Politecnico di Torino

Industrial Engineering and Management

Contributions of Ergonomics to MSD prevention

Ergonomic evaluation of workstations in an asbestos testing laboratory

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Abstract

Musculoskeletal disorders are costly for both companies and operators. The most common prevention approaches are aimed at identifying physical risk factors in order to improve them. In recent decades, ergonomic assessment grids have gained popularity and are now a widely used tool to identify activities with a higher risk of developing MSDs. This paper describes the use of an ergonomic grid to evaluate the risks of workstations in an asbestos testing laboratory. It presents the results of the analysis with the associated improvement actions. It also uses tools and practices retrieved from the literature to complete the analysis and to properly identify the occupational risks. This made it possible to identify the shortcomings of the company's grid and to propose improvements. It shows how ergonomics can integrate traditional prevention approaches to improve working conditions.

Keywords

Ergonomics; evaluation grid; Musculo skeletal disorders; ergonomic evaluation

Topic and issue

How ergonomics can improve working conditions by integrating existing prevention approaches.
An ergonomic evaluation of MSD risk factors in an asbestos testing laboratory.

Results

The comparison of the results from the approaches has found shortcomings in the existing practice and has proposed improvement for both the company's current approach and the working conditions.

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Introduction

Musculo skeletal disorders (MSDs) are the most common work-related health problem in Europe and they affect workers in all sectors and occupations. The costs faced by both the companies and the operators have driven the research of prevention approaches for the last few decades. Ergonomics is a scientific discipline that was created with the purpose of improving working conditions by adapting work to people. It is now common practice for companies to adopt an ergonomic approach for the prevention of occupational risks. In particular, some prevention projects focus on identifying the MSD physical risk factors to which operators are exposed in their activities. The work observations and the ergonomic evaluation grids have become widespread tools to improve working conditions.

Several ergonomic evaluation grids have been developed in the last decades: some include sector-specific characteristics, while others focus on a particular work dimension or are adapted to a category of users. These tools have also been developed internally by companies so that they meet their own requirements. However, their ease of use and little need of training bring the disadvantage of misrepresenting work situations, which lead to a poor identification of occupational risk.

This work describes the ergonomic evaluation of work activities in a Eurofins asbestos testing laboratory. The project was launched to improve working conditions after some MSD declarations within the company. The analysis was carried out with the grid developed internally by the company. In addition to the grid, the evaluation was performed with the tools and knowledge from the ergonomic scientific literature. The results from the evaluation include the risks identified and the actions to improve work stations, as well as the improvements for the grid.

The central issue of this work is demonstrating how ergonomics can contribute to current prevention practices. The objective is integrating the traditional approach with the ergonomic one, centered on the operator, to improve working conditions. The essay is divided in two parts:

1. The first is the scientific review of MSD etiological models and prevention practices, presenting both the state of the art and most common practices within companies.
2. The second part is the empirical framework that presents the results from the analysis. It compares the outcome from the evaluation grid with that from the evaluation carried out with ergonomic tools and knowledge from the literature. With this comparison, some improvements for the grid are presented and justified. Later, we discuss the novelty of results and how they answer to the central question.

This work is divided in a theoretical and practical section.

The theoretical part gathers all the theoretical concepts to which we refer for our work and comprises 4 parts. Chapter 1 briefly introduces the science of Ergonomics, with its history and different currents, with a link to occupational risks. Chapter 2 introduces the musculo-skeletal disorders and the existing etiological models. It shows how MSD can be caused by work organization and how they appear inside companies. Chapter 3 aims to present the state of the art for the prevention of MSD. Chapter 4 presents how firms act for prevention by use of reports and researches carried out within companies. Then it shows the limits of current practices and how ergonomics can contribute to prevention.

In the theoretical part, the etiological models of MSD have been presented. Then, an analysis has been carried out on the literature about the prevention and evaluation of MSD risks. Finally, several reports have been used to present what are the means available to firms to prevent occupational risks.

The empirical section presents the methodology used to carry out the study and the results. Chapter 5 presents the methodology used for the ergonomic intervention carried out on the field, the internship mission as well as the company. Chapter 6 will present the results of this work carried out with the methodology presented in the previous chapter. Our results will try to show how the ergonomic approach can be complementary to traditional approaches and improve both working conditions and prevention practices. It includes the ergonomic evaluation for each workstation and then it identifies improvement actions for each activity at risk. Finally, it also proposes how to improve the ergonomic evaluation tool currently used by the company. The Chapter 7 discusses the results and the perimeter of their validity, i.e. the applicability to other work situations, and their novelty.

1 Ergonomics and working conditions

1.1 What is ergonomics

The term Ergonomics has been coined in 1949 to name an interdisciplinary society for the study of human work and working environment, the 'Ergonomics Research Society' (now the Chartered Institute of Ergonomics and Human Factors) (Murrell 1958). It is the union of the two Greek words *ἔργον* (work) and *νόμος* (natural laws). In France the "Société d'Ergonomie de Langue Française" was instituted in 1963 to develop a European counterpart to reflect on the issues that the operator faced on his or her job.

In the international field the terms ergonomics and human factors (HFE or EHF) are often used interchangeably or together. It is defined as the scientific discipline which studies the interactions among humans and other elements of a system (IEA 2020, Bridger 2008). Its aim is to "match jobs, systems, products and environments to the physical and mental abilities and limitation of people" (ISO 2016). It seeks to safeguard human safety, health and well-being whilst optimising overall system performance (ISO 2016, IEA 2020).

In the French scientific literature, instead, the terms ergonomics and human factors are different meanings. The term *human factors* is considered to be the classic ergonomic approach, widespread in the international field. It is described as a current that focuses on adapting work on people by using a standard model for people. On the other hand, the ergonomics current widespread in France, as defined by French ergonomists, focuses on the activity and it assures the adaptation of work tools to the real work situation, taking into account the context in which it takes place.

1.2 Ergonomics academic research

Figure 1: Number of ergonomics articles published each year from 1950 to 2021 presents the number of scientific articles published each year from 1950 to 2021. It counts all the articles that include the word 'ergonomics' in either the article title, the abstract or in the keywords. The first article is published on the year of the creation of the Ergonomics Research Society. The interest for ergonomics has been rapidly growing in the last 30 years, reaching 4000 publications in 2019.

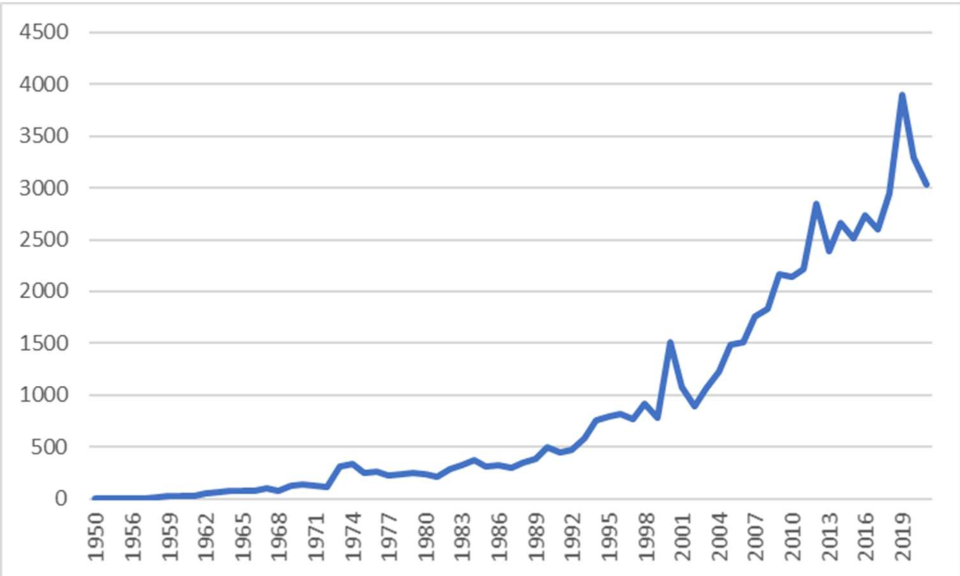


Figure 1: Number of ergonomics articles published each year from 1950 to 2021

Ergonomics is a multidisciplinary field which draws from medicine (physiology and anatomy), social sciences (psychology and business) and engineering. Figure 2: Percentage of documents by subject area rank the percentage of articles by subject area, mainly highlighting the fields of Social Sciences, Engineering, Medicine and Computer Science. The latter has a substantial percentage because it studies the interactions between computer systems (such as autonomous vehicles and robots) and people.

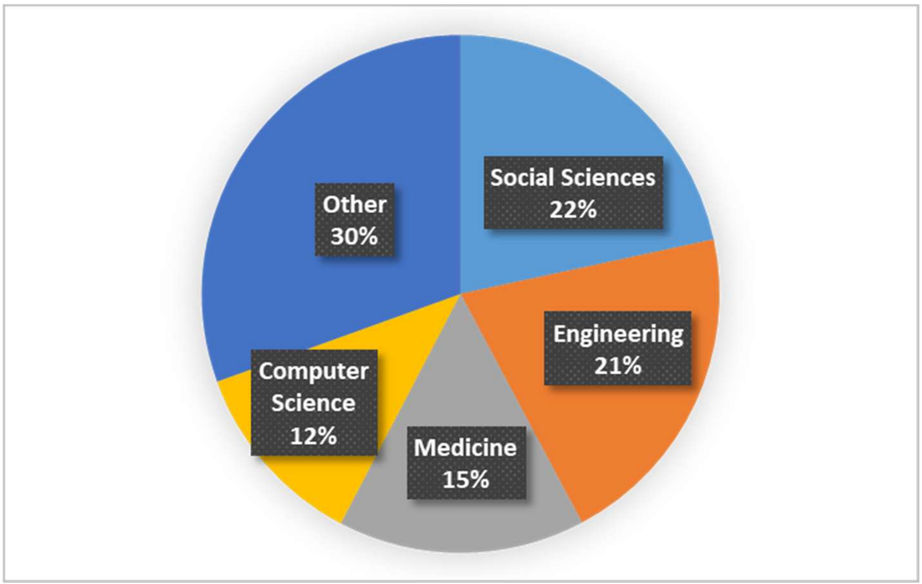


Figure 2: Percentage of documents by subject area

Since the purpose of ergonomics is improving operators' working conditions, it seems necessary to give some clear definitions to terms that are frequently used in the domain of Health and Safety at Work.

1.3 Occupational risks

This paragraph aims to remind some definitions on occupational risks

Accident. - An accident is an undesired, unexpected event that affects the integrity of people or causes damage to both technical and ecological systems. The National Safety Council (1988, 45) uses Firenze (1978) to list different probable causes of accidents: « Oversight or omissions or malfunction of the management system; situational work factor, for example, facilities, tools, equipment and materials; Human Factor, either the worker or another person; environmental factors, such as a noisen vibration, temperature extremes, illumination. »

Hazard. - It is the intrinsic property of a hazardous substance or a physical situation to be able to cause damage to human health and/or the environment (Council Directive 96/82/EC known as Seveso II 1996). Another definition comes from the UN (2009): "A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage". Hazards are usually quantified on ordinal scales (more or less hazardous) with *hazard indicators*.

Risks. - Risk is first described in terms of probability of occurrence: "It is the chance or the probability that hazards is likely to result in an accident, taking account of the severity of outcome (Grayham 1999). Risk is defined as a measure of the level of hazard that characterizes an undesired event by its probability of occurrence, severity and acceptability. Technological risks are those considered to be caused by caused by man; in some cases, they can be qualified as major insofar as even if the frequency is low their severity can be enormous. It is important to emphasize that the evaluation of risk indicators is based on a number of assumptions and data, which are sources of uncertainty (especially for the identification of long-term effects or of events that have never occurred) (Dos

Santos 2002). When taking decisions, some risks are accepted because of their severity and probability of occurrence (Garrigou, et al. 2004). Risk acceptability is usually negotiated between parties concerned by the risk.

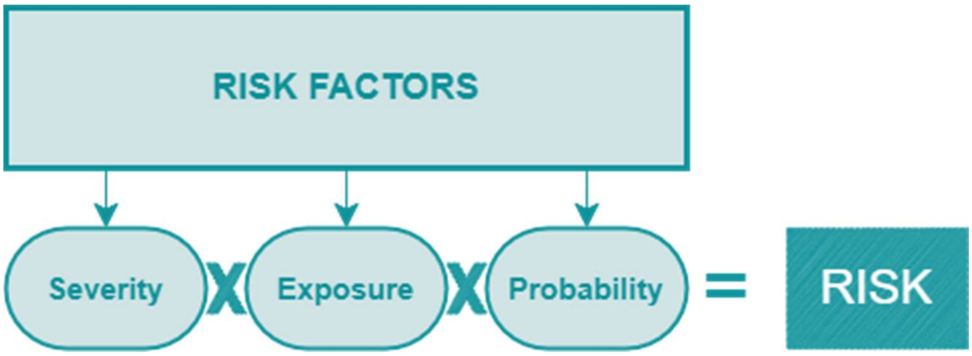


Figure 3: Risk as the result of the severity, exposure and probability of occurrence of an undesired event.

