in the area of industrial health, this method measures dustiness in conventional health-related aerosol fractions. The mechanism of emitting particles in suspension by the rotating drum method is relatively close to the mechanisms involved in the industrial handling of bulk powders. The choice of a standardised method was motivated by the need to interpret the results in a European context aimed at assessing chemical risk and labelling dust emitting products. The influence of the mechanical properties of powders on their dustiness was also studied. The results led to the conclusion that it is necessary to measure the dustiness itself, independently of the other physical parameters of the powders.



## Characterization of the products of the thermal degradation of plastics

**Marianne GUILLEMOT, Benoît OURY**  
Pollutant Metrology Division

### ■ Presentation of motives and aims

In France, almost 3,300 enterprises transform plastics. They employ over 132,000 people, 59,000 of whom are directly involved in workshop production or in industrial process maintenance. During hot transformation, plastics emit volatile products that are potentially toxic for employees.

The aims of this study were twofold:

- > to develop a methodology applicable to all polymers allowing the characterization of thermal degradation products and the determination of the weight loss at a given temperature,
- > to apply the defined protocol to all the targeted polymers and to make available the results in a database consultable on the INRS site in order to orient prevention specialists in their risk assessment and reduction approach.



## ■ Approach

This study examined the thermoplastics most used in France, i.e. 23 references, classified in 11 polymer families (polyolefins, vinyl polymers, polystyrenes, polyacrylics, polyacetals, polyamides, polycarbonates, linear polyesters, polyfluoroethenes, cellulosics and thermoplastic polyurethanes). Two techniques of thermal degradation in air were retained: thermogravimetric analysis (TGA) and pyrolysis. The influence of different parameters was studied to define the most appropriate protocols for thermally degrading plastics: sample preparation, speed of heating and technique used.

The validity of the protocol developed was then assessed over several sampling campaigns in enterprises. The compounds identified in plastics production workshops were compared to those generated during thermal degradation of the same polymer in the laboratory.

## ■ Main results

From the data obtained in the laboratory, two protocols could be determined:

- > cold grinding, TGA thermal degradation at 20 °C/min, 450 °C, in air: determination of the decomposition temperatures of polymers and the mass content of certain toxic compounds among the effluents released during heating,
- > cold grinding, pyrolysis thermal degradation at 20 °C/min in air: determination of the thermal degradation products released at a known transformation temperature and at 450 °C.

The analysis of the results obtained during the sampling operations in enterprises and those obtained with the laboratory analytical protocol on the same samples of plastics show agreement of the compounds identified.

## ■ Discussion

An analytical protocol was developed in the laboratory. The protocol was assessed by comparing the products sampled from plastics workshop emissions and those identified in the laboratory. In this regard, the thermal degradation products, the decomposition temperatures and the mass content of certain toxic compounds were determined according to this protocol for the 23 references of polymers studied. All this information has improved knowledge of exposures to chemical risk in this sector, and will be useful for prevention in two respects: limiting plastics emissions through knowledge of the initial degradation temperature and knowing the nature of the main compounds likely to be released in the case of thermal degradation, as well as their quantity if this involves toxic compounds.

Secondly, and to facilitate the prevention diagnosis step, the results of this study and from future assistances will be made available and disseminated by way of a database accessible and hosted on the INRS website.



## Beryllium exposure in France. Characterisation, prevention, knowledge dissemination

**Davy ROUSSET**

Pollutant Metrology Division



### ■ Presentation of motives and aims

The aim of this study was to give coherence to prevention actions relative to the risk of employee exposure (currently standing at between 9,400 and 14,500 in France) to beryllium and its compounds, which, even at very low concentrations, can result in the development of a serious chronic pulmonary disease, namely berylliosis. To prevent the risk of this pathology development, it was recommended to greatly lower the occupational exposure limit value (OEL), notably in France and the United States. One of the aims of this study was to demonstrate the feasibility of sampling and analytical methods to assess exposures to beryllium at a lower OEL. Furthermore, to strengthen medical monitoring schemes, different exposure or effect markers (quantitative analysis of urinary beryllium, early effects on respiratory health, sensitization test) were developed and/or tested within the context of this study. Finally, work was carried out to improve knowledge of the exposed populations in France, as a supplement to the studies already done.

### ■ Approach

Several areas of work were undertaken in this study. First, the analytical developments which were the subject of previous studies were adapted to very low beryllium concentrations in multiple matrices (air, urine, exhaled air condensates) and validated in enterprises whose activities, processes and materials employed could lead to beryllium exposure. These methods were applied in a field study encompassing atmospheric measurement and surface sampling campaigns, with urinary kinetics tests in parallel on certain subjects. Secondly, a transversal epidemiological study was conducted in which respiratory health markers (respiratory function, and inflammation and oxidising stress markers in exhaled air condensates) were determined on a group of subjects exposed to beryllium and a group of unexposed subjects. In parallel, an alternative sensitization marker to the standard test (BeLPT) was developed. Finally, the branch specific studies conducted previously were updated and broadened in scope to sectors not yet covered.

### ■ Main results

This study allowed the proposal of different methods to assess exposures to airborne beryllium in response to a significant lowering of the 8h-OEL from  $2 \mu\text{g}\cdot\text{m}^{-3}$  to  $0.05 \mu\text{g}\cdot\text{m}^{-3}$ . They were applied in certain emerging sectors (EEEW recycling) where exposure to beryllium had been suspected and very low beryllium concentrations measured.

Moreover, a joint atmospheric and urinary exposure assessment was conducted in five enterprises, with over 390 airborne samples and more than 3,200 urinary quantitative analyses. In two of the enterprises, the presence of beryllium could not be highlighted either in the aerosols or in the urines. For the other three (foundries), while the urinary beryllium values were, on the whole, in the same range of values encountered in the general population, a number of workstations with a higher exposure, consistent with the airborne measurements, could be identified.



The study of the correlation between urinary and atmospheric/airborne beryllium, although statistically significant, was not fully conclusive. However it did appear to be more pronounced in one enterprise.

The epidemiological study included 120 subjects in eight enterprises, 83 of whom were exposed. No relationship between the semi-quantitative beryllium exposure indexes and respiratory function could be detected. However, the level of exhaled NO was higher among the exposed subjects and was positively correlated with the present exposure level for soluble forms of beryllium. In addition, the inflammation level (TNF- $\alpha$  marker) measured in the exhaled air condensate increased with the duration of exposure to less soluble forms of beryllium.

Finally, validation of the sensitization test developed was not possible on account of a lack of subjects whose sensitization could be validated by BeLPT.

The branch specific study showed that most employees involved in sectors of activity related to defence (aeronautics, nuclear, armaments) had already been taken into account in previous assessments of the number of potentially exposed employees.

### ■ Discussion

The performance of current methods intended to assess exposure to beryllium allows for a significant reduction in the 8h-OEL to be envisaged. These results could help lawmakers in the consideration they give to an eventual lowering of this value. However, it would be necessary to continue to develop tools intended to strengthen medical monitoring of employees exposed to beryllium in France.

## Assessment of occupational exposure to cytotoxic drugs by urinary or surface sampling

**Sophie NDAW**

Toxicology and Biometry Division

### ■ Presentation of motives and aims

Occupational exposures to cytotoxic drugs, particularly in hospitals, must be assessed and controlled owing to the mutagenic, carcinogenic and teratogenic character of certain of these compounds. In this context, INRS has developed an exposure assessment strategy based on urinary biomonitoring and measurement of surface contamination. This concern is shared by IOCOEM (Institute and Outpatient Clinic for Occupational and Environmental Medicine) of the University of Munich (Germany), which has also developed an assessment strategy based exclusively on measuring of surface contamination and has published guidance values for 5-fluorouracile.

A partnership focusing on 5-fluorouracile was concluded with IOCOEM to compare these two assessment methods in two hospitals in Germany and two hospitals in France.

Moreover, the assessment was extended to other cytotoxic drugs (cyclophosphamide, ifosfamide, methotrexate) and to a higher number of employees in the two French hospitals retained within the framework.



### ■ Approach

An assessment of exposures to 5-fluorouracile by urinary biomonitoring and by measuring surface contamination was conducted in Germany and in France. Some ten people (pharmacy technicians, nurses, health carers) were followed up in each hospital (pharmacies and healthcare departments). The surface samples (laboratory bench tops, floors, etc.) were taken in the same departments.  $\alpha$ -fluoro- $\beta$ -alanine (FBAL), a urinary metabolite of 5-fluorouracile, was quantified in the urine samples by INRS, and OCOEM ensured the analysis of 5-fluorouracile in the surface samples.

In addition, the complete assessment of exposures in the two French hospitals concerned 44 and 50 people respectively. The quantitative analysis of the biomarkers of exposure to cyclophosphamide, ifosfamide, methotrexate and 5-fluorouracile was conducted in urines, and cyclophosphamide, ifosfamide and 5-fluorouracile were quantified in different surface samples.