Prevention. - The United Nations (2009, 22) defines prevention as " The outright avoidance of adverse impacts of hazards and related disasters. […] It expresses the concept and intention to completely avoid potential adverse impacts through action taken in advance".
For Dennis and Draper (1989). « Prevention, [...] can partly be understood as paying attention to the physical, chemical, biological, social and economic environments with the aim of reducing accidents illness and death. Preventions is also concerned with health education and preventive services such as screening » (1787). « Primary prevention seeks to prevent diseases and accidents from ever occurring; [...] Secondary prevention tries to detect disease in the earliest stages and while it is still treatable. [...] Tertiary prevention attempts to prevent deterioration in established diseases... » (1788). Prevention can also mean « eliminating or reducing the sources of potential risks and triggering causes can be achieved in a number of ways and by influencing physical and human factors: sources of energy, working methods, human errors may be prevented by careful selection of workers and by adequate professional and safety training, e.g. » (Andréoni 1989, 1541-1542).

Safety.- For Andréoni (1989, 1539): « Safety has therefore taken a broader meaning than the past. It is now usually regarded as "freedom from damage" to health (injury or disease) and to property. As damage is the result of a risk, it is also said that safety is freedom from risk. Safety is not a concept in itself: it is dependent on the concepts of damage and risk. A state of safety is one in which no danger of an accident causation damage exists. »

2 Musculo-skeletal disorders

Musculoskeletal impairments include more than 150 different conditions that affect the locomotor system, comprising muscles, bones, joints and connective tissues (NIOSH 1997, WHO 2022). These diseases are characterized by pain and limitations in mobility and dexterity, reducing people's ability to properly work and participate in society. The most frequently affected body parts are: the back, the upper limbs (wrist, shoulder, elbow), more rarely the lower limbs (knees). The most common MSDs include: carpal tunnel syndrome in the wrist, rotator cuff syndrome in the shoulder, lateral epicondylitis in the elbow and low back pain (Assurance Maladie 2022). In France, MSDs include the pathologies listed in tables 57, 69, 79, 97 and 98 of the social security occupational diseases (Code de la sécurité sociale 2022).

An analysis of Global Burden of Disease 2019 data showed that almost 1.72 billion people in the world live with musculoskeletal conditions (Cieza 2021). High-income countries are the most affected in terms of number of people – 441 million – where MSDs are also the second leading cause of disability. This constitutes a major issue for health prevention at work: in France, MSDs are the leading source of occupational diseases accounting for 87% of disease cases in 2016 (CNAMTS 2018) which represents 42,535 cases.

This section will illustrate the etiological models for MSD (how they originate) in the first part, by presenting internal, physical and psychosocial risk factors. The second part will show the link between the organization and the onset of MSD through the external risk factors related to the company and through the model of room for action and improvement left to the operator. The third part will present models that try to take into account multiple risk factors. The fourth part will present the forms of appearance of MSD within the organization, as implicit and explicit.

2.1 Risk factors for MSDs

The origin of musculo-skeletal disorders is multifactorial. This part is devoted to present the internal risk factors and linked to the individual, the external determinants as well as how they integrate in a more complex and complete etiological model for MSDs.

2.1.1 Internal risk factors related to the individual

Multiple internal determinants for the onset of MSDs have been determined in the scientific literature (Hagberg, et al. 1995): sex, age, physical features, consumption of alcohol and tobacco as well as medical history.

Age. – The age increases the risk of MSDs through a cumulative effect because an operator who progresses in age and seniority at a workstation has been exposed to repetitive movements for longer. In addition, physical degeneration and previous injuries add-up to increase the perceived pain.

Sex. – Sex is risk factors not because of physical difference but rather due to the difference in employment for men and women in our society. Women are indeed less exposed to physical factors than men because they are in larger percentage employed in services. Nonetheless, they represented 58% of MSD cases in 2003 (Guignon 2008). Different occupations entail different risks: health and social activities, whose workforce is composed by 75% of women, imply standing for long periods of time, heavy loads, dangerous products and emotionally demanding situations.

Pain experienced. – Pain felt by the operators can help to define the problem and the relations between biomechanical factors and elements of work (Kuorinka 1999). Asking operators to signal the pain they experience while carrying out tasks allow them to reflect on the elements of their work that entail the onset of pain (Vézina, Ouellet e Major 2009). The interest for the experienced pain in the ergonomic evaluation tools focuses more on identifying the precise regions of the body solicited by work, rather than surveying the potential diseases (Vézina, Ouellet e Major 2009).

How to alleviate the individual risk factors of MSD is not clear yet, since they cover just a small part of all the risks operators are exposed to in an industrial environment (Leclerc, et al. 1998).

2.1.2 Physical risk factors

MSDs are periarticular disorders that affect the tendons at the periphery of the joints (Hubaut 2020) and they are an expression of hyper-solicitation (Roquelaure, et al. 1996). The biomechanical factors are elaborated by analysing the movement of body parts in the framework of a work situation.

Exerted force. – The effort is necessary for moving one's own body or objects. It has an effect on muscles, tendons and nerves. This is measured with the weight of mass. For lifting and transporting, a weight is considered dangerous above 15 kg and harmful above 25 kg. In case it is pushed or pulled (trans pallet, bed and patient or cart) the weight of the whole load and carrier is considered.

However, since for not all actions is not always possible to measure the objective exerted force (clamping, support, clipping, manual screwing with one or two arms...), a subjective measure of perceived effort can be used. The RPE (rating of perceived exertion) is used for the whole body and e CR10 (Categorial Rating 10) for localized effort.

Posture. – Articulations have a limited range of motion in bending, extension or rotation and going beyond the limit positions entails a solicitation of tendons. In addition, accomplishing the same movement can require very different amount of effort depending on the articulation angle (lifting a 20 kg weight at a height of 180 cm requires much more effort than lifting the same weight at a height of 150 cm). This includes uncomfortable postures, flexion or rotation of the trunk performed in the work activity. Workers should have workstations with adjustable positions (desk, chair etc.) so that they can improve their position according to the activity or their preferences.

Repetitiveness. – It consists in executing the same movement cyclically, thus engaging the same body parts. It becomes harmful when the cycle and/or the rest time get shorter. There are also other physical factors related to time:

- Work in flow tense / imposed rhythm: it obliges to produce and deliver at a very accelerated pace demanded by the client. This way of working can drastically increase the burden on the physique due to sudden changes in the rhythm.
- Rest time and freedom of pause: cycle time is usually longer than what it takes the operator to accomplish the task, to allow some rest but also account for variabilities. Operators should also be able to take informal pauses if they feel like so.

Handling and carrying of loads. – The handling and carrying of loads by an operator is a risk factors that is often cited and is presently separated in some MSD evaluation tools. However, handling is not a risk factor *per se* but a combination of other factors: effort, posture and repetitiveness (Hubaut 2020). The probability of onset of a MSD increases with the combination of these three factors. According to the European standard NF X35-109 for handling and carrying of loads (AFNOR 2011), handling is usually measured with tonnage, which is the aggregate handled weight per unit of time (t/h). The standard sets tonnage limit values for different total handling times.
In addition to the previous three the grip and ease of handling is used to further parametrize the handling of masses.

2.1.3 Psychosocial risk factors

Prevention actions and the emergence of MSDs in service activities have led the scientific community to the scientific community to add a number of psychosocial factors to the MSD model. The term psychosocial refers to the psychological development of the individual and their interaction with a social environment. These factors rarely lead to the onset of the disease on their own, but research has shown a statistically significant relationship between some of them and the occurrence of MSDs (Lasfargues, et al. 2003, 141, Ming Ng, Voo et Makip 2019). The link between MSDs and these factors makes MSDs a multifactorial disease, which is highlighted in a number of research studies (Buckle 2005, Hubaut 2020, Paoli et Merllié 2001). The intervention of these factors in the occurrence of MSD led to go beyond the purely biomechanical viewpoint of the work situation. This section will analyse the effect on health of stress, work intensification, monotony, control over the work situation, cognitive content of the task and social support.

Stress

Aptel and Cnockaert (2001) define stress as « a set of physiological, behavioral and emotional responses that occur in reaction to situations which are potentially harmful to the individual's physical or psychological health.» At work, stress will arise from a mismatch between the psychological and physiological demands of the job as perceived by the employees and their level of knowledge and abilities (WHO 2020). The maintenance of a level of demand above the employee's self-perceived capacities will cause the individual to enter a vicious circle and generate stress. Several models have been developed to summarize the stress process (Cox, Griffith et Rial-González 2000, Hubaut 2020, Cooper et Marshall 1976, Aptel et Cnockaert 2001, Karasek 1979, Karasek, Baker, et al. 1981). Figure 4: Dynamics of work stress adapted from Cooper and Marshall is a model adapted from Cooper et Marshall (1976), as amended from (Cox, Griffith et Rial-González 2000, 44).

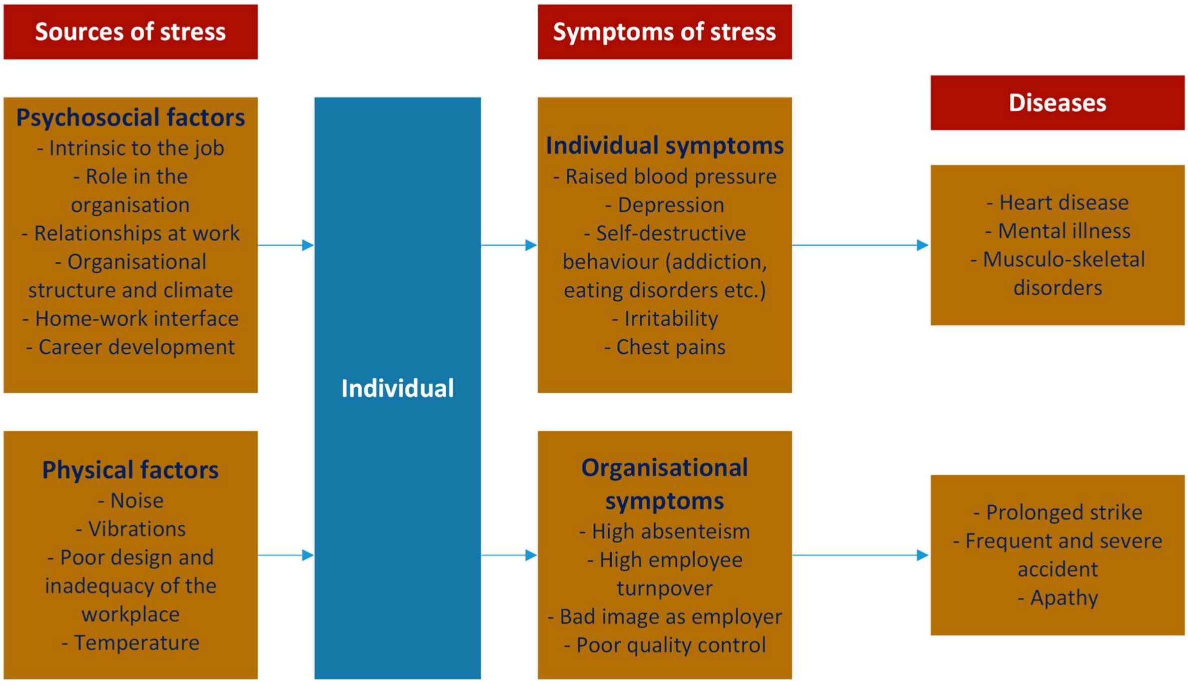


Figure 4: Dynamics of work stress adapted from Cooper and Marshall (1976)

The origin of stress is multifactorial and is a relationship between the individual and his or her work environment, including the social environment. It is possible to distinguish between physical risk factors in the work environment (noise, cold, heat, vibrations, etc.) and the psychosocial risk factors (intrinsic to the work, role in the organisation relations at work, professional development, organisational structure and climate, professional and private life balance etc.).

When a person appraises that his mental and physical resources are insufficient to cope with the challenge, they feel stressed. This stress upsets their body equilibrium and lower its immune defences, which opens the door to physical disorders (high blood pressure, gastrointestinal disorders, disturbed sleep patterns, getting sick more often etc.), accidents and neurophysical disorders (depression, low energy level, eating disorders etc.).

Aptel et Cnockaert (2001) tried to describe the relationship between stress and the onset of MSD. The responses to stress involves the central nervous system, autonomous nervous system, endocrine system and immune system. The chains of reactions is described in Figure 5: Relations between stress and MSD, adapted from Aptel et Cnockaert , adapted from Aptel et Cnockaert (2001).

- ❖ Under stress the central nervous system increases activity in the reticular formation, which in turn increases muscle tone. This increases load on tendons and muscles, thereby contributing to an increased risk of MSD.

- The stimulation of the autonomic nervous system triggers the secretion of a substance that goes in the vascular system and restricts blood circulation in muscles and tendons. This reduces the delivering of nutrients, which hampers self-healing of micro lesions caused by excessive loading and encourages the development of chronic muscle fatigue and muscle pain.
- Stress triggers the release of corticosteroids (cortisol and corticosterone) that act on kidneys and may disrupt and may disrupt body's fluid and mineral balance, the most visible sign of which oedema, i.e. excessive accumulation of watery fluid in tissues. Oedema may cause *tunnel syndromes*, as these tissues cause local compression of the nerves.
- Central nervous systems, once activated, produces and releases cytokine, which are pro-inflammatory and possibly cause of MSD.

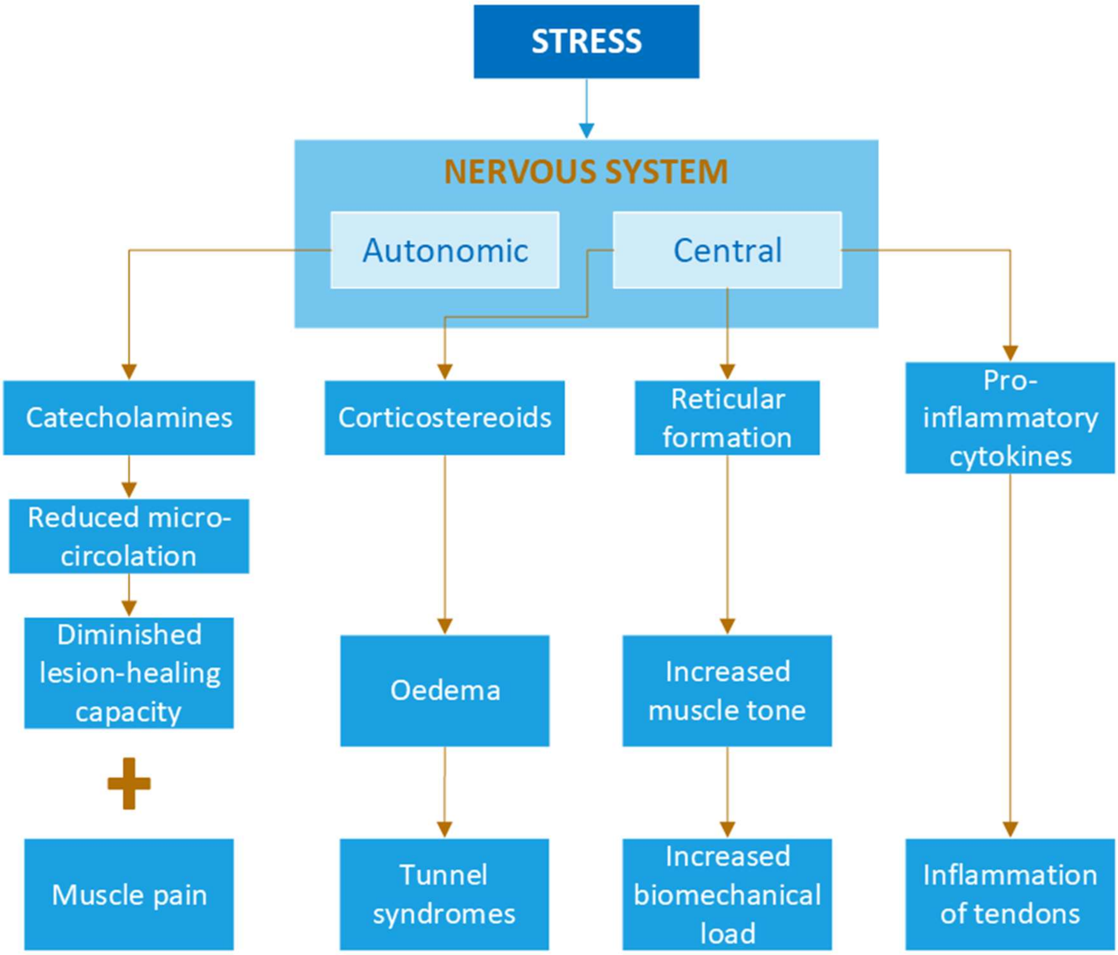


Figure 5: Relations between stress and MSD, adapted from Aptel et Cnockaert (2001)

Work intensification

The intensification of work in the last century has increased the health issues related to stress (Dhondt 1997).

The intensification of work acts as an agent that aggravates all the physical and psychosocial risk factors by increasing their intensity compared to the previous situation or by creating new combinations of risk factors.

The role of psychosocial factors in the development of MSDs is rooted in the power to act at work which is based on personal initiative and room for manoeuvre. This initiative is mediated by the social relationships within which all individuality develops (Coutarel 2011). If social relations are weak, it will be more difficult for the operator to transform the initiative into power to act. Clot (1999) states that the power to act concerns the activity, that it is in the activity that it develops or that it atrophies. The increase in this power to act is the result of the development of the meaning and efficiency of the activity. The development of the meaning of the activity allows the subject to make new connections in and through the activity, which are sources of energy for the mobilisation psychological resources of the subject (Clot 2001). These liberated psychological resources enable the subject to seek efficiency (optimisation of the resources mobilised to carry out a task) in his activity. This efficiency allows the subject to free up time which authorises him to return to the meaning of the activity in order to take it further. We can see that if we do not allow the power to act to develop in the activity, the work loses all or part of its meaning, which prevents the search for efficiency and will lead to the appearance of pathologies (Hubaut 2020).

Monotony

Monotony is related to both the repetitiveness and the cognitive content of the work. It is sometimes associated with machine-paced work. Monotony concerns the content of a job which, because of repetitiveness and the poverty of its content, becomes uninteresting for the operator. Cadenced work can add to this monotony a subordination of the worker to the speed of the machine, which is a major constraint for the operator (Teiger 1973, Salvendy et Smith 1981). Monotony is linked to the repetitiveness of the work to make it harmful. Indeed, the repetition of a gesture is not necessarily harmful in itself. It is often an essential condition for achieving performance and developing performance and the development of force or energy saving strategies in the execution of active gestures. Monotony linked to the impoverishment of the work content perceived by the operator leads to the limitation of margins of manoeuvre and the deprivation of the possibility of acting (Bourgeois, Lemarchand, et al. 2000). In this case, repetitiveness becomes hypersollicitation which can lead to the appearance of pathophysiological mechanisms (Kuorinka 1999). The operator can no longer develop alternative strategies for coping with the variability encountered and this impossibility of constructing new gestures becomes an important factor in the appearance of important factor in the appearance of MSDs. The association of monotony with the loss of autonomy by the imposition of a cadence from a machine adds an aggravating element to this combination.

Control on the work situation

As mentioned in the previous paragraph for cadenced work, control on work and lack of autonomy have an influence on the onset of MSD. Autonomy concerns the freedom given to the operator to realise her work but also in the evolution of the organisation or on the work conditions. The operators that enjoy more control over their own work can put in place strategies to diminish the risk of MSD (Daubas-Letourneux et Thébaud-Mony 2002). It is important to remark that also the dependence on colleagues has an impact on control on one’s own work.

Cognitive content of work

The cognitive content of the task refers to all the mental processes mobilized by the operator in the performance of his work. These are the activities of memorization, identification and interpretation activities that mobilize cognitive resources to carry out a physical activity. The impact of the cognitive content of the task on the risk of MSDs is linked to the required level of attention and on time pressure. High attentional demands in a context of high time pressure obliges the operator into an elevated muscular contraction.

Support

Social support concerns the interactions that are useful to the operator in carrying out his work. It is both vertical with the hierarchy and horizontal with colleagues (Cox, Griffith et Rial-González 2000). Social support is an important source of alleviation of the constraints present in the activity. It is the possibility, for example, of obtaining help for heavy handling or of being able to change jobs in the event of muscular fatigue. Social support is also one of the components of work recognition. The cooperation, mutual aid and discussion are linked to better working conditions (Cartron et Gollac 2022). Managerial practices can promote health by being favorable to discussion and support for operators (Devereux et Buckle 1998).

Recognition of work and social support sometimes go hand in hand within the work group. An individual who receives no social support at work, either at the vertical hierarchical level, as well as at the horizontal level within his team, will have little or no impression of recognition of their work (Russell, Altmaier et Van Velzen 1987). The absence of support makes carrying out activities collectively more difficult and leaves the operator alone to face the work situation. This situation will lead to the manifestation of MSDs, exhaustion or depression depending on the other dimensions of the task.

Some of the factors of the psychosocial approach share strong links with each other and with biomechanical factors, such as work at a fixed pace, little control over the work situation and monotonous work. Because the pace of the activity is set by an external agent, the operator has little control over the choice of his work rhythm. The model of the movement and gesture in work situations tries to integrate for all these different dimensions and build a more complex model of the risk factors for the onset of MSD.

The model of movement and gesture

Gesture models aim to reconcile the physical, psychological and social dimensions in the realization of movements at work. These models allow us to understand the subjective and collective parts that make up the gesture and how the prevention of the expression of the gesture can lead to the appearance of MSDs. The biomedical model of MSDs has naturally led to analyze the problem of human functional capacities from an energetic point of view. Since MSDs are the reflection of muscular overload, it is necessary to be able to quantify it in order to indicate the thresholds not to be exceeded. This model places movement, which is the voluntary action of mobilizing muscles that contract or lengthen as needed, as the source of muscular fatigue (Gaudez et Aptel 2008). In addition, one movement seemingly using only one muscular group can fatigue other groups.

The gesture is a complex structure: psychological, organizational, economic (Chassaing 2010), physiological and social. The movement, gesture and automatism are considered as three distinguished and non-overlapping poles of a whole which have inter-functional relations (Simonet 2011). The automatisms are mobilized in the motor skills of the gesture, for example grabbing a pen involves numerous automatism which make the movement possible. Movement is the subjective part of the model. It engages the whole body to perform an action and the overall posture shows the attitude of the subject (Simonet 2011). Movement is made at will and it is the result of what a professional environment considers appropriate or inappropriate (Simonet 2011). The gesture, instead, is the motion of the limbs or body that allows the operator to express a feeling, a desire, a way of being (Feyereisen et de Lannoy 1985). It results from the organizational constraints of the work situation, of the choice or not of the times of pauses and of the freedom to vary the rhythm of work. The economic dimension also considers the movement as a performance, taking into account the ratio of the energy cost and the result obtained.

The prescription of movement carried by Taylorism under the pretext of rationalization of work of work tends to deprive the operator of his initiative. This deprivation of initiative during the work day induces the most dissociating, the most tiring, the most exhausting effort that can be (Simonet 2011).This situation of renunciation imposed to the operator leads him not to be able to exert the complementary movements and necessary to the accomplishment of the gesture. Like the activity of which it is the result, the gesture is socially constructed. It participates in what are called the rules of the trade. When the organization leaves the necessary room for maneuver, operators can create gestures that allow efficiency and performance and to maintain the operator's health. When these actions are socially constructed, they give rise to recognition from peers (Hubaut 2020).

The questioning of these actions by the organization can have harmful consequences on the quality of work, when the organization does not realize that the result of the work is due to the singularity of the gesture and to the fact that the gesture is socially constructed. We can also witness an identity crisis of the operators whose professionalism is denied. The questioning of the gesture, even for a movement considered less biomechanically harmful, can on the contrary aggravate a situation in terms of MSDs.

The reduction of margins of maneuver, which leads the operator to be able to use only a gesture that hurts, raises the question of the prevented gesture (Bourgeois, Lemarchand, et al. 2000). The ergonomist will therefore have to identify the variability of gestures performed according to the characteristics of the work situations and identify those in which the process of reduction-privation of room for maneuver is at work (Bourgeois, Lemarchand, et al. 2000). The prevented gesture opens the analysis of the activity to what was not done, what the operator could have done , what she would like to do and even what she did without wanting to do it (Clot, Faïta, et al. 2001, 24). The situation in which the operator knows and perceives the gap between the prescription and the way to carry out the activity with better results or with the same results without pain, makes it possible to understand the process of altering the gesture and its effects on health. MSD are the consequence of not being able to perform the same actions that would prevent them (Bourgeois, Lemarchand, et al. 2000).

In this context, MSD become diseases that origin from the low collectivization of work (Simonet 2011) due to the gap between prescription and optimal movement, which comes from the contrast between the operator and the firm. The models of the gesture and movement aim to integrate the physiological, subjective, psychological and social dimensions into the model for the onset of DMS, traditionally focused exclusively on mechanical factors. In addition, many risk factors depend from organizational factors that are going to be presented in the next paragraph.

2.2 The link between organization and MSD

In a Taylorian conception of work, exposure to MSD risk factors is largely due to the organization, since this model separates work designers and work designers and operators, reducing the latter to the rank of simple executors of a prescription carried out with the sole aim of achieving productivity and profitability objectives. As a result, in addition to being a health hazard, MSDs are a symptom of organizational rigidity (Hubault 1998). This section will address the issue of risk factors related to the work environment, then how firms deal with MSD and, finally, the question about the room and freedom for action in the organizations.

2.2.1 External determinants and risk factors related to the work environment

The risk factors presented below are determinants of the work situation. Since items that relate to such factors are very often present in MSD risk assessment tools, the next part will present some of these factors.