### ■ Main results

The surface samples revealed generally higher contaminations in the pharmacies of the French hospitals. On the other hand, regarding the healthcare departments, the contaminations were systematically higher in Germany. The biomonitoring data show significant urinary excretions of FBAL, highlighting employee exposure to 5-fluorouracile in all the hospitals, with no relationship with the surface contaminations. However, no difference was observed between the French and German hospitals.

Regarding the second part of the study, very significant urinary excretions and surface contaminations were highlighted in both French hospitals.

### ■ Discussion

It would appear, in the light of these data, that employee contamination is not linked to that of work surfaces. This measurement alone is not enough to estimate staff exposure or to guarantee its control. Biomonitoring most definitely must be employed. It is this assessment strategy that was adopted by INRS.

The second part of this study confirmed the aforementioned conclusions. The exposures highlighted in both hospitals show that it is still necessary to improve the prevention measures applied, in every department and for every professional category. These prevention measures have been the subject of an information brochure "Cytotoxic drugs and healthcare workers. Handle with caution" published with the reference INRS ED 6138.



As part of this focus,  
eleven other studies are underway in 2014

- **3-Hydroxybenzo[a]pyrene, a potential bio-indicator of exposure to polycyclic aromatic hydrocarbons: role of the enterohepatic cycle**  
> Jean-Paul PAYAN - Toxicology and Biometry Division
- **Biological monitoring of exposure to several volatile organic compounds by measuring their residual fraction in urine: feasibility study**  
> Amandine ERB and Alain ROBERT - Toxicology and Biometry Division
- **Study of the performance of semi-volatile organic aerosol samplers**  
> Benjamin SUTTER and Eddy LANGLOIS - Pollutant Metrology Division
- **Decision making models for assessing occupational exposures**  
> Frédéric CLERC - Pollutant Metrology Division and Nicolas BERTRAND - Technical Advice and Appraisal Division
- **1,3-butadiene: update on current knowledge of work environment and exposure assessment**  
> Sarah BURZONI - Pollutant Metrology Division
- **Mapping of sectors and processes generating PAHs**  
> Catherine CHAMPMARTIN and Hubert MONNIER - Pollutant Metrology Division
- **Study of supercritical CO<sub>2</sub> desorption coupling and chromatographic analysis techniques**  
> Eddy LANGLOIS - Pollutant Metrology Division
- **Cutaneous contact with bitumen in road surfacing: analysis of work activity and prevention**  
> Florence HELLA - Working Life Division
- **Study of metal plating processes: characterising the aerosols emitted and biological monitoring of operators**  
> Nadège JACOBY - Toxicology and Biometry Division
- **Study of personal sampling devices for the thoracic fraction of sulphuric acid aerosols**  
> Peter GORNER - Pollutant Metrology Division
- **Development of a methodology to assess surface contamination: metrological aspects and transfer by contact**  
> William ESTEVE - Pollutant Metrology Division

## Focus 3: making prevention solutions available

Other INRS studies focus on developing prevention solutions that give preference to reducing emissions at source, and on incorporating such solutions into the design of facilities and equipment. In addition, investigations are conducted to identify priority operations or activities for which technical solutions should be developed

### Assessing personal breathing apparatus in work situations

**Sandrine CHAZELET**

Process Engineering Division

#### ■ Presentation of motives and aims

The procedure for choosing breathing apparatus is based on assessing the exposure at the workstation, knowledge of the occupational exposure limit values (OELs) and the assigned protection factor (APF) of the equipment. Standard EN 529 (2006) emphasises that the values of this factor vary from one European country to another due to the absence of protocol harmonisation concerning how it is determined in work situations. To examine this issue, this study became part of a PEROSH (Partnership for European Research in Occupational Safety and Health) project entitled "Determination of Workplace Related Protection Factors for Respiratory Protective Devices" ("Détermination des facteurs de protection des appareils de protection respiratoire en situation de travail"), the main aim of which was to propose a common method to determine the protection factor in the field.





## ■ Approach

The methodology was the following for the different institutes taking part:

- > identify the key parameters to measure to determine the protection factor and allow its interpretation: characteristics of the pollutant, work environment and physiological factors of the wearer of the respirator,
- > compare the different measuring tools available to carry out this determination and choose a common metrology by means of inter-comparison trials,
- > validate the method on different types of breathing apparatus.

## ■ Main results

The different European partners of the PEROSH group opted for a condensation nucleus particle counter (TSI Portacount 8038 Respirator Fit Tester) and focused on its procedure for use in work situations and on the overall approach, which also includes recording the particle size of the aerosol and compiling data about the respiratory protection scheme in the enterprise (employee training, equipment follow-up, etc.). The experimental work conducted at INRS on voluntary subjects highlighted the need to couple the protection factor measurements with physiological measurements, notably the heart rate of the operator, in order to obtain a better interpretation of the respiratory protection measured.

Validation of the protocol on real metal thermal spraying operations allowed the compilation of previously unpublished field data about Class 4B air fed respirators (NF EN 14594, 2005) and an assessment of operator exposure to the large quantities of ultrafine metal oxide particles emitted by these processes.

## ■ Discussion

The work of the PEROSH working group has resulted in the establishment of a harmonized protocol. Implementation of the PEROSH protocol must be associated, as from now, with the aim of improving respiratory protection (carrying out a fitting test, proposal to modify the type of respiratory protective equipment employed if necessary, etc.). The coming years will be given over to compiling field data about the protection factors, in compliance with this protocol, which will be pooled to define the assigned protection factors.

## Development of tools to predict and detect the life cycle of adsorbant media: applications in the area of organic vapours

**Stéphanie MARSTEAU, Bruno GALLAND**

Process Engineering Division

### ■ Presentation of motives and aims

Service life of respirator cartridges has always been a recurring question raised by users of respiratory protective devices (RPD). The aim of this study was to respond to this question by following two distinct yet complementary paths: developing a computer tool that provides an estimation of the predictive breakthrough time of a cartridge in given conditions and designing an onboard saturation detector that warns the user of the need to change the cartridge in real time.





### ■ Approach

Several experimental test systems had to be developed and employed to perfect knowledge of the real behaviour of cartridges during exposure to organic vapours.

The predictive calculation tool is based on the Wheeler-Jonas model and standard tests conducted on a test rig. From the exposures of each cartridge model to cyclohexane (vapour test laid down in Standard NF EN 14387), it was possible to determine the parameters that would allow extrapolation of the duration of use in the case of exposure to substances other than cyclohexane.

In parallel, a demonstration unit of an onboard saturation detector was designed and developed around a miniature gas sensor (sensitive surface area of 4 mm<sup>2</sup>). Inexpensive and robust, this metal oxide sensor has the advantage of reacting to numerous gases and vapours and of having been characterised at length during a previous study.

### ■ Main results

Designed by INRS, the tool to calculate the life cycle of cartridges, the PREMEDIA software, has been available on the website of the institute (<http://premedia.inrs.fr>) since summer 2013.

It allows users to determine the duration of use of a cartridge as a function of different exposure parameters which must be determined and entered: product(s) and associated concentration(s), environmental conditions, workload, type of respiratory protective device, and model and number of cartridges.

The onboard saturation detector demonstration unit, DETECSAT, was laboratory validated on the various test rigs of the laboratories. Ten autonomous demonstration units (electronic with integrated battery) allowed validation of the reliability and feasibility of the concept: as soon as a tiny amount of pollutant (well below the lower OEL currently in force) transits the cartridge, the demonstration unit sends a visual and audible signal to the user.

### ■ Discussion

PREMEDIA has aroused the interest of users (2,200 connections in two and a half months). Incorporating parameters such as high relative humidity and utilisation cycles should further enrich the tool. In addition, users have indicated that broadening the scope to include inorganic gases would be greatly appreciated.

DETECSAT has been presented to an industrial concern specialising in respiratory protective devices. A collaboration agreement ultimately aimed at developing an industrial prototype is currently being negotiated.



## Ventilation of confined spaces: application to degassing intermodal containers

**Robert BRACONNIER, François-Xavier KELLER**

Process Engineering Division

### ■ Presentation of motives and aims

Work in confined spaces is carried out inside areas that are totally or partially enclosed, occupied occasionally for inspection, cleaning, maintenance and repair operations, etc., and that have small-size openings (e.g. a manhole) through which air circulation with the surrounding atmosphere is greatly reduced. The aim of this study was to contribute scientific and technical data about the aerulic design of ventilation systems intended for work in confined spaces. The work primarily looked at reducing exposure to chemicals when opening, entering and emptying intermodal containers (stevedores, customs officers, handling staff of logistics centres or addressee enterprises). The atmosphere of these containers can indeed be polluted by vapours released by the goods being transported or by residues of any fumigation done to protect the goods against parasites or to hinder the spread of these parasites.

### ■ Approach

The process of degassing containers was examined in this study using two different methods: tracer gas measurements were taken in a port, and numerical air flow simulations were conducted using a numerical fluid mechanics software tool. The tests focussed on two of the most commonly used sizes of intermodal containers: 12 metres and six metres in length.