Workplace lighting

The European standard NF X 35-103 (2013) sets the rule and best practices for workplace lightning. The work activity requires visual information, in particular to accompany the gestures and to ensure the gestures and to ensure the necessary precision and to carry out the taking of information. In many cases sunlight is not sufficient due to being in a building. The eye needs a minimum amount of light to accomplish a task. This quantity must increase with the following factors:

- The fineness of the detail to be perceived
- The weakness of the contrast (object standing out little from the background)
- The age of the employee: eyesight is at its optimum until age 35
- The difficulties of vision of this last
- The task

The amount of light that reaches the work surface is called the illumination level. It must be sufficiently homogeneous in the visual field, not cause glare and give a good rendering of colors. When this is not the case the insufficiency of the level of lighting can generate postural constraints to compensate for this weakness.

Clutter and congestion in the workspace

The workspace is a place that is often delimited and where the workers who have to carry out a task (Hubaut 2020). It is the activity of the operator itself that defines the workstation (where tasks are carried out, tools are kept etc.). The spatial organization is related to the requirements of the task, such as the need to stock material, the handling of objects or other needs. It can happen that unnecessary documents, materials, tools or waste can accumulate and reduce the available space. Clutter is an obstacle and it becomes dangerous for the operator, as a risk for an accident or for the onset of MSD since it requires more effort and it worsens the posture.

Environment temperature

The ambient temperature at the workstation will cause two reactions from the body depending on whether the environment is hot or cold:

- In a hot environment, the body triggers sweating which allows the body to cool down.
- In a cold environment, the body fights against the loss of warmth by limiting the surface area of the skin in contact with the air (shrinking skin) and by increasing the thermal production (heightened metabolism).

Clothing or the physical intensity of the activity can diminish the impact of the ambient temperature on the operator. The effects of the biological reactions to the environment are reflected in the performance of tasks:

- In the case of work in the heat, vigilance decreases, decision time increases, sensory-motor coordination deteriorates; these effects are more marked when there is a time constraint. These effects can aggravate the repetitive aspect of the activity and its impact on the activity and its impact on the risk of MSDs.

- In the case of cold work, mental activity (vigilance, speed, precision) is little affected. However, manual activity is very much affected because the body reduces the circulation in the outer parts of the limbs (feet and hands), therefore handling can be difficult. This biomechanical factor directly impacts the risk of onset of MSD.

The severity of the effects of the environment temperature depend on its significance:

- If the temperature is extreme, the body temperature might go beyond the autoregulation limit. It entails acute or chronical diseases: hyperthermia, cramps and heat strokes for ho temperature; hypothermia and frostbites for cold temperatures.
- If the temperature is moderate, the body will put in place autoregulation mechanisms to preserve its internal temperature. Sweating, blood vessels dilatation and increased heart rate intervene in cases of hot temperatures; blood vessels constriction and chills are produced in cases of cold temperatures.

Noise

In addition to the temperature and lightning, noise is recognized as a risk factor for the hearing and more in general for fatigue. Disturbing communications and perception of the environment, it increases the risk of accident and deteriorates performance in physical tasks.

Vibrations

Vibrations are risk factors as well for the motor apparatus because of some direct acute or deferred effects (low-back inflammation, wrist and elbow arthrosis, tunnel syndromes etc.) or indirect (excessive effort etc.) (INRS, Vibrations et mal de dos 2012). Vibrations can also alter visual and sensorial perceptions causing accidents or errors.

Exposition to toxic materials

The presence and concentration of toxic substances must be evaluated according to the manufacturing processes and products used. The rating is for consequences related to the physical load and not the toxicity of the product. Dusts can be inert and annoying to breathe, but they can also be a toxic vector. Physical work can multiply by 3 or even 5 the resting respiratory volume and thus increase the toxic effect of the of the surrounding products. The purity of the air must always be sought, but even more so in an environment where physical tasks are performed (INRS 2019).

Personal protection Equipment

It must be ensured that collective measures (which are to be preferred) can avoid the need to wear PPE. Personal protective equipment can interfere with the activity (vision, breathing, movement, grip...) and even increase the physical workload (insulating clothing, etc.). If PPE is essential, it is all the more easily accepted if it is adapted to the individual characteristics of the employees, if it is in good condition, if it interferes with the activity as little as possible and that the employee is involved in in its choice (INRS 2013).

2.2.2 MSD and the organization

Human resources management based on a Taylorian and mechanistic vision of activity, considers work from the point of view of production and not of the human being accomplishing it. This conception of work makes it difficult for the operator to give it meaning and prevents him from reconciling his objectives with those of the organization. This discrepancy will encourage the appearance of MSDs. These elements relating to the organization of production and work can take many forms, for example:

a demand for high productivity will lead to an intensification of the activity with a hunt for useless gestures as a source of wasted time. Sometimes, to reduce a cycle time, work designers will opt for the reduction of the inter-cycle "dull" time for the operator. These decreases in the operator's in the operator's room for maneuver will be a source of MSDs.

The links between MSDs and organization are illustrated in the mechanics of infernal loops, illustrated in Figure 6: The infernal loop adapted from Nahon & Arnaud adapted from Nahon et Arnaud (2001). An enterprise that does not take into account the needs of operators, when facing a problem in performance, will try to cope by modifying some factors that will negatively impact the operators' task, thereby further inducing stress and more pressure, which lead to MSD. The infernal cycle highlights the need to take different measures to allow operators to develop ways to face variability and improve efficiency.

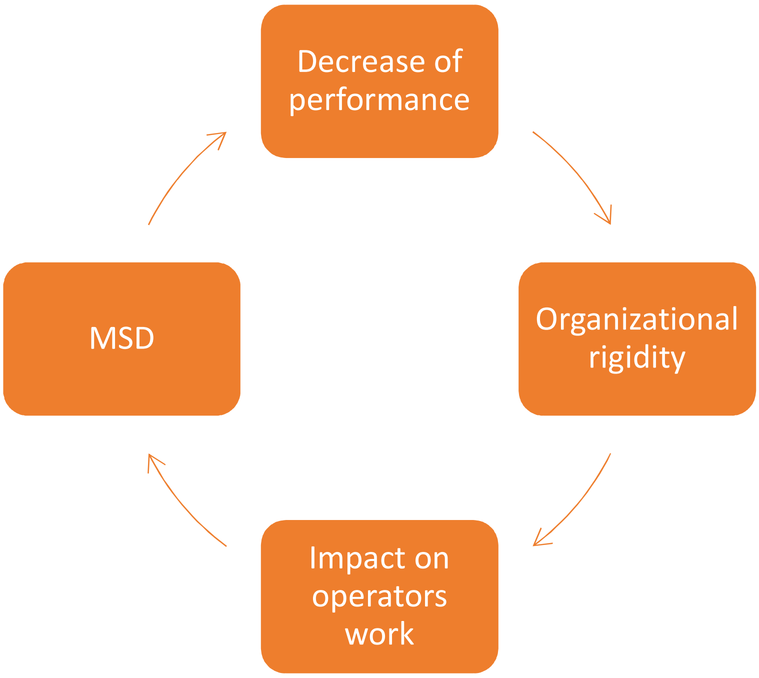


Figure 6: The infernal loop adapted from Nahon & Arnaud (2001)

2.2.3 The room for action as a risk factor for MSD

The interaction between organizational risk factors and MSD is best seen on the room for action and regulation left to the operator. Virtually every decision impacting the operator's health will have an impact on these two factors.

Regulation of the activity

Regulation is intended as the notion of control and subsequent adjustment of the activity. According to Faverge (1966), regulations are necessary to enable the operator to control the effects of the activity, but the organization must give him the necessary leeway to implement them. Regulations are functions that allow the operator to work with rival and opposing requirements, but in a heavy and costly way. In other words, they constitute all the strategies of the operator to accomplish his activity when the operator is in a situation. The operator constantly regulates activity and the redefinition of the prescribed task is a regulation (Weill-Fassina et Rabardel 2010). The regulation approach includes what the operator chooses to do and what he does not do. The reality of the activity is also what is not done, what cannot be done, what we fail to do, what we would have liked to do or could have done (Clot 1999).

Regulations arise from activity that was not done, due to technical and organizational constraints that potentially have an impact on the health of the operators. The cycle of regulation for Leplat (2006) is represented in Figure 7: The cycle of regulation adapted from Leplat, in which regulation is a control mechanism that compares the output of a process with a desired output and regulates this process according to the desired deviation. Then the process is controlled again for deviation and it is either modified again or validated.

Figure 7: The cycle of regulation adapted from Leplat (2006)

Margin of maneuver

By margin of maneuver (Vézina 2000), it is meant the autonomy left by management to operators in the execution of their task. The margin of maneuver depends on the skills and experience of the operator. The organization does not give the same autonomy to all its employees and not all employees need the same room for maneuver to experience well-being at work. If too little room for maneuver can be detrimental to the activity, too much autonomy can also create discomfort or encourage the occurrence of accidents. The link between activity, regulation and room for maneuver is represented in Figure 8: The model of activity centred on the person and her work**,** adapted from Hubaut (2020) as an amended version of Vézina (2000).

This model considers the person at work and all his or her characteristics. The psychosocial factors are included in this model in what the person is and in what conditions his activity. The activity is central in this model and must be described taking into account its physical, mental and social components. The consequences of the activity are both on the state of health of the person and on the production as much in terms of quantity to produce as of quality of the product. The activity is carried out taking into account the production requirements, the social environment and the conditions and means offered by the company. All these elements constitute the determinants of the activity which will weigh more or less heavily on the operator and determines the margin of maneuver to regulate her activity. Occupational health is the reflection of a balance between the demands of production and the possibilities of regulation. This balance depends on the margins of room for maneuver. If the balance between work demands and the possibilities of regulation in the activity does not exist, the work situation will generate MSDs (Coutarel 2004).

The development of room for maneuver is favorable to the development of health and to the efficiency of the system. Provided that the operator has the individual and collective possibilities of to make the necessary adjustments.

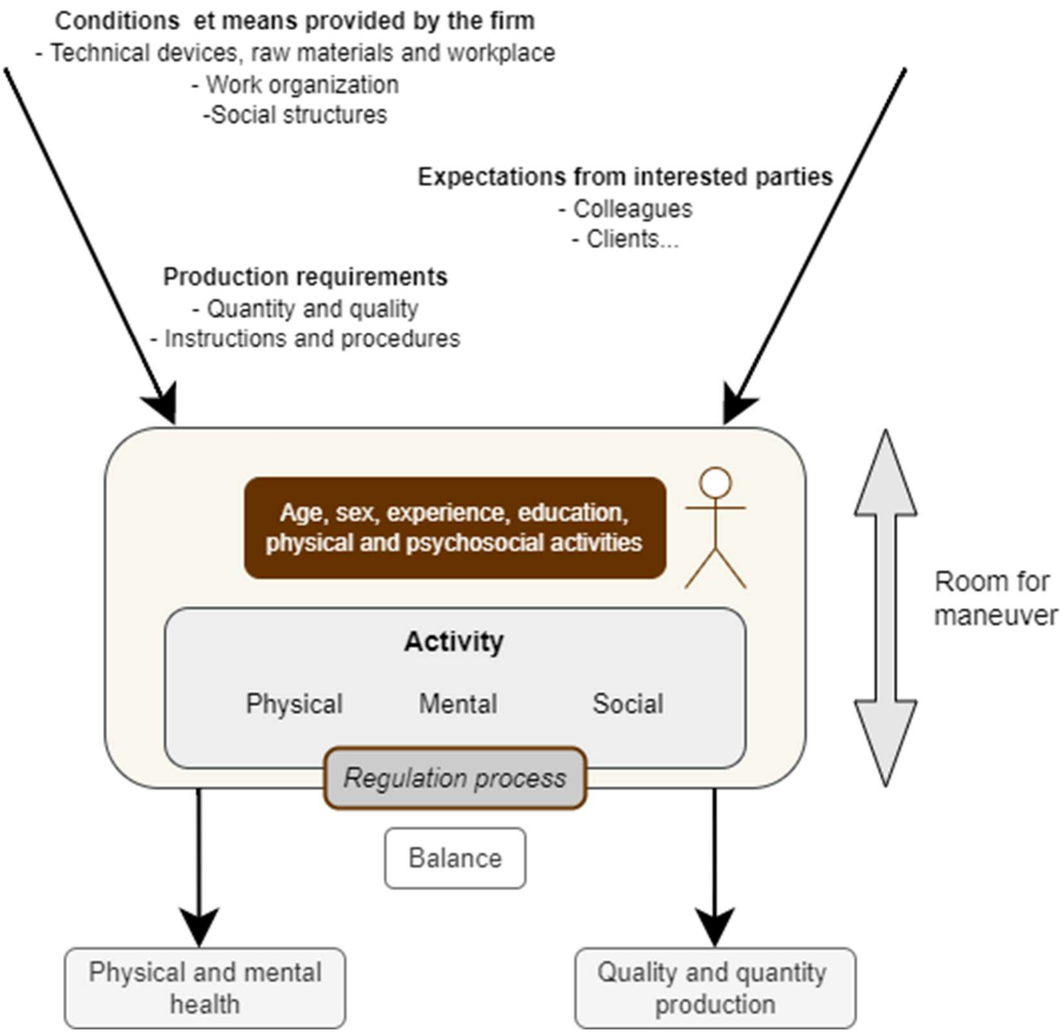


Figure 8: The model of activity centred on the person and her work, adapted from Vézina (2009)

2.3 Combination of risk factors

The combination of MSD risk factors strongly increases the probability of developing these conditions (Kuorinka and Forcier 1995). The factors can be combined in two ways:

- Within the same family of risk factors: for example, handling and carrying loads is a risk for the effort, as well as the posture, quality of the grip and repetitiveness.
- Different families of risk. In this case there are two types of effects:
    - Factors that act in a cumulative way. For example, stress can add a strain to the musculo skeletal system to the already existing injuries due to handling weights.
    - Factors can cause one another: for example, having little help or support available can force the operator to make a strong effort.

The following paragraph presents two models for the causes of the MSD that account for these combinations.

2.3.1 INRS model

The model in Figure 9: INRS Model for the combination of MSD risk factors adapted from, adapted from (Cail, Aptel et Franchi. 1996), tries to summarize the mechanisms of the onset of MSD for the upper limbs.

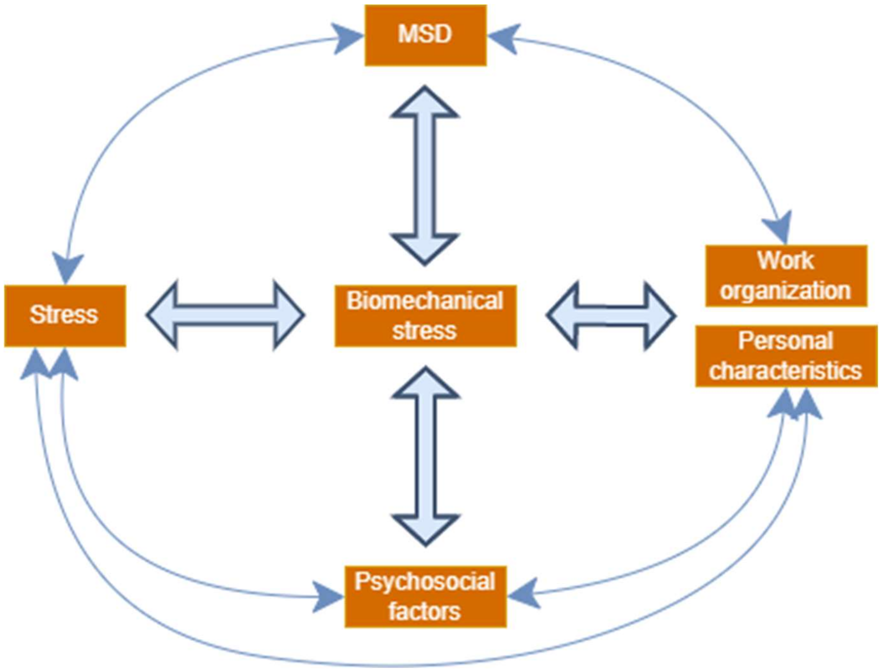


Figure 9: INRS Model for the combination of MSD risk factors adapted from (Cail, Aptel et Franchi. 1996)

The model focuses on biomechanical risk factors, while emphasizing that MSD risk is often the result of a combination of factors. The notion of personal characteristics brings together risk factors specific to the individual, such age and gender and other complex variables such as the health state and work experience. Stress is presented distinct from psychosocial factors as being the result of exposure to these factors. Nevertheless, it is not retained as the exclusive mode of action of psychosocial factors on biomechanical factors. Stress can be seen as the result of psychosocial factors, adding the strain of these physiological effects to the musculoskeletal load. Organizational factors are present in the model, in the sense that they determine the level of biomechanical solicitations experienced by the operators. The cumulative effect of these risk factors would be through the relationship between psychosocial factors, stress and biomechanical stresses.

2.3.2 Hubaut's model

The following model, in Figure 10: Model for MSD risk factors and dynamics from (Hubaut 2020), is more complex and it takes into account the different types of combinations of risk factors. The nature of MSD is multifactorial and biomechanical factors are shown to be the main cause. However, the previous paragraphs show the relevance in the onset of such diseases of the personal and psychosocial factors. Bellemare (2002) shows that there are some factors, called *determinants*, that reduce the room for action for the operators and expose them to risk factor. These determinants are divided in three groups:

- Technical: Instruments processes, procedures, materials, products etc.
- Organizational: work hours, responsibilities, control, support etc.
- Human: Experience, competences, training etc.

In this model the determinants reduce the room for maneuver which exposes the operator to risk factors. They combine with scarce room for improvement, physio pathological mechanisms and organizational stiffness to give rise to poor performance and TMS.

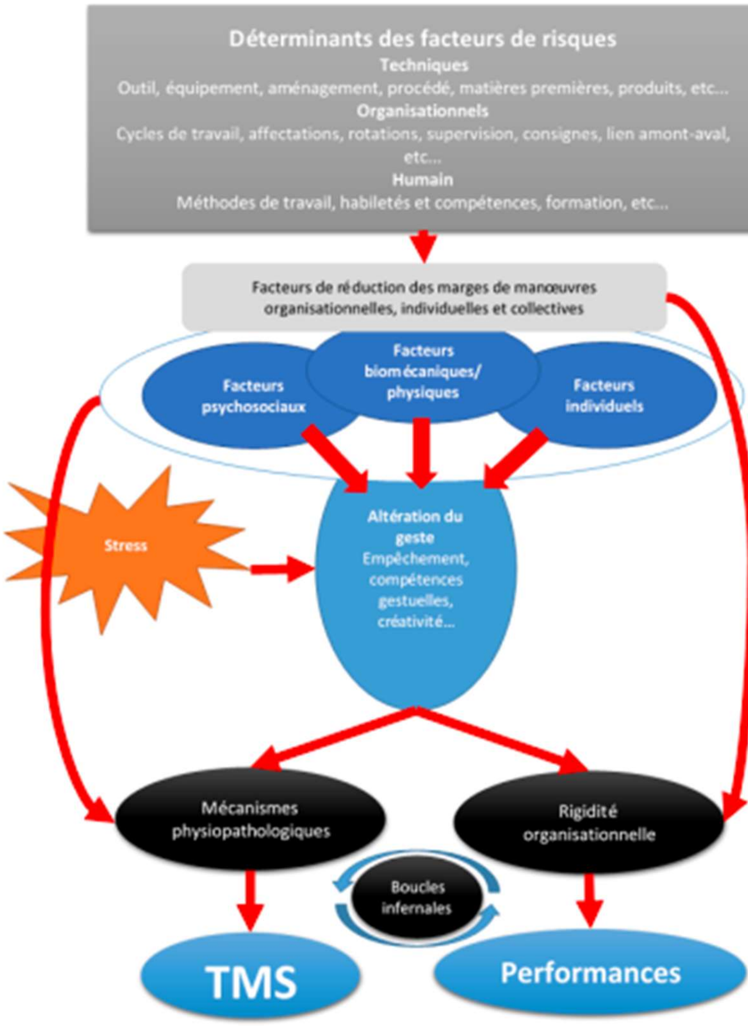


Figure 10: Model for MSD risk factors and dynamics (Hubaut 2020)

This section introduced the general notion of occupational risks, the traditional preventive approaches as well as their limits and the benefits that ergonomics could bring. In addition, etiological models for MSD and their causes have been presented.

2.4 The forms of appearance of MSD

Globally, MSD direct costs for firms are estimated to be more than 20 billion dollars. However, this figure only includes workers' compensation payments, medical payments and legal expenses. Many indirect costs, for example the cost for the loss of productivity or for hiring new personnel, are not accounted for. In addition, as the next section will show, many cases of MSD are not declared by employees for fear of retaliation or unwanted consequences by the employer.

The MSD problem manifests itself in very different ways from one company to another according to the context, the events that mark its history, the interplay of the stakeholders, the extent of the phenomenon, the difficulties posed to production, etc. The main question is “What makes a firm start to worry about MSD?”. Caroly et al. (2008) state that the problem of MSD assumes a higher priority within the firm when complaints are made to occupational health physicians about the issue of adequacy and the impossibility of transforming a work station or of reassigning workers to other stations. The issue is put on the main agenda not only for the reasons of absenteeism and its costs for the firm. In facts, what brings the question of MSD inside the firm, are the complaints and difficulties about managing MSD, whether they are brought by the HSE committee, work inspector, the operators or the occupational health physician. The difficulties arisen from MSD are concerns an increased work charge for the operators and an additional complexity in the work organisation for the firm.

When MSD are put on the main agenda for the enterprise, there are different approaches to the problem:

- *The problem is already known*
  It has already occurred and its direct consequences, MSD declaration, fitness restrictions and absenteeism, have already been experienced. The increase of these issues lead to other effects: HR management, production management, legal obligations, etc.
- *It is not a problem*
  The position is of denial with defensive attitudes, if not with some obstructions for the debate between the different parts concerned by MSD.

It is important to note that the position of the firm is not ingrained and fixed but it can evolve with actors that conduct projects and actions for preventions. Nevertheless, it appears that the road to sustainable MSD prevention will be longer when the company is, at the start of an intervention, in a position of denial of the MSD problem. This will be illustrated in the following later.

2.4.1 Explicit forms of MSD

2.4.1.1 Declared and recognized forms of MSD and work unsuitability

Companies become alerted on very heterogeneous thresholds of the number of recognized and reported cases of MSD. Some already react with a few cases, other does not until the cases are more than 10, still others do not act until a percentage threshold of the number of employees is reached. Most companies rely on *reported* MSD, as these figures, which are known in the social balance sheet, serve as levers for action (Caroly, et al. 2008). Companies do not necessarily use the indicator of *recognized* MSDs and few of them analyze the difference with the indicator of reported cases.

It is also common for companies to have poor data on reported MSDs (Hubaut 2020). The figures are rarely related to the size of the workforce, the characteristics of the populations and their evolution, which gives a relatively poor picture of the MSD problem. Little data is analysed according to activity sectors, pain locations and even less according to the evolution of the work content. Few comparisons are made with known data for the industrial sector.

Organization of the data is generally poorly structured for the purpose of alerting and evaluation of prevention actions (Caroly, et al. 2008). There are several reasons for this result: lack of training and definition of the tasks of the people responsible for producing and managing the data, lack of interest on the part of the company in the lessons that can be learned from the data, scattering of data. The people who use this data have different roles and sometimes do not communicate with each other: HR assistant, QHSE coordinators, CHSW representative and health workers.

Furthermore, MSDs are manifested through work unsuitability declarations. The workers’ relationship to this form of health preservation are extremely varied. Some employees ask the occupational physician for it. Others, on the contrary, refuse to accept the occupational physician's proposal for any form of unsuitability for fear of losing their job or bonuses.

Public health measures do have an impact on MSD declarations: for example, the French government measure to reduce by 20% the number of MSD is a strong message from public authorities. However, Caroly et al. (2008) finds that the underreporting of MSD cases is still an important factor. In one firm in the study, 9 cases of work-related illnesses out of 200 employees have been reported, whereas 119 said they were experiencing pain in the hand and wrists and 140 pain in the shoulder and arms. Underreporting can also be the result of not starting the process of recognition or validation of a medical diagnosis by a physician.

2.4.1.2 Indicators of absenteeism, work-related accidents and OSH insurance contributions

Some indicators likely to alert the company are presented in the following.

Absenteeism is one of the indicators shared by all the players in the company when prioritizing MSD prevention, although it does not specifically account for MSD-related absenteeism. The "absenteeism" indicator is at the crossroads of the different departments present in the company: HR, analysts, occupational physicians, production managers. Finally, absences lead to an overload of work for local managers, who have to manage daily schedules with a disorganization of work that makes it difficult to meet deadlines and production targets.

Work-related accidents are not a relevant indicator of MSD manifestation, except for low back pain in the case of lesions or pain following a fall, contusion or trauma. This indicator, given the cost of work-related accidents, is closely watched by companies. Indeed, many firms set as HSE objectives having zero accidents, reducing severity and frequency.

OHS insurance contributions represent a significant cost for the company, which under pressure from the pressure of the work inspector and the insurer, can be controlled or advised on the prevention of occupational diseases with requirements made to the CHSW to carry out an investigation, and to the company to carry out precise and assessable actions.

Other than the cost of insurance and the pressure from external actors, it is possible to identify the cost of the consequences of illnesses. The disorganization of work results from difficulties in managing unsuitability declarations and absences. The resulting work overload can lead to an over-solicitation of gestures and stress for the other operators.

The hiring of a safety coordinator, an ergonomist or a QHSE, in charge of a mission to reduce work-related injuries, shows the company's willingness to take the problem seriously and to entrust the MSD prevention project to a contact person. These recruitments often take place following the first declarations of occupational illness. Sometimes, trainees in psychology or ergonomics come and go in the company. On the basis of an initial diagnosis, they indicate to the company of the positions at risk.

The link between MSD data and absenteeism data should be examined in the company depending on the management of health indicators. MSD could manifest themselves not through reported cases but through high absenteeism or it could be the opposite with many reported cases and low absenteeism. These different ways of manifesting MSDs therefore require a complete exploration of exploration of data related to absenteeism.