A comparative experimental validation of the application of the simulation methods used in this confined-space study was conducted in relation to the published data of the laboratory. This validation concerned the ventilation of an oxygen-deficient confined space.

### ■ Main results

Three container ventilation conditions were studied. In natural ventilation, degassing is carried out by only opening the door. In mixed ventilation, this door opening is associated with air being mechanically blown towards or extracted from the rear of the container. In forced ventilation, the door is closed and all air inputs and outputs are ensured by orifices transiting the panels or a door degassing system. The tests conducted allowed quantification of variations in degassing time as a function of various factors including container size, filling rate and load type. Natural ventilation performance turns out to be very variable depending on the environmental conditions, in particular the exterior wind direction and speed conditions. The use of a mechanically driven incoming or outgoing air flow, employed in both mixed and forced ventilation, greatly speeds up degassing. In mixed ventilation, extracting air from the rear of the container ensures faster degassing than feeding air into this zone. In forced ventilation, degassing speed is proportional to the ventilation flow rate employed. Moreover, this speed depends on the choice of air inlet position, the most favourable being located above load level.

### ■ Discussion

Many of the results acquired during this intermodal container degassing study can be generalised to other cases of air cleaning in confined spaces by general ventilation. For example, the priority given to the position of air inlets or the advantage of generating high air velocities that ensure maximum mixing of the air in confined spaces can be transposed to other occupational situations.



As part of this topic,  
twelve other studies are underway in 2014

- **Development of a prototype of a monocyclic aromatic selective chemical exposure sensor**  
> Bruno GALLAND and Patrick MARTIN - Process Engineering Division
- **Reducing the risks caused by grinding**  
> Eric SILVENTE - Process Engineering Division
- **Technical-economic assessment of ventilation systems incorporating an energy recovery unit**  
> Roland RAPP - Process Engineering Division
- **Development of a methodology to measure the dust emissions of electrical hand-held woodworking machines**  
> François-Xavier KELLER - Process Engineering Division
- **Joint assessment of the capture efficiency and ergonomics of fume extraction welding guns**  
> Francis BONTHOUX - Process Engineering Division
- **Impact of office area ventilation on internal air quality**  
> Laurence ROBERT - Process Engineering Division
- **Passive elimination of formaldehyde in the services sector**  
> Fabien GERARDIN - Process Engineering Division
- **Contribution to modelling the behaviour of respiratory protective equipment cartridges: exposure to complex atmospheres of organic vapours and effect of utilisation cycles**  
> Stéphanie MARSTEAU and Bruno GALLAND - Process Engineering Division
- **Separating the ultrafine particles generated by metalworking processes**  
> Denis BEMER - Process Engineering Division
- **Three-dimensional simulation of powder aerosolisation when transferring pulverulent materials**  
> Emmanuel BELUT and Jean-Raymond FONTAINE - Process Engineering Division
- **Interests and limits of dust wetting in industrial hygiene**  
> Fabien GERARDIN and Emmanuel BELUT - Process Engineering Division
- **Reducing PAH sources during pyrolysis operations**  
> Hubert MONNIER and Catherine CHAMPMARTIN - Process Engineering Division



# Mechanical risks and new technologies for accident prevention

In 2012, machinery was involved in 12.4% of occupational accidents with sick leave, 27% of which were due to lifting and handling, 24% to machinery, and 47% to tools (data provided by the French National Health Insurance Fund for Salaried Workers (CNAMTS)).

The machinery and personal protective equipment (PPE) directives and all of the accompanying standards, to which INRS has contributed to a large extent, have had a definite impact on reducing accident rates. Through its actions, INRS has contributed to making numerous items of work equipment safer.

INRS is playing a major part in preventing such risks by:

- > continuing the work aimed at making work equipment safer,
- > contributing to developing safe control systems,
- > making criteria available for choosing and using prevention systems based on new technologies, and
- > studying the real performance levels of PPE in order to improve use of such equipment.

## PRECEP: prevention of mobile worksite plant-pedestrian collisions

**Pascal LAMY**

Work Equipment Engineering Division

### ■ Presentation of motives and aims

Many sectors of activity are affected by the prevention of mobile worksite plant-pedestrian collisions, including civil engineering and construction, handling, and waste products. Regrettably, over the past decade there have been about 200 serious accidents, more than half being fatal. In the past few years, detection devices originating in the automobile production sector have been adapted to mobile worksite plant, and new technologies have emerged and been fitted to these vehicles, often on a case-by-case basis in response to requests from prevention professionals. These changes are at the origin of many requests from the CARSATs/CRAMs, but also from users and federations. This study aimed at looking for a structured approach to analysing risk, reviewing and assessing techniques for detecting obstacles and humans, conducting studies to assist in the development of new technologies, coordinating study initiatives, and assisting in and developing training and information tools to prevent this risk. The ultimate aim was to contribute elements of a response to dealing with the risks linked to mobile worksite plant-pedestrian collisions and to implement appropriate prevention solutions.



### ■ Approach

Six areas of work were tackled in this study. Area one allowed the definition of a prevention approach based, in particular, on activity analyses that characterised a number of work situations, both from the mobile plant standpoint and in relation to the presence of nearby pedestrians. This approach was presented in several enterprises, some having adopted it. Area two reviewed the different detection techniques by examining their human detection capability. The aim of area three was prospective studies, and even to contribute to the emergence of new detection technologies. Area four prepared the topic of driver visibility, and an ergonomic study of pedestrian recognition by means of camera-screen systems was carried out. Area five consisted in conducting a bibliographic study of human-machine interface aspects. Finally, area six aimed at constructing the framework for the different assistance initiatives and experiments conducted in the field and at establishing intermediaries in the field, notably with the drafting of a training module intended for prevention specialists.

### ■ Main results

The activity analyses conducted in three sectors of activity (grader in the civil engineering and construction sector, loader and cherry picker in the waste recovery sector and self-propelled bogie in the automobile industry) showed that the presence of pedestrians is real, even if the “no pedestrians in the movement zone of mobile plant” rule has been laid down, that the start-up and reversing phase has the highest number of risks, and that, depending on the activity, the view of drivers is insufficient to permanently monitor their surroundings.

The general approach to prevention proposed consists in favouring organisational measures, then in working on the complementary nature of the measures to improve visibility and those intended to introduce detection techniques to warn drivers of the presence of pedestrians in an at-risk zone. When detection systems are envisaged, the detection requirement must be clearly stated by taking into account, in particular, an analysis of the specific features of the work situation aimed at assessing the risk situations linked to the movements of the vehicle. It is then necessary to choose a detection system capable of fulfilling the need, either entirely or partly, fit it to the vehicle, and accompany and follow-up its use.

The main detection technologies available on the market were assessed and their characteristics of use clarified, which gives prevention specialists the elements necessary to orient their choice in the case where this prevention solution is envisaged.

The partnership entered into with the French Atomic and Alternative Energy Commission (CEA) has allowed image analysis technology to be transferred to the case of worksite vehicles. A product based on this technology is now being marketed.



The statistical analysis undertaken in the ergonomic study on the perception of a pedestrian by camera-screen systems showed that the image of a pedestrian must measure at least 10 mm on the screen for the pedestrian to be detected. It also highlighted the influence of conditions linked to the scene, including environment, luminosity and garments worn, on the detection ability of the driver.

The work conducted in this study resulted in:

- > scientific results with five presentations at congresses, and a publication submitted to an international journal,
- > written articles intended for prevention specialists (three INRS documentary notes, a brochure, and a chapter in the journal "Travail et Sécurité"),
- > knowledge transfers to prevention specialists and training of intermediaries with the creation of a general training course on vehicle and pedestrian movements within the enterprise, organisation of a technical day, and participation in "safety days" organised by professional federations or enterprises,
- > emergence of new detection device manufacturers.

### ■ Discussion

Re-establishing the visibility of at-risk zones is prerequisite to installing a human detection system. Visual aid systems contribute to assisting the driver, but alone are unable to reduce risks sufficiently.

The assessment of automatic pedestrian detection technologies has confirmed that no detection device exists on the market that is able to fulfil the role of a "protective device". However, they can contribute to reducing risk by intervening as a means to warn drivers, and even pedestrians, in the case of an at-risk situation in conjunction with visual aid systems providing the driver with visibility of the at-risk zones.

The prevention approach, which could lead to the use of a detection device, allows for a decision to be made regarding the relevance of installing an automatic detection solution while taking into account, for example, that too many alarms will lead to the driver rejecting the technical prevention measure.

The work on automatic image analysis technology has resulted in promising detection performance. It can be pursued in order to improve the compromise between false detections and non-detections, and also to integrate functions to self-check the correct operation of the system. Besides, it may allow a transfer of technology developed for cars to the case of mobile worksite plant, as a company is now marketing a product based on this technology.