2.4.1.3 Links with strategic issues for the firm

The MSD problem can be manifested in the company through the management of other projects, such as human resources management, knowledge management, production and quality management, and safety management. In this case, the issue of MSDs is directly linked to other logics of the company's operations.

In terms of human resources management, several companies are concerned about the ageing of their employees in the workplace, an ageing linked to the general demographic evolution of the western population and, for some, to a high level of seniority with retirements in the near future. The problem of MSDs links to that of maintaining employment most of the time, of the lengthening of the professional activity, but also that of recruiting young people for certain companies already affected by the renewal of the workforce. Between the departure of older employees and the arrival of young people, companies recognize that the transmission of know-how is strategic for their development and that structuring the transfer of skills is a key issue for apprenticeship, particularly with a view to preserve the health of workers while ensuring the efficiency of the production system. Very few companies make this link between MSDs and learning and place the MSD issue directly in the context of knowledge management (Caroly, et al. 2008).

The strategic issues best identified by companies in relation to MSDs concern the quality/production ratio, particularly with the difficulties of managing people with work unsuitability declarations. Some managers are able to go beyond a simplistic interpretation of the cost of OHS contributions and absenteeism to take into account links between efficiency and health. They are aware that a person with MSDs who works at his or her job without stopping or adapting will have a lower performance leading to quality defects and/or fewer products. However, the link between health and efficiency is not always perceptible; it depends on the distribution of work by the team leader, on the experience of the workers and on the functioning of the work groups. For example, medical surveys can be carried out to ensure the links between health and efficiency. It is also possible for companies to focus their actions on the design of jobs considered critical or on the implementation of a rotation system. The relocation of machines or manufacturing areas is an opportunity to address the problem of MSDs by revising work flows and spaces. In addition, MSD risks can be put at the same level of other health risks, such as chemical, biological or social by putting them in the statutory risk analysis.

2.4.2 The hidden signs of MSDs

Sometimes MSDs do not manifest themselves explicitly. To be more precise, the company is not able to put itself in a prevention dynamic. Faced with a problem that it considers either too complex, or too simple, it gives up and does not manage to build a minimum of common agreement between the interested parties to diagnose the difficulties posed by MSDs and to try to solve them.

2.4.2.1 Defence positions

Caroly et al. (2006) observe some common reasons from firms for not engaging in MSD prevention.

- The over specialization
- Limited offer from designers
- Describing the problem as personal
- Simplification of the problem

Firms justify inaction by mentioning an advanced specialization of the market, which would not allow to carry out tasks otherwise. Discussion with designers in this case difficult since they are resistant to change and afraid to lose their privileged position in the market.

The limited offer of materials and equipment by designer to firms specialized in a domain, or for public companies with a limited market of suppliers, does not allow for competition. Every cooperation between users and suppliers seem impossible. However, this position is a way for firms to dodge how MSD might be treated together with technical systems. Indeed, some larger projects, with the participation of analysts and designers, aiming at adapting the technical system to human characteristics would be the way to develop innovations to avoid the MSD issue.

The request to deal with the MSD problem can be made very quickly to an actor, targeted for their competence, for example, a production manager, a safety engineer, an occupational physician, etc. In several companies, the person is uniquely responsible for the project. If the person so designated does not have the means to coordinate prevention actions, the crystallization of MSDs on a person responsible for the issue will very quickly fuel denial of the problem, preventing more collective sharing on the issue and on how to implement prevention.

Another form of denial of MSDs is found in a simplifying representation of reality. For example, the belief that automation will solve every problem. The company approaches the MSD problem mainly from a biomechanical perspective, with a short-term solution. When MSD worsen despite this automation, the cause of the MSD problem is related to the inappropriate behaviour of the operators rather than to a misrepresentation of the complexity of the socio-technical problem.

2.4.2.2 Social dialogue is blocked

There are at least two types of blockage in the social debate in the company: the first, a tension between the actors in the company, which leads to the problem of MSDs being ignored. This conflict in the social debate has various origins, which lead to various ways of raising the issue of MSDs and their prevention. The second type of blockage concerns differences in representations and knowledge of the etiology of MSDs, which represent the first difficulty for actors to pose the MSD problem together. This is often a misrepresentation of a cause/effect logic. MSD might be attributed to a single factor, for example the hours worked in a week. Despite reduction of weekly hours or early retirement, the problem might persist. The parties are unable to find the root cause and they look for ways to solve the problem more in terms of management.

The poor knowledge about work appears to be another dimension of blocking the debate. On the one hand, there are obstacles to proposing relevant adjustments due to lack of knowledge of the operators' work. On the other hand, the group's decision-making power is too far removed from the field, which reduces the possibilities of action for the unit's manager.

The difficulties of social dialogue on MSDs are also manifested in the rigid positions of certain rigid positions of certain actors, which do not favour compromise with others. For example, the role of the occupational physician in his or her MSD reporting practice. To take two extreme positions, an occupational physician who systematically advises the employee to report MSDs without discussion is quickly side-lined by the employer. Or conversely, a physician who is too dependent on his relationship with management and who never declares MSDs, whereas the majority of employees express complaints. The MSD problem is then difficult to address collectively. Another example is that local management pressure to get the people of unsuitability declarations or illnesses out of their department is in a strategy of avoiding and displacing the problem. In the same way, the company that refuse to declare an occupational disease and contest it is not in a positive dynamic to address the problem and try to solve it.

Lastly, the conflicts of different approaches to prevention lead to blockages in the debate in the company. Some reasoning focuses solely on management indicators and others only on human factors. For example, a safety coordinator in a prevention department who defends a technical approach (adapted equipment, user training) to avoid to avoid risks is in conflict with an occupational nurse in the same department who advocates a social approach (listening to people, taking breaks, recognizing work) to reduce psychosocial risks.

Opposing safety and health is a dead end for prevention. The difficulties of discussing the indicators for measuring the effectiveness of prevention actions and their effects on health are known. The evaluation of the expected effectiveness of prevention actions relates, in most cases, to a reduction in the number of MSD which makes it impossible to develop any other discourse on the manifestations of MSD. As explained in a previous paragraph, there is a gap between reported cases and recognized cases of MSD. As a result, responsibility is attributed to the person responsible of the project and is not shared by the various players.

2.4.2.3 Rigid structures and work variations.

The problem of MSDs is hidden in certain companies that base their work organization on a standardized system that does not take into account human and industrial variability. Companies that advocate standardization of the correct movement or manoeuvre for the purpose of prevention deny the variability of work and individual and collective skills. The culture of the right gesture prevents the development of other organizational solutions. However, the risks of accidents and conflicts within the production units remind the company that rigid organization does not eradicate the problem of MSDs.

3 Research on MSD risk management

This section will illustrate the elements that the literature shows to be the most effective in the prevention of MSD risk mitigation. The first part presents the elements that are necessary to eradicate MSD in a more lasting way. The second presents what are the principles of an ergonomic intervention, what are the tools used and why it can be effective in eradicating MSD.

3.1 The elements of an effective prevention

The levers for sustainable MSD prevention lie more in maintaining a lasting concern about MSDs than in relying on their immediate eradication after an external intervention. There are some main factors that need to be achieved in order to do this:

- Project management capabilities (Daniellou et Béguin 2004, Caroly, et al. 2008)
- Common knowledge on MSD
- Dealing with organizational difficulties with prevention in mind

3.1.1 Managing prevention projects

According to the analysis carried out by Caroly et al. (2008), some elements in project management can facilitate prevention inside the firm. First, a distinction must therefore be made between the person who commission the project, the project owner, and the person who is in charge of the good progress and execution of the project, the project manager. It is necessary to have a project owner who defines the objectives, validates the actions and is responsible for their results. The project manager, instead, has to have the means to find solutions adapted to the project. The third entity is the intervener who carries out the project, who might be internal, i.e. an employee with knowledge in ergonomics, or external, e.g. a consultant.

The relationship of the intervener with both entities varies, depending on the existing resources. However, the intervener must ensure that the project owner is aware of MSDs, whether in terms of the health of employees or the economic health of the company. It is also important to help the project owner to make links between the different aspects of the project and to stimulate the choice of orientation between the diagnosis or the search for a solution. The intervener can also bring in other points of view by bringing in other actors (occupational physician, consultants...) or divisions of the company with links to the work situation.

For the project manager, the intervener must ensure that common knowledge is built up in terms of knowledge in terms of MSDs by carrying out demonstrations on workstations or situations at risk. The facilitator must also ensure that a broad field is opened up for the search for solutions, by bringing to the table the actors with the necessary skills.

3.1.2 Organizational difficulties

As explained in Chapter 2, work organization can create a context in which the onset of MSD is more likely. There are two main actions, at the organizational level, that can allow a company to achieve an effective prevention. First, work organization must be put at the center of design and prevention projects. Secondly, the company's administration must take into account the human factor so that occupational health issues are truly part of the company's priorities and targeted actions of the company.

To center projects around work organization, maintenance operations must be recognized in the work organization to make managing malfunctions easier. This is necessary since maintenance operations can be very stressful on operators, due to the time loss and less experience. In the same way, the commercial offer to clients must take more into account the constraints of the organization of production. Coherently, actions with suppliers should be planned to impose ergonomic requirements as part of the required criteria.

The production organization that involves managing spaces and situations should indeed take into account the industrial and personal variations. This allows operators to develop strategies to anticipate unexpected variations, accidents and stock ruptures. It is essential for the field managers to be formed on this way of working to allow the operators to have a margin of action on time management, work repartition, anticipation of changes and feedback on the difficulties encountered.

Secondarily, for occupational health to become a real priority for companies, there are some conditions to be satisfied:

- Engineers, supervisors and designers should be formed on managing prevention projects by providing tools to analyze current work situation and to design future work situations.
- Analyzing the costs of MSD within companies with the help of indicators measuring work conditions and their effects on health can make managers aware of the benefits of prevention and stimulate social debate on such complex issues.
- The statutory document for risk analysis could integrate a thorough MSD risk analysis and establish some related preventive actions.

3.1.3 Common MSD knowledge

The gesture model presents a set of factors involved in the appearance of MSDs. It makes it possible to take into account all the components of the work situation: internal and external determinants, organization, work relations and psychosocial factors. The company's strategies have a direct impact on the work gesture and, as a result, not taking into account all the possible impacts on these dimensions will lead to the development of a poor prevention plan.

The professional gesture contains the history of the company, but also of the operator and his career in the company. It is also an anticipation of what is expected and perceived by the operator to be able to carry out his production. The development of individual and collective room for maneuver in the performance of work is a major challenge for the design of work situations (Coutarel 2004). Actions are constructed individually and collectively and it is advisable to consider the means of transmitting these skills and training within the company. If the newcomers find themselves learning their gestures from people who are in a situation of impediment, they will not be able to build an efficient professional gesture.

The construction of an efficient gesture requires a stability of prescriptions and organizations. The too frequent changes of procedures, production rules etc... undermine this capacity. The construction of a perennial gesture also consists in making sure that that provisional prescriptions do not last, because what is designed to be provisional is always equipped with fewer resources and not designed with a long-term vision that takes health into account.

Finally, it is necessary to be able to organize moments of exchange in the company around the professional gesture. It is during these moments of confrontation that the action can be enriched and become more efficient.

3.2 Ergonomic intervention

The first part will present the principles of the ergonomic intervention on work situations and how it can help taking into consideration overlooked factors that can eradicate MSD.

The following parts will present how the methods and tools that the ergonomic activity can use to characterize work situations (Daniellou et Béguin 2004):

1. Analysis of work
2. Deferred questioning about the activity
3. Risk evaluation grids and other tools

Finally, the last part will illustrate how an ergonomic intervention is structured in different steps and how they are defined and carried out.

3.2.1 Prevention and ergonomics

The contributions of epidemiology, physiology and ergonomics have made it possible to enrich the etiological models of MSDs. The consensus established around the bio-psychosocial model of MSDs integrates the physical, psychological, social and organizational characteristics of MSD risk. Risk factors can be classified into direct factors (biomechanical factors) and indirect factors (psychosocial factors and constraints related to the organization of the work). In addition, the gesture model tends to move towards a joint effect of biomechanical and psychosocial risk factors in the appearance of MSDs. Figure 11: Complete model of MSD risks from is the model that integrates the different spheres of influence and risk factors of MSD.

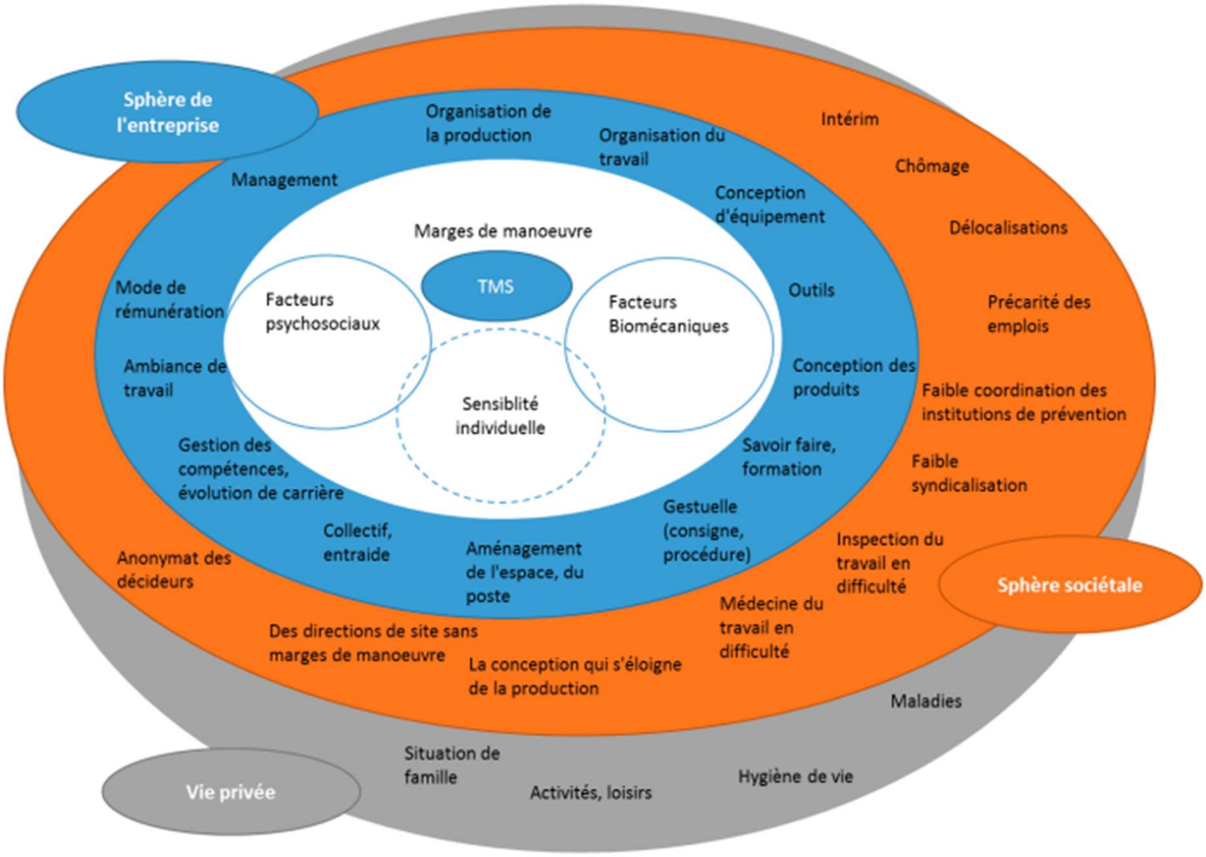


Figure 11: Complete model of MSD risks from (ANACT)

MSDs require a multidimensional approach that focuses on the constraints of the work constraints of the work situation, their determinants and even the determinants of the determinants (Coutarel et Petit 2013, Coutarel, Roquelaure, et al. 2013), these elements being interdependent. The overall model of MSD risk in Figure 11: Complete model of MSD risks from highlights this overlap and makes it possible to distinguish the proximal risk factors to which the worker is directly exposed: biomechanical factors, psychosocial factors, reduced room for maneuver (white circle in the model) which are determined by the external determinants of the task, indirect proximal risk factors (material and organizational conditions of the task), which depends on the organizational constraints of the company (blue circle of the model). The company's constraints are of the socio-economic type but also of the territory in which it is embedded (orange circle of the model). The internal determinants and risk factors are placed in the circle of private life (grey in the model), they are kept away from the center of the problem as being determinants that cannot be changed of the MSD risk or on which the company has only limited means of action, due to the fact that actions on other organizational determinants is more powerful.

The ergonomic intervention is based on a multifactorial model elaborated by Bellemare (2002). This model in Figure 12: MSD model for ergonomic intervention adapted from Bellemare gathers the determinants of the risk factors in three families: the technical determinants (tool, equipment, layout, process, raw materials etc.), organizational determinants (work cycles, assignments, instructions, rotations, supervision, upstream and downstream processes etc.) and the human determinants (processes, competences, experience) which are the determinants on which the company can act.

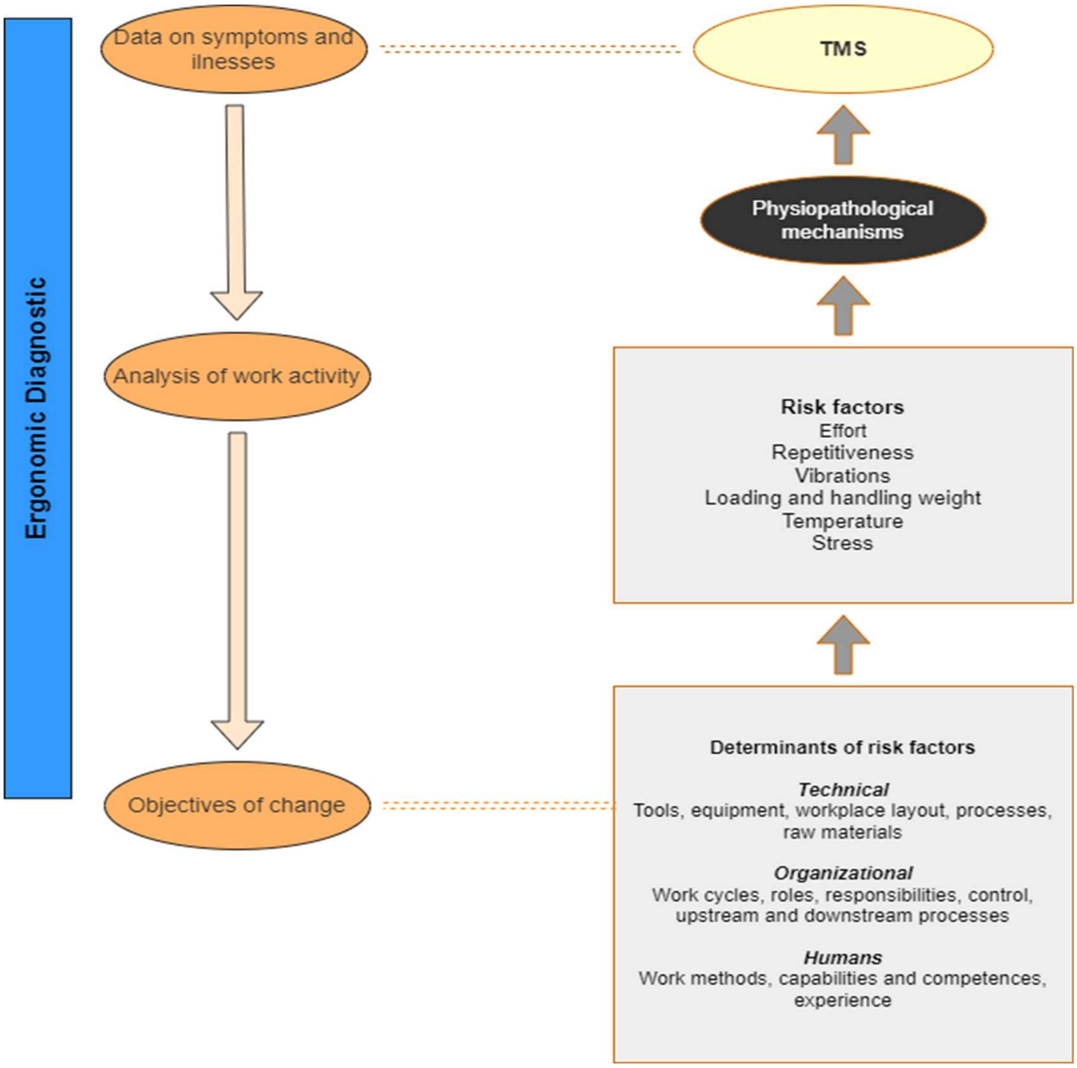


Figure 12: MSD model for ergonomic intervention adapted from Bellemare (2002)

The model assumes that in conducting an ergonomic intervention, the practitioner will find data on symptoms and injuries that can be linked to the determinants of the activity through the analysis of the work situation. This analysis is carried out on the basis of observations of actual work, interviews with the various actors in the work situation, including the operators. This model, rather than a direct action on the risk factors, tries to act on them by transforming the technical, organizational and human determinants of the activity. The aim is to act on the consequences of the activity by trying to reduce the negative effects both on the health of the operators, but also on the production. The following section will explore how the ergonomic action and analysis and work can be integrated into prevention measures.

3.2.2 Ergonomic analysis of work situations

At the heart of the ergonomic activity there is the characterization of the work situations. However, the analysis cannot be limited only to the observation of work. As seen in the previous models of the ergonomic intervention, also the determinants of the activity are taken into account (technical, organizational and human). The task is performed by the operator under several constraints linked to the general functioning of the company and it is not possible to comprehend them only with the observation of the activity. Consequently, the ergonomist that carries out such analysis is supposed to have the means to identify the requirements and constraints of the company, as well as the representations which have driven the decisions in the same domains of the problem to be analyzed.

The identification of the general context of the company and of the determinants of its activity is crucial for the ergonomic intervention. The collection of information will comprise many domains, including but not limited to (Daniellou et Béguin 2004):

- History of the company (foundation, development...) and its structure (headquarter and units, corporate and business, contractors etc.)
- Economic context, market, clients and seasonal variations
- Regulatory contexts (HSE regulations, ISO standards) and the designed control structures
- Geographical context and industrial cluster
- Demography of the company (contracts, recruitment, employees age distribution, turnover)
- Employee health and history (MSD, occupational illnesses, accidents, absenteeism)
- Technical processes

3.2.3 Deferred questioning about the work situation

in the analysis of the activity, observation and questioning are intertwined: questions are often linked to observed actions. The skills that the ergonomist acquires to question the operator while observing his activity can also be mobilized to ask questions outside the moment of observation of the activity in question. This skill is for example useful to question the operators about the course of rare incidents that the ergonomist does not have the opportunity to observe. It is also useful in certain training situations.

The three basic principles of the postponed questioning of the activity are to make an example, to respect of the chronological thread, and to explore the diversity of sensory experiences. To make an example corresponds to the fact of not questioning the operator on a class of situations, but on a specified situation: not "what happens when there is a power cut", but "do you remember the last power cut? can you tell me how it went?" It is then possible to obtain a narrative, following the chronological order. The ergonomist's questions will aim to give the operator a chance to evoke the different sensory experiences involved: which visual clues, which sounds, which sensations, which tactile controls are put in place by the operators to perform his or her tasks.

3.2.4 Evaluation grids

The ergonomic analysis of work is used to characterize a small number of activities in order to act on their design and layout. It is used only for a small number of work situations, since it is time consuming and it requires a large amount of information for every workstation. This factor has created the need for standardized tools in the last decades. Evaluation grids have been developed to rapidly identify dangerous tasks or situations and are now a widespread tool used in many companies. Another reason for their success is that they can used also by people with little to no experience in ergonomics, thus enlarging the pool of actors able to perform an ergonomic analysis. Among the first tools, some have been developed within enterprises, for example by Renault. However, these tools have been developed in particular industrial sectors (automotive, textile, slaughterhouses…) and they are often limited to a sole investigation of the physical work risks. Therefore, other grids have been developed by universities, for example the LEST grid, to include a participatory and concerted approach and to support the observation of work, the acquisition of knowledge, the search for solutions and, finally, training. The next paragraphs will present a brief history of evaluation grids, with a focus on the LEST and MAECT grids.

3.2.4.1 The LEST grid

The grid has been developed by the "Laboratoire d'Économie et de Sociologie du Travail" (Guélaud, et al. 1975) in response to the requirements of a 1973 law obliging company with more than 300 employees to report the improvements achieved in work conditions. The method aims to describe the working conditions as objectively as possible and to report on them in order to construct a balance sheet which should serve as a basis for the definition of a program to improve working conditions. The definition of working conditions that has been adopted by its authors includes the content of the work and the repercussions that it can have on the health, personal and social life of the operators. The authors exclude beforehand the questions of remuneration, job security or benefits, which, from their point of view, belong to other fields of study. The analysis of working conditions made possible by the tool is based on five main themes: physical work environment, physical workload, mental workload, psychosocial aspects and working time.