## Validation of lashing procedures for steel products

**Pierre LEMERLE**

Work Equipment Engineering Division

### ■ Presentation of motives and aims

A French subsidiary of a European metallurgy group requested INRS to assist in improving its metal product stowage procedures, both to avoid load losses on public roads and to reduce the risk of accidents and the ergonomic impact on employees, particularly when securing these products. The products in question are steel wire meshes (used for reinforcing concrete structures). The meshes are transported in the form of coils on the trailer beds of heavy goods vehicles. A load comprises a maximum of 13 mesh coils, two being stacked.

The procedure in force in the enterprise requires the use of a minimum of eight lashings arranged transversally to the trailer and placed across the top of the mesh coils. The stacked mesh coils must compulsorily be lashed. Some ten wooden wedges are used to limit any rolling movement of the mesh coils on the trailer bed. The distribution of the wedges under the load does not respond to clearly established instructions.

## ■ Approach

The study was broken down into three phases:

An initial phase consisted in conducting extreme braking tests on a heavy goods vehicle with real scale loads. The aim was to acquire experimental data (movements, friction coefficients and strain forces in the stowage systems) to characterize and validate the laboratory braking test simulations. The loads studied were reduced to sets of between one and three mesh coils. These tests demonstrated the ineffectiveness of the current lashing rules, which do not guarantee immobilization of the mesh coils in the case of heavy deceleration.

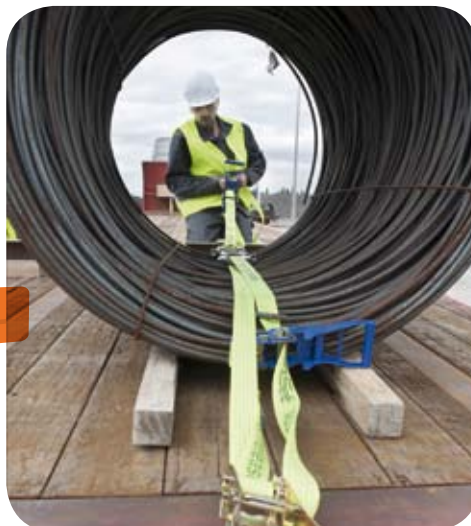
In the second phase, a braking test rig was designed and manufactured to carry out 1/6 scale simulations. Its principle is based on a rail guided platform, gravity driven by means of a system of weights and pulleys, which is then braked on contact with several layers of polyurethane foam of different thickness. The rig was fitted with instrumentation and allowed the testing of an original stowage method consisting in grouping mesh coils in twos and lashing them facing each other by means of two top-over lashings arranged obliquely. The validation of this lashing was carried out in real scale in the third phase during an extreme braking test on the heavy goods vehicle. No wedge was necessary to retain the mesh coils in any of the test configurations tested.

## ■ Main results

This study resulted in recommendations being given to the enterprise to systematically stow the coil meshes obliquely (transversal top-over lashing of the stacked mesh coils). The number of stowage resources is minimized as the method requires only one lashing per mesh coil. This method is safe and does away with wedges. It also limits the risks run by operators by doing away with coactivity operations. Particular attention must be paid to the anchoring of the lashing points on the outer edge of the trailer to avoid any risk of the load sliding.

## ■ Discussion

The interest of this study goes beyond the results obtained, having led to the development of a safe stowage method. It has been shown that an experimental approach based on reduced scale tests allows a rapid and accurate test of efficient and optimized stowage methods in terms of the resources employed.





As part of this topic,  
three other studies are underway in 2014

- **Safety of servomotor presses**  
> James BAUDOIN and Jean-Paul BELLO - Work Equipment Engineering Division
- **Development of a method to specify the requirements of an electro-sensitive device and a guide to choosing**  
> David TIHAY - Work Equipment Engineering Division
- **Safety net ageing: understanding the phenomena and analysis of the test methods**  
> Ghislaine GRAND - Work Equipment Engineering Division



# Psychosocial risks

On the basis of European studies by Eurofound in Dublin and by the European OSH Agency in Bilbao, and of French surveys by DARES (France's Research, Development, Studies and Statistics Directorate), the issue of psychosocial risks in working situations emerged in the early 1990s, grew considerably to the early 2000s, and then levelled off with a period of relative stability over that decade, but the situation is deteriorating once again due to the economic and financial crisis. Psychosocial risks (PSRs) concern all categories of workers (executives, employees, and self-employed workers), and all sectors of activity.

Exposure to PSRs can increase by 50% to 100% the risk of cardiovascular diseases, musculoskeletal disorders (MSDs) or mental pathologies. The high prevalence of exposure to work-related psychosocial factors, and their impact on health in terms of pathologies that are disabling for the working population and in terms of cost for society, make psychosocial risks a major public health issue.

The work done by INRS is aimed in particular at:

- > giving firms and OSH specialists tools for diagnosing PSRs and new methods of preventing PSRs,
- > studying the effects of new organisational factors and new constraints on physical and mental health, and mechanisms for regulating such effects,
- > exploring work factors favourable to health construction,
- > developing tools for objectifying factors in PSRs.

## Modelling violent situations at work

**Marc FAVARO**

Working Life Division

### ■ Presentation of motives and aims

The study was aimed at formalising the organisational dynamics contributing to the emergence of violence at work and their prevention prospects. This work results from the observation of the inexistence in the French language literature of a general model, (the available models are highly specialised, either by type of suffering or by sector), capable of promoting a comprehension of the various types of violence observable in different professional contexts.

### ■ Approach

The methodology is based on the experience of a field intervention conducted over several years in an enterprise faced with various problems of violence, as well as on the data in the international literature related to this field. It also exploits the theoretical knowledge acquired along with work system accidentology and reliability methods.

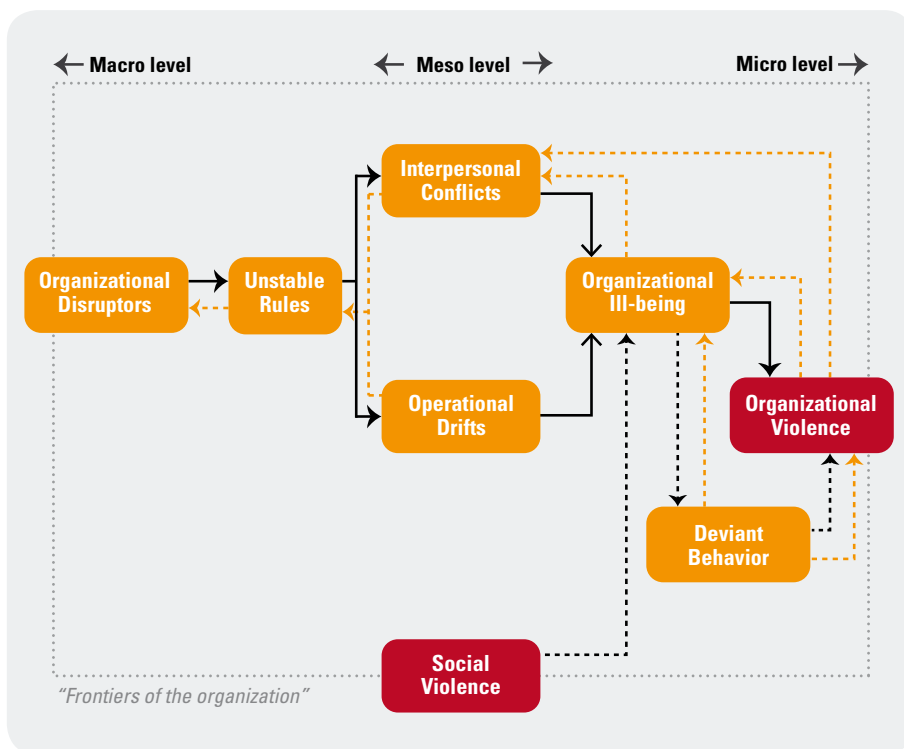




On this basis, the approach consisted in establishing different ‘patterns’ grouping related situations. For example, the class “Operational Drift” (cf. schematic below) groups examples of drift: job (strikes, lateness, and absenteeism), technical (physical accidents, incidents), psychological (lack of motivation, isolation), etc. The patterns were then linked to each other to depict the relationships (causal or more circular, represented in the schematic below by the black and orange arrows) contributing to the emergence of acts of violence and their possible evolution (regulation, attenuation, exacerbation).

■ Main results

The schematic below presents the model developed during the study. It comprises six classes (of an organisational, technical, relational nature, etc.) contributing to the emergence of situations of “social/external” and “organisational/internal” violence.



■ Discussion

The points of discussion stemming from this work result from its inductive and qualitative dimension. They primarily concern the issue of the limits of validity, applicability and adaptability of a model of this type when transferred to different areas of enterprise.

Concerning the applicative prospects of the model, they comprise four aspects: **documentary** (structuring the literature in a coherent conceptual framework), **pedagogical** (presenting the mechanisms of formation of violence and the associated means of prevention), **interventional** (improving the management of prevention actions and contributing to promoting innovative practices), and **normative** (taking part in the drafting of a reference position regarding the prevention of violence at work).

## From psychosocial risks to organizational factors: approach using a Health/Well-being questionnaire

**Vincent GROSJEAN**

Working Life Division

### ■ Presentation of motives and aims

Several transnational bodies and European countries have developed approaches to well-being at work in response to the rise in psychosocial risks. Seeking to emphasize the constructive character of good health in work activities, these approaches underline the benefits in terms of performance to an enterprise that listens to the ambitions of employees.

This study is an extension of previous work that resulted in the drafting of a validated initial version of a health/well-being questionnaire. Designed with the aim of promoting constructive dialogue bringing together HR departments, employees or their representatives, and bodies tackling occupational health issues, this tool has been integrated into an approach intended to transform the organisational conditions of work execution.

The first aim of the study consisted in consolidating the scientific basis of the questionnaire and making it self-supporting. Thereafter, this involved verifying that a large enterprise could adopt it and employ it in all its subsidiaries and sites.

### ■ Approach

A thorough analysis of the theoretical models linking organisational factors, stress, and health was conducted. This allowed the construction of a taxonomy of the characteristics of work environments which, according to these models, have an impact on health from a psychosocial angle. This taxonomy was employed to construct a second version of the questionnaire.

The psychometric validation and the operational effectiveness of the tool were verified within the context of several interventions. Interviews with employees were conducted to check for correct understanding of the items. Interviews with third-party users of the questionnaire (occupational health services, advisory consultants, HR departments) were also conducted to better identify the real uses of the tool and the accompanying approach.

A transfer to an enterprise present throughout France was initiated to verify that the occupational physicians and the HR managers were able to adopt the tool.

### ■ Main results

The analysis of the aforementioned theoretical models was published, and the taxonomy of the characteristics of the work environments stemming from this work resulted in a second version of the questionnaire. A user handbook and automated analytical tools were developed. The handbook has been available to users on the INRS site since January 2013, while several amendments have been made to the tools.

The examination of the practices of users showed changes to the take-up of the tool. While it had been developed to respond to the needs of occupational health services (the questionnaire was given out during the periodic visits), it turns out that it was mainly employed outside of these contexts, by consultants and HR managers in particular.

The wide scale test identified a number of difficulties linked to its use over a long period. Difficulties related to non-attendance must be taken into account in an enterprise where the workforce is mobile and the regularity of medical visits varies from one employee to another. Insofar as the questionnaire is employed uniquely at a collective level, it turns out that it is undoubtedly easier to propose handover procedures that can be uncoupled from the periodic visit and to remind enterprises that utilisation foreseeing handover at fixed periods is also possible, as is the case with periodic surveys for example.

## ■ Discussion

The philosophy underpinning the development of the questionnaire is an important element of its attractiveness, as is the relative ease of application brought by the associated tools. Setting it apart from questionnaires thought out in terms of diagnosis, the designers of this tool considered that the key point was the introduction of a non-conflictual dialogue around working conditions. Adopting this position has not meant going back on the outcome of the study. The HR function constitutes a new group requesting such tools, which go beyond observation in order set in motion transformation actions.

## Promotion of a policy of well-being in service sector enterprises

**Vincent GROSJEAN**

Working Life Division

### ■ Presentation of motives and aims

Small service sector enterprises are an important target for psychosocial risk related interventions. Psychosocial questions carry a great deal of weight compared to other prevention questions, whereas methodologies built around questionnaires are poorly adapted due to limited workforces. As intervention is involved, the systemic framework appeared interesting: it favours rapid action, has been used in contexts with similarities to small-size enterprises, and rules out individual criticism in favour of taking interactions into account. Following on from the work on well-being, the main aim of the study was to develop and then test a method to intervene on psychosocial risks, constructed on the basis of systemic theories, for these service sector SMEs.



## ■ Approach

A bibliographic search allowed the construction of an intervention method and the identification of relevant tools and concepts for the context retained. The methodology can be broken down into three parts: an information gathering phase by means of interviews, a collective dialogue phase, and a change implementation phase. Two outcomes are essential to the systemic approach: the construction of the conditions necessary for those directly involved in the enterprise to stand back and consider the situation, and the promotion of dialogue oriented towards solutions that rule out bringing people into question. The methodology was applied in five enterprises. An assessment of the results of these interventions was conducted by analysing multiple cases on the basis of the interviews carried out among the employees concerned. Criteria such as autonomy in implementing changes and their extent were used to judge success and the difficulties encountered in relation to the precise techniques employed and to the overall method. The three questions central to this assessment encompassed the conditions of change, the results obtained subsequent to the intervention, and the nature of the changes obtained.

## ■ Main results

An intervention method was produced and matched with tools (e.g. circular questions, images-contexts) usable in the information gathering phases among employees, then during the dialogues/restorations. It involves a method based on a coherent conceptual context and benefits from a recognized scientific foundation. It joins other recent methodological developments by its characteristic of being focused on the empowerment of employees turning their backs on growing normative pressures. Recommendations concerning the position of external participants have also emerged from the theoretical framework tested in this study.

Concrete tools for the use of external participants on issues of well-being/PSR were also produced: intervention guide and back-up material for the interview and restoration. They have been made available to external participants by way of the INRS site.

## ■ Discussion

The ease of use of the method turned out to be dependent on the structural characteristics of the enterprises in which the interventions were conducted. It is better suited to structures with an entrepreneurial rather than a regulatory culture. If the work is to be pursued, it could go further in exploring the links between the modes of governance of the enterprise and the values underpinning the intervention.

# Prevention of psychosocial risks and transformation of the practices of occupational physicians

**Eric DRAIS**

Working Life Division

## ■ Presentation of motives and aims

In the context of the health multidisciplinary approach introduced by the law of social modernization of 2002, the study "Prevention of psychosocial risks and transformation of the practices of occupational physicians" was aimed at examining the practices of occupational prevention teams, who are faced, in particular, by emerging risks such as psychosocial risks (PSR). The first aim of this study, carried out for the purpose of a PhD thesis in sociology, focused on knowledge, with particular emphasis on documenting the functioning of a multidisciplinary team and on approaches to preventing PSR.





The associated aim was to analyse potential needs in terms of prevention tools or methods. The theoretical approach retained proposed considering the functioning of occupational health teams – essential players in preventing suffering at work – as the outcome of professional dynamics linked to the strategies of those involved and to adjustments between professions or professional groups.

### ■ Approach

To examine the professional adjustments of occupational physicians linked to a recent and gradual reform of occupational health HP and safety, the study, qualitative in nature, opted for a longitudinal and comparative follow-up between teams. The observation took place from April 2010 to April 2012 at a French regional level. For practical reasons relative to the survey, this study excluded occupational health teams dedicated solely to one company and took place in inter-companies occupational health teams. The methodological resources employed to conduct the study, besides a regularly updated review of the literature, combined an ethnographical survey in three teams of differing sizes spread over a region, and observations of national and regional professional gatherings (conferences, seminars, training courses, etc.). In these two complementary contexts, 125 interviews were conducted, including over forty among occupational physicians, the others involving occupational risk prevention personnel (ergonomists, nurses, psychologists, prevention or health assistants, etc.) and institutional bodies (CARSAT (Regional health and retirement insurance fund), ARACT (Regional agency for the improvement of working conditions), DIRECCTE (Regional executive for enterprises, competition, consumption, work and employment), local institute of occupational medicine, academics, etc.).

### ■ Main results

Although multidisciplinary as a principle appears as a consensual response to occupational health challenges, including mode of organisation, it does cause a division of work and collaboration modes that can generate professional conflicts, in particular for PSR. For some, PSR prevention is based on proven practices and is found in professional areas well identified within occupational health teams, whereas for others this prevention is being created. Through new action modes (service provision, etc.) and new professionals (occupational risk prevention personnel, assistants, etc.), a professional restructuring is taking place, reinforced for PSR requirements, which goes beyond corporatist stakes. Multidisciplinary, as a management tool, encompasses economic and administrative logic allowing for prevention renewal.

### ■ Discussion and conclusions

The study has looked at the implementation of the reform of occupational health and has highlighted the different views and representations of health caused by the functioning of health teams in a multidisciplinary structure, between which physicians decide the outcome or more often waver. The analysis has thus clarified the professional activities which, at corporate and professional or institutional levels, are combined and allow for local and detailed conditions of health care, notably mental, of employees at work. Knowing the basics of the options structuring PSR prevention will help to adjust the tools and methods made available to health professionals.



As part of this topic,  
three other studies are underway in 2014

■ **Assessment of PSR and MSD prevention interventions**

> Christian TRONTIN - Working Life Division, Stéphanie BOINI-HERRMANN - Epidemiology  
in Enterprise Division, Dominique CHOUANIERE - General Executive

■ **Work situations with a high emotional load and organizational prevention practices**

> Corinne VAN DE WEERDT - Working Life Division

■ **Interactions between health and work: effect of psychosocial work conditions on the evolution  
of mental health**

> Stéphanie BOINI-HERRMANN and Michel GRZEBYK - Epidemiology in Enterprise Division

And other studies exploring this subject are mentioned in the topics  
"Musculoskeletal disorders of the limbs and of the back", and "Design  
of Work Equipment, Workplaces, and Working Situations".



## Occupational road accident risk

Large numbers of employees spend large fractions of the day behind the wheel of a vehicle for doing their job. They are therefore exposed to occupational road accident risks. In addition to the risk of accident, driving for work reasons exposes employees to other occupational risks, such as psychosocial risks or musculoskeletal disorders, and INRS is paying attention to these other risks.

In addition to the prevention actions in collaboration with the French National Health Insurance Fund for Salaried Employees (CNAM-TS) and with the various Trades Associations, INRS is proposing to study the effect of using a motor vehicle on the health (excluding accidents) of employees who drive for work reasons.

The results of prior research into the interior design of light commercial vehicles are going to enable tests (industrial interior design in the event of emergency braking or of impacts) to be transformed into prevention solutions, for vehicle manufacturers and vehicle interior designers.

## Assessment of the load restraint ability of fitted light vans during frontal crash

**G rard FLEURY**

Work Equipment Engineering Division

### ■ Presentation of motives and aims

Few studies have examined the secondary shocks between people and objects transported inside a vehicle during a road accident. However, the accidentology data indicate that this risk is significant. This is the case in particular for the occupants of the three million light vans used by enterprises to transport goods and the material necessary for their activities. To protect the occupants in the case of a frontal collision, the load must remain firmly stowed in the vehicle. More and more, the rear of light vans is equipped with furniture manufactured by industrial fitters. In 2010, an INRS published metho intended to assess the ability of fitted furniture to retain its contents in the case of a frontal collision. The laboratory test consists in reproducing the conditions of a 50 km/h accident of a light van equipped with furniture with loaded racks. As a vehicle cannot be destroyed for each fittings tested, the furniture is installed on a rigid support. However, in a real situation, the bodywork can tear away from the furniture attachment points. This study aimed at making this protocol more realistic and at exploiting it in industrial concerns with a view to their designing more resistant furniture.

### ■ Approach

Two types of measurements were taken: the tear resistance at various points of a bodywork panel and the dynamic forces transmitted by the furniture to the rigid support during the NS286 tests. In parallel, calculation models were developed to improve the understanding of the phenomena at work. A specification was drawn up for selecting, designing, sizing and producing a device representative of an anchor point of a light van intended for insertion between each lateral furniture attachment point and the rigid support, as used during a NS286 test.



## ■ Main results

A anchoring device with a set rupture value (ball joint giving way at a force of 8,000 Newtons) was developed and produced. Test protocol NS286 was amended to integrate this device. By proposing to conduct the tests with anchor points giving way at 8,000 Newtons, method NS286 has become more realistic, but also more constraining. This improvement must encourage vehicle fitters to optimise their fixing brackets. Solutions do exist, notably that developed by INRS based on the principle of an energy absorption bracket.

## ■ Discussion

The majority of vehicle fitters proposing metal and/or wooden solutions, not only in France but also in Germany and Sweden, have already conducted NS286 tests and regularly report on progress made via the professional press. An increasing number of enterprises using light vans have integrated a constraint of compliance with the requirements of method NS286 into their technical specification for purchasing furniture and fittings. Work intended to exploit the results of this study will be pursued.



As part of this topic,  
one study is underway in 2014

### ■ Driving a light van, working conditions and musculoskeletal disorders among parcel delivery operators

> Anca RADAUCEANU and Stéphanie BOINI-HERRMANN - Epidemiology in Enterprise Division



# Musculoskeletal disorders of the limbs and of the back

Musculoskeletal disorders (MSDs) of the limbs and of the back accounted for 85% of occupational diseases recognised by the general social security system in France in 2011. They remain a major occupational health issue in view of the socioeconomic and medical costs that they generate.

The actions undertaken for MSDs and low back pain are conducted in synergy with numerous partners (institutional players or research organisations). They involve ergonomics, biomechanics, and design of work equipment and of workstations.

As regards research, INRS is proposing:

- > to assess and to adapt the intervention strategies to various contexts (sociological approach by targeting more particularly small and medium-sized enterprises),
- > to develop methods and tools incorporating the most recent knowledge on relationships between organisation, psychosocial factors, biomechanical factors, and MSDs, and to transfer them to OSH specialists and to managers on site, and
- > to introduce MSD prevention principles into the process of designing working situations (gestural variation, less demanding tools, etc.).



As part of this topic,  
four studies are underway in 2014

- **Identification of the emerging determinants linked to the risk of MSD: ergonomic and biomechanical analysis of the activity of meat cutting**  
> Adriana SAVESCU - Working Life Division
- **Local supervision and prevention of MSDs: representations and actions**  
> Aude CUNY - Working Life Division
- **MSD and screen work: effects of mouse type and position of dominant upper limb on biomechanical risk factors**  
> François CAIL, Clarisse GAUDEZ - Working Life Division
- **Development and validation of a walking system to assess postures and movements of the upper limb in real work conditions**  
> Adriana SAVESCU - Working Life Division

And other studies exploring this subject are mentioned under the following topics: "Psychosocial Risks", "Design of Work Equipment, Workplaces, and Working Situations", "Ageing, Staying in Work and Preventing Occupational Exclusion", and "Occupational Road Accident Risk".

# Ageing, staying in employment, and preventing occupational exclusion

The issue of ageing at work remains little-addressed in firms, in spite of the obligation to set up “senior” agreements since 1st January 2010. And yet the population of working age is ageing, in particular due to the rise in the number of employees in their fifties over the next 15 years, and due to the 2010 pension reform that raised the legal retirement age to 62 years in France.

INRS studies and research in this field have three focuses:

- > Putting together strategies for raising the awareness of companies to the issue of ageing at work.
- > Acting on constraints responsible for premature ageing (approach for assessing risk factors, and adapting working situations for older workers).
- > Establishing positive and negative determinants between career and health on the basis of various parameters: socio-professional category, sector of activity, working conditions, career changes or interruptions, unfitness for work, changes in physical functional capacities, etc.).



As part of this topic,  
four studies are underway in 2014

- **How can enterprises be helped to better integrate the question of health and prevention into age management policy?**  
> Isabelle SALMON - Working Life Division
- **Comprehensive assessment approach to arduous work**  
> Kevin DESBROSSES, Jean-Pierre MEYER and Emmanuelle TURPIN-LEGENDRE  
Working Life Division
- **Age related impact of varied temporal constraints in an assembly task on biomechanical and physiological exertions**  
> Martine GILLES, Laurent CLAUDON and Anne PICHENE HOUARD - Working Life Division
- **Assessment of physical functional abilities as a function of the physical constraints encountered over the course of a professional career**  
> Emmanuelle TURPIN-LEGENDRE - Working Life Division

And other studies exploring this subject are also mentioned under the following topics: “Psychosocial Risks”, “Musculoskeletal disorders of the limbs and of the back”, and “Ageing, Staying in Work and Preventing Occupational Exclusion”.



# Partnerships

The INRS strategic plan identifies as an objective for studies & research to “Associate INRS with the national and/or international research teams”. In practice, scientific partnerships frequently constitute working frameworks for INRS research teams. Many theses in partnership are supervised at INRS in partnership with universities. Furthermore, INRS is increasingly involved in research projects funded by ANR, ANSES, ADEME or European agencies.

A majority of the studies currently being conducted are being run in partnership, be it with French universities or organisations (ANACT, ANSES, CEA, CNRS, InVS, INERIS, IRSN, etc.), or with foreign universities or counterpart institutes (IFA, IRSST, IST, NIOSH, etc.), or indeed with the French networks of health insurance, occupational health insurance, and pensions insurance bodies (CRAMs/CARSAT), and with the European or international networks (PEROSH, ISSA).

## Twelve research projects have been conducted with external co-funding

### ■ 4 European projects

- > **Nanogenotox:** closed in February 2013, this project aimed to propose methodology for studying the genotoxicity of manufactured nanomaterials. Over a period of three years, seventeen research institutes took part in developing an *in vitro* analysis method applicable to nanomaterials based on data from experiments on animals, INRS being more particularly in charge of the silica samples.
- > **Nanodevice:** this European project that closed in March 2013 brought together twenty-six partners and its objectives were to study the aspects of the safety of nanomaterials while they are being manufactured. It made it possible to develop new concepts, reliable and portable methods, detection devices, and means for analysing and monitoring nanomaterials manufactured in air. The major contribution from INRS was to develop and validate a test bench for controlled generation of nanoparticles (CAIMAN).
- > **NanoReg:** INRS is a partner in the European project NanoReg that is co-ordinated by the Dutch Ministry for the Environment and that was initiated in 2013. About sixty partners from 16 Member States are taking part in the project for a period of four years, with the aim of making relevant methods available to the legislator for improving assessment and management of the risks related to nanomaterials for humans and the environment, and for improving regulations relating to those materials. Essentially, the work will be focused on characterising nanomaterials, developing *in vitro/in vivo* methods of testing for ecotoxicology and toxicology, and determining exposures throughout the life cycle of nanomaterials.
- > **NanoCen:** Under Mandate 461, the European Commission has commissioned CEN, CENELEC, and ETSI to standardise activities relating to nanotechnologies and nanomaterials. INRS is taking part in several projects including pre-standardising research actions and developing 8 standards, and it is steering the actions relating to nanomaterials in powder form. In 2013, INRS took part in an inter-comparison campaign for mutually comparing condensation nucleus counters (CNCs) with its German counterpart IFA, developed measurement protocols associated with the Nanoduster test bench, and conducted tests jointly with its Polish counterpart CIOP.

## ■ At national level, INRS is involved in:

### ■ 3 projects for the French National Agency for Food, Environmental and Occupational Health & Safety (ANSES)

- > GABO: acoustic discomfort in open-plan offices.
- > MEPAS: method of predicting the soundscape in open-plan offices.
- > DICER: defining indicators for characterising exposure to radiofrequencies.

### ■ 3 projects for the French National Research Agency (ANR)

- > The MESURE project that was closed in April 2013 aimed to develop flexible statistical approaches for modelling relative survival.
- > The CENSUR project, following on from the MESURE project, aims to apply the methods developed: for this project, INRS is developing methods specific to the issue of occupational health studies.
- > The aim of the MYCODIAG programme is "Integration of selective tools for analysing Ochratoxin A – diagnostic methods for assessing toxicological risks". The aim of INRS's actions is to test the use of certain instruments for analysing the samples to be used in industrial hygiene (atmospheric samples of contaminated dust).

### ■ 2 projects for the French National Environment and Energy Management Agency (ADEME)

- > The objective of the project REFORBA is to develop a process of recycling automotive shredder residue. With the unit operations of the recycling process having been defined and tested by the project coordinator (BRGM, the French Geological Survey bureau), in 2013 INRS evaluated their pollutant emissions with a view to proposing reduction solutions during the industrial development phase.
- > The objective of the project ATENA is to optimise conventional methods of dust removal when dealing with fine particles such as particles emitted by metal coating processes. In 2013, the work on bubble columns was continued with the study of parameters such as bubble residence time, air flow rate, bubble size, and presence of packing.

## International partnerships

International partnerships are initiated through institutional networks such as PEROSH, through the European OSH Agency of Bilbao, or on the basis of bilateral relations:

### ■ PEROSH

In order to reinforce European scientific knowledge sharing, INRS is involved in the PEROSH (Partnership for European Research in Occupational Safety and Health) network that brings together, at European level, the main occupational safety and health research bodies (12 bodies and 11 countries). INRS has chaired the PEROSH since 2011. Research projects are also being developed through the PEROSH and INRS is actively participating in three of them:

- > **Exposure to nanomaterials through the NECID** (Nano Exposure and Contextual Information Database) Project that aims to build a European database, by making advantageous use of the data on exposure to nanomaterials and of the related contextual information.
- > **Determining the protection factors of respiratory protective devices (RPDs)**, in particular by developing a harmonised protocol for evaluating their protection efficacy in real-life use situations.
- > **Well-being at work**: the main objective of the project being to develop a common understanding of the concept of well-being, and to define focuses for research and actions in various countries.



## ■ The Bilbao-based European Agency for Safety and Health at Work

- > In October 2013, in collaboration with the European Agency of Bilbao, INRS organised a seminar entitled “Moving towards 2020: Priorities for occupational safety and health (OSH) research in Europe for the years 2013-2020”. The objective of the seminar was to discuss the conclusions of the Agency’s report on the European priorities for safety and health at work. That report had been co-ordinated by INRS in collaboration with partners FIOH (Finland), BAUA and IFA (Germany). The report and the seminar were an opportunity to exchange views and ideas about the needs for new knowledge in occupational safety and health and about the research focuses of the various OSH players in Europe.
- > INRS has also been continuing to work in partnership with the Agency on the tool for Online interactive Risk Assessment (OiRA). The Institute has developed a sector-based second tool designed for small restaurant and catering businesses.

## ■ Other partnerships

Internationally, in 2013, INRS continued to be involved in bodies such as the International Labour Organization, the European Agency of Bilbao, ISSA, etc. and to develop joint research projects with its counterparts.

- > For instance, a new co-operation agreement was signed with the AIHA in 2013. It concerns a modelling tool known as “IH SkinPerm” enabling occupational chemical risk prevention specialists to estimate absorption through the skin of chemical pollutants. Through this cooperation, INRS will be able to distribute a version of the software in French on its website.
- > In the course of its cooperation with IRSST (Quebec), an amendment was signed to the “ProtecPo” specific partnership agreement. That amendment will make it possible to continue to gather and to enrich the data for pre-selecting polymer materials used in personal protective equipment for use when handling solvents.
- > Continuing on from our cooperation with IRSST on chemical risks, a tripartite agreement has been signed with IRSST and the University of Montreal concerning the software MIXIE. That software makes it possible to assess chemical risks in the context of co-exposures to pollutants. The objective, for INRS, is to adapt the software to accommodate the French occupational exposure limit values and then to make the tool available to OSH stakeholders in France.
- > INRS is also working with the Institute for Work and Health of Lausanne (Switzerland). Work has been done in collaboration on cutaneous permeation and tarmac fumes. Other subjects are being addressed by less formal collaborations (beryllium, mycotoxins, etc.).

## ■ Long-term partnerships with university-based research units

A particular form of partnership involves setting up integrated teams known as “project teams”, making it possible to pool skills and facilities for achieving common goals. In 2013, four project teams were already set up and a fifth was in the process of being set up.

- > **Filtration et Adsorption (LFA, Filtration and Adsorption Laboratory):** between CNRS’s Process Engineering and Reactions Laboratory (LRGP), and INRS’s Pollutant and Air Cleaning Process laboratory (PROCEP).
- > **Laboratoire Mixte de Prévention de la Pollution (LMPP, Joint Pollution Prevention Laboratory):** between the Energetics, Theoretical and Applied Mechanics Laboratory (LEMTA), a CNRS-University of Lorraine joint research unit, and INRS’s Aerodynamics Engineering laboratory.
- > **Acoustics of Surfaces in Industrial Workplaces (APLI, Acoustique des Parois dans les Locaux Industriels) Project Team:** between the LEMTA and INRS’s Occupational Noise Reduction laboratory.

- > **Safe Design of Working Situations Laboratory (LC2S, Laboratoire Conception Sûre des Situations de Travail):** between the Design-Manufacture-Control laboratory of ENSAM Paris Tech in Metz, and INRS's Safe Systems Design Engineering laboratory (Ingénierie de Conception des systèmes sûrs).
- > **A new project team** is being prepared between the Interactions between Genes and Environmental Risks and Effects on Health (INGRES) "Équipe d'Accueil" (research unit receiving PhD students).



### A new research partnership signed by INRS, University of Lorraine, and CNRS

INRS, the University of Lorraine, and France's National Scientific Research Centre (CNRS) signed a framework partnership agreement on Monday 28 April 2014, World Day for Safety and Health at Work.



From left to right, Messrs Pierre MUTZENHARDT, President of the University of Lorraine, Wilfrid STRAUSS, Director of INRS's Lorraine Centre and Philippe PIERI, CNRS's Regional Delegate for the Centre-East Region

This collaboration will make it possible to set up **joint research**, participation in European projects, in symposia, or in any action ensuring the scientific and technical culture is developed. Furthermore, it will foster **sharing of facilities, thereby rationalising the use of resources and means**. As regards teaching, the University is paying particular attention to developing vocational courses. In this context, **new training courses in occupational risk prevention could be deployed in the medium term in initial higher education syllabuses in Lorraine**, based on INRS's expertise.





## Supervision of PhD theses

These partnerships are also conducive to joint supervision of university theses, procuring mutual scientific enrichment and pooling of resources at the service of improvement of knowledge. In 2013, 26 doctoral researchers in all have contributed to the INRS's programme of activity, and the following nine theses have been defended:

- > Modalités de médiation et de restitution inspirées de l'approche systémique, dans le cadre d'interventions "bien-être" dans les PME du tertiaire (mediation and restoration procedures inspired by the systemic approach, in the context of "well-being" actions in tertiary small and medium-sized enterprises: Virginie ALTHAUS
- > Intelligibilité dans les espaces de travail ouverts : étude de la gêne dans un environnement multi-sources de paroles (Intelligibility in open-plan workspaces: study of discomfort in a multi-speech-source environment): Ange EBISSOU
- > Gestion de l'équilibre d'un mannequin virtuel dans un environnement fortement perturbé (Management of balance of a virtual manikin in a highly disrupted environment: Darine MANSOUR
- > Étude et conception de la commande de mannequins virtuels dynamique pour l'évaluation de l'ergonomie des postes de travail (Study and design of dynamic virtual manikins for assessing workstation ergonomics): Giovanni DE MAGISTRIS
- > Modélisation multiparamètres de l'adsorption de vapeurs organiques : effets de l'humidité, des cycles et des copolluants (Multi-parameter modelling of adsorption of organic vapour: effects of humidity, cycles and co-pollutants): Romain CHAUVEAU
- > Dynamique d'un nuage de nanoparticules : modélisation de la coagulation des particules et du transfert d'agrégats (Dynamics of a cloud of nanoparticles: modelling coagulation of the particles and transfer of clusters): Romain GUICHARD
- > Application des techniques de biologie moléculaire pour la caractérisation des bioaérosols (Application of molecular biology techniques for characterising bioaerosols): Laetitia BETELLI
- > Développement d'outils de caractérisation physico-chimique des particules ultrafines (Development of tools for physically and chemically characterising ultrafine particles): Thibaut DURAND
- > Évaluation de l'efficacité des réflexes de protection de l'oreille par la mesure des produits de distorsion acoustique chez le rat : développement d'un nouvel outil clinique pour l'homme (Evaluation of the efficacy of ear protection reflexes by measuring the acoustic distortion products in the rat: developing a new clinical tool for humans): Cécile RUMEAU



## Other national partner teams

Among the other teams that have contributed significantly to the studies conducted in 2013 at INRS for addressing certain research issues in the best possible way, we might also mention:

- > **Endocrinology Department of the Teaching University of Nancy:** Research on endocrine disruptor type effects, when exposed to DiNP in an industrial environment.



- > **University of Montreal Hospital (CHUM, Centre Hospitalier de l'Université de Montréal) and Institute for Health and Work in Switzerland (IST, Institut Universitaire Romand de Santé au Travail):** Decision assistance models for evaluating occupational exposures (MIXIE) and a project relating to creating exposure models on the basis of data available in the Colchic and Scola databases.
- > **Faculty of Medicine of Lille (pôle Inflammation pulmonaire et toxiques professionnels et environnementaux (Centre for Pulmonary Inflammation and Occupational and Environmental Toxic Substances)):** Occupational exposure to beryllium and effects on respiratory health.
- > **Laboratoire d'Hygiène de la Ville de Paris (Paris City Hygiene Laboratory):** developing a method for measuring bioaerosols (1,3)- $\beta$ -D-glucans in workplace atmospheres.
- > **University of Lyon 1 and IFSTTAR (French Institute of Science and Technology for Transport, Spatial Planning, Development and Networks) in Lyon:** developing an ambulatory system on the basis of inertia sensors making it possible to obtain a realistic representation of postures and of movements of the upper limbs.
- > **Laboratory of Chemistry, Physics, and Microbiology for the Environment (Laboratoire de Chimie Physique et Microbiologie pour l'Environnement, a CNRS/University of Lorraine joint research unit):** Developing a prototype sensor for selectively sensing chemical exposure to monocyclic aromatics.
- > **Fluid Mechanics Institute of Toulouse (IMFT, Institut de Mécanique des Fluides de Toulouse) (CNRS-INPT (Institute National Polytechnique de Toulouse)):** Three-dimensional simulation of aerosolization of powders when transferring materials in powder form.
- > **ANACT (French National Agency for the Improvement of Working Conditions):** developing evaluation of complex interventions for preventing MSDs and PSRs, conceptualisation of a theoretical framework for evaluation in 2013.
- > **PACTE (Public Policy, Political Action, and Local Development) Laboratory of the Université Pierre-Mendès-France of Grenoble:** two collaborations: identifying the role of on-site management in preventing MSDs on the basis of analysis of real activity in a context of internal sub-contracting in the agri-food sector, and construction and management of risks related to nanoparticles in industry and in research laboratories.
- > **Business Administration Institute (Institut d'Administration des Entreprises) of the University of Grenoble:** studying age management in firms in relation to taking account of occupational health.
- > **JF Champollion University Centre for Training and Research in Albi (Centre universitaire de formation et de recherche JF Champollion (Albi)):** analysing cognitive activities in operators in the transport sector, and elements in generalising planning activities for improved prevention.
- > **The Cognition, Languages and Language, and Ergonomics Laboratory (Laboratoire Cognition, Langues, Langage, Ergonomie) of the University of Toulouse 2:** broadening knowledge of the effects related to introducing New Information and Communication Technologies in networked companies from a psycho-ergonomic angle and in a prevention approach.
- > **Work Study Institute (Institut d'Etude du Travail) of Lyon:** project for transformation, territoriality and occupational health: experimentation on extending sorting of plastic packaging.
- > **Health, Work, and Environment Laboratory (Laboratoire Santé Travail Environnement) of the Inserm Centre U897 and of the University of Bordeaux Segalen:** Ergonomic identification of situations of exposure of skin to asphalt during road works, and developing shared prevention practices.
- > **Institut Jean-Lamour (CNRS Nancy):** custom synthesis of nanomaterials for studies on the relationship between the physical and chemical parameters of nanomaterials and their toxicological properties.
- > **Health and Work Division (Département Santé-Travail) of the French Institute for Public Health Surveillance (Institut de veille sanitaire):** INRS is taking part in setting up the system for surveillance of the health of workers exposed to nanomaterials (EpiNano) and is designing tools for gathering data, prior to an epidemiological research project.
- > **Energetics, Theoretical and Applied Mechanics Laboratory (LEMTA, Laboratoire d'Energétique et de Mécanique Théorique et Appliquée) of the University of Lorraine.** Examining setting up a study for developing knowledge in the field of modelling vascular remodelling phenomena consequent upon exposure to vibration of the hand-arm system.
- > **French National Institute of Applied Sciences (INSA) of Lyon,** on the field of intelligibility in acoustics.
- > **The CETIM (Technical Centre for the Mechanical Industries) for** developing a methodology for assisting with drafting of specifications, that methodology being based on the concept of working situation.

# Scientific presentations and publications in 2013

## Presentations in 2013

Every year, INRS researchers and experts take part in numerous national and international congresses: 141 presentations were given at various events in 2013, including 78 at foreign congresses, and, in particular:

- > 8 presentations by INRS at the Congress for the 50<sup>th</sup> anniversary of the French-Language Ergonomics Society (SELF) in Paris.
- > 7 presentations by INRS at the 28<sup>th</sup> French Aerosol Congress, also held in Paris.
- > 5 presentations at the European Aerosol Conference (EAC - Prague), at the French Process Engineering Society (SFGP - Lyon), and at the American Industrial Hygiene Conference and Exhibition (AIHCE - Montreal)
- > 4 presentations at the 15<sup>th</sup> symposium of ADEREST (Association for the Development of Epidemiological Studies and Research in Occupational Health) in Paris, at the 9<sup>th</sup> International Symposium on Biological Monitoring in Occupational and Environmental Health in Manchester, and at the International Symposium of DIM Gestes (Domaine d'intérêt majeur : Groupe d'étude sur le travail et la souffrance au travail (Field of Major Interest: Study Group on Work and Suffering at Work)) in Paris.

In addition to the symposia in which it takes part, INRS organised three major scientific events in 2013:

- > In April, the 3<sup>rd</sup> edition of the cycle of occupational safety and health research conferences/lectures for the national and international scientific community, focusing on the topic of occupational allergies, it brought together 200 participants (researchers, experts, OSH specialists, and physicians from various horizons: allergology, toxicology, occupational safety and health, biological monitoring, ethics, etc.). A summary was published in the journal "Hygiène et sécurité du travail", 10 INRS presentations were given at this scientific conference.
- > A national day on prevention of collisions between site vehicles and pedestrians was organised by INRS in partnership with FNTP (French National Civil Engineering Association) and FNADE (French National Association for Depollution and Environmental Activities), on 19 November in Paris, bringing together 287 people.
- > Technical day about thermal desorption, at which 120 professionals from laboratories, industry, occupational health services, or the OSH world were present on 21 March 2013, in order to share their knowledge on the topic of thermal desorption.

## Publications in 2013

The findings of the "studies & research" are published in scientific and technical journals.

**85 articles were published in 2013, including:**

- > 47 in international peer-reviewed journals
- > 38 in national journals, including
  - > 19 in the INRS journal "Hygiène et Sécurité du Travail"
  - > 7 in the INRS journal "Références en Santé au Travail"
  - > 14 editions of "Note scientifique et technique de l'INRS"
  - > 6 chapters in various books.

**As well as:**

- > 31 congress proceedings.

## List of publications 2013

### Accidentology, and perception & acceptability of occupational risks

- > **LECLERCQ S., MONTEAU M., CUNY X.**  
La prévention des accidents du travail aujourd'hui : quelle attente vis-à-vis des modèles ?  
Leclercq Sylvie et al, "Quels modèles pour prévenir les accidents du travail d'aujourd'hui?",  
*Le travail humain*, 2013, vol. 76, p. 105-127.
- > **DAVILLERD C.**  
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