The method does not propose a specific user of the LEST grid a priori, it is intended to be standardized and it leaves little room for interpretation by the investigator, by integrating a maximum of measurable elements in its evaluation, so that the investigator is quickly trained. The LEST grid evaluates working conditions using 5 categories of risk factors:

- Risk factors relate to the work environment (noise, vibrations, lighting, temperature)
- Physical load is divided in static (work and rest posture) and dynamic (movements, handling and efforts)
- Psychological load includes time constraints, complexity and rapidity of the task, required focus and meticulousness

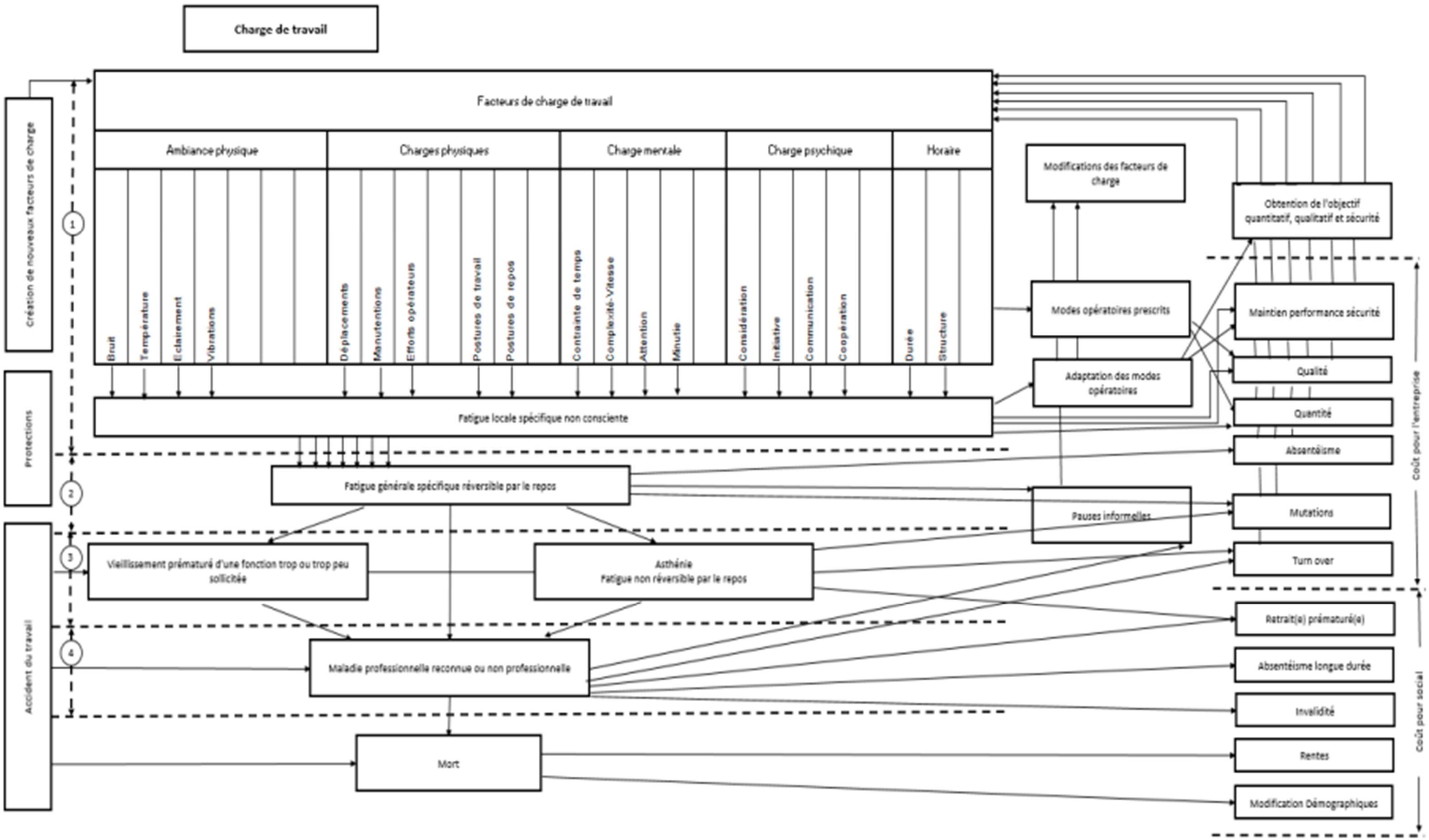

Charge de travail
Création de nouveaux facteurs de charge
Facteurs de charge de travail
Ambiance physique
Charges physiques
Charge mentale
Charge psychique
Horaire
Bruit
Température
Eclairement
Vibrations
Déplacements
Manutentions
Efforts opérateurs
Postures de travail
Postures de repos
Contrainte de temps
Complexité-Vitesse
Attention
Minutie
Considération
Initiative
Communication
Coopération
Durée
Structure
Modifications des facteurs de charge
Obtention de l'objectif quantitatif, qualitatif et sécurité
Modes opératoires prescrits
Maintien performance sécurité
Adaptation des modes opératoires
Qualité
Quantité
Absentéisme
Fatigue locale spécifique non consciente
Protections
1
2
3
4
Fatigue générale spécifique réversible par le repos
Pauses informelles
Mutations
Turn over
Vieillissement prématuré d'une fonction trop ou trop peu sollicitée
Asthénie
Fatigue non réversible par le repos
Accident du travail
Retrait(e) prématuré(e)
Maladie professionnelle reconnue ou non professionnelle
Absentéisme longue durée
Invalidité
Mort
Rentes
Modification Démographiques
Coût pour l'entreprise
Coût pour social

Figure 13: Facteurs de risque et leurs conséquences dans le modèle LEST (Guélaud, et al. 1975)

- ❖ Psychosocial risk factors are the initiative, social status, communication, cooperation and identification of the product
- ❖ The working time is a risk and it is divided in length and organization

The LEST grid makes it possible to take a look at the work situation, focusing on the task, the constraints it imposes on the operator and the conditions under which it is performed. It lacks a certain number of elements for it to be a complete tool for evaluating working conditions, as it does not apprehend the exposure to chemicals or general hazards for the health in the work area. Similarly, the external determinants and the organization of work are deliberately left out. The grid favors a focus on the workstation. In the search for objectivity and indisputable elements, it also reduces to a minimum the interactions of the user with the operator whose working conditions are being evaluated (Hubaut 2020). Despite one of the main objectives being the ease of use, it carries a lengthy user guide that looks like a treaty on work physiology plus an engineering physics course content.

3.2.4.2 The MAECT grid

This grill “Méthode d’Analyse et d’Evaluation des Conditions de Travail” has been conceived following a 1985 French law for the construction sector (INRS 1999). Intended for people working in prevention in this sector, it is simple and it allows users to define the priorities in terms of improvement of the working conditions. It is interesting as it includes considerations on work organization and also remuneration and work contracts. It is considered more as a method of analysis rather than as a grid.

The MAECT analyzes working conditions around 20 factors: 5 organizational factors, 11 factors for the environment and physical workload and 4 factors for the and 4 factors for the mental dimension and relationships at work. For each factor, a variable number of indicators are retained. The organizational factors include the market, the preparation of the site, the deadlines imposed, their adequacy with the material human resources and plans. They also question the presence and the content of safety training and the presence of hygiene facilities as well as the status of the workers. The environmental factors give an overview of the physical environment and risks present in the activity area. These factors are based on legislative measures (noise level, dangerous products), but also on the simple presence of risks, to lead to their reduction or elimination. The factors relating to physical activity try to evaluate the amount of physical effort produced by the team during the working day. The aim here is to address the issue of MSDs but also the use of tools and work postures. Mental activities and work relations are as important as physical activities in terms of working conditions. The question is whether the workers have sufficient means to carry out the task. Communication and the work are also questioned as elements participating to the working conditions on a construction site.

This grid allows the collect of information for the construction sector. However, the difference between the physical handling of weight and physical efforts can be difficult to be seen on the field. The combination of factors leaves some doubts as well, since it would be difficult to categorize a complex task with multiple movements. It also time consuming as it requires an entire day for a team on a construction site.

3.2.4.3 Other tools for MSD risk evaluation

The rapidly growing number of cases of MSD created the need for readily available tools, easy to use even for people with very little to no experience in ergonomics. Some specific grids have been developed: *Rapid Upper Limb Assessment* (RULA) in Annex 2 , *Occupational Repetitive Action* (OCRA) in Annex 1, *Quick Exposure Check* (QEC) in Annex 3 , the Nordic Musculoskeletal Questionnaire in Annex 4 from Descatha et al. adapted from . Risk factors are addressed singularly (for example effort is not correlated with work pace), whereas the combination of these factors has been identified as the cause of the onset of MSD (Kuorinka and Forcier 1995). In addition, they lead the analyst to focus mainly on local factors and causes, thus not considering the bigger picture of organizational factors and other determinants (work organization, social support and status etc.). The outcome of these analyses is usually a new design and layout of workstations.

3.2.5 Steps for assessing and preventing MSD

The steps for the evaluation of risks have been developed around the tools used for evaluation, presented in the previous part. The prevention process group together the steps to follow, the tools to use, the actors to involve and the realization of the solutions. The next part will briefly illustrate an evaluation process developed in Belgium in 2007.

3.2.5.1 The strategy Sobane-Deparis

The process combines the SOBANE risk management strategy, developed by Malchaire (2006), with the DEPARIS screening method. It is based on 4 progressive steps: Screening, OBservation, Analysis, Expertise in Figure 14: SOBANE strategy steps from Direction générale Humanisation du travail .

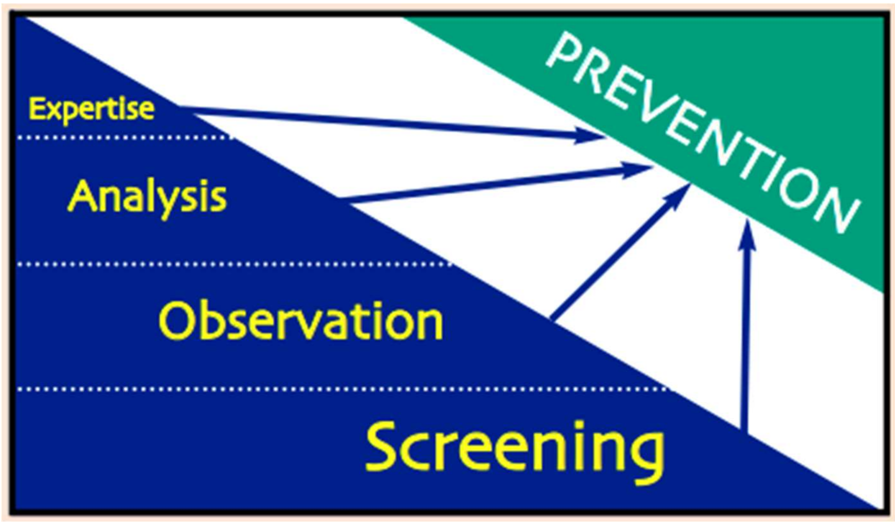


Figure 14: SOBANE strategy steps from Direction générale Humanisation du travail (2007)

- Screening: This level involves identifying the main problems and correcting the obvious errors. This identification is based on the Deparis method and is carried out internally by people in the company, without any particular skills in in the field of prevention. This phase also involves a working group and requires a coordinator to collect actions, coordinate the implementation of solutions or initiate the continuation of the study on a higher level.
- Observation: It consists in involving the actors of the work situation in the resolution of problems with less immediate solutions or to determine for which the assistance of a prevention consultant is prevention advisor is essential. This level is based on an observation grid and requires the involvement of the same working group and coordinator as the screening level.
- Analysis: When screening and observation levels do not address the issues or when the identified issues are beyond problems or when the problems identified exceed the immediate competencies of the actors of the actors involved, or when doubts persist, it is advisable to

activate the analysis level. This level calls for the assistance of a prevention advisor with the competence, tools and techniques to deal with the problems. These consultants are generally external to the company and they work in close collaboration with the internal prevention department. The analysis may require simple measurements, with common devices for authentication of the problems, the search for causes and the optimization of solutions. The analysis work is based on the data collected at the previous levels, including working with the coordinator. If the analysis shows limitations that require further investigation, it may be decided to call on the expertise.

- Expertise: It is to be carried out by the same people from the company and prevention consultants, with the additional assistance of highly specialized experts. It will concern particularly complex situations and may require special measurements.

The SOBANE approach presents a complete articulation between assessment and prevention, each level having its own specific assessment tools. It leaves two levels for people in the company people in the company, without any particular skills in ergonomics, since the involvement of an of an expert should only be done if no means of prevention has been found by the previous levels. The whole process relies on a coordinator who knows it and involves the right actors at the right time of the process.

4 How firms act for prevention

This section will try to present the most common companies' approaches towards prevention. The first part will illustrate the traditional approaches for the prevention of occupational risks and accidents, while the second will present approaches for the prevention of MSD. The third part, instead, will show the shortcoming of current practices and the fourth part will demonstrate how ergonomics can contribute to prevention

4.1 The traditional approaches on prevention of occupational risks

The objective of this chapter is to briefly present some of the approaches usually used by prevention specialists in companies in order to outline their principles, to discuss their limits and finally to show the connections with ergonomics.

4.1.1 From the analysis of accidents to the root cause analysis

The analysis of accidents is an *a posteriori* approach because it takes place *after* the event. The objective of this approach is to identify, once the accident has occurred, the different factors that generated its occurrence (Garrigou, et al. 2004). Jorgensen (1998) distinguishes between different types of analysis: the analysis and identification of where accidents occur; measuring the impact of accidents in order to evaluate the effects of the effects of preventive measures; analysis of the frequency and severity of accidents in order to prioritize preventive actions; identification of the direct and indirect causes of the accident.

The systemic approach has greatly renewed accident prevention. Indeed, the human being becomes an element of a more complex system, the accident being as a particular event of the Man/Machine system, of the socio-technical system. In the conception of the accident perceived as an event, it is no longer treated as a separate phenomenon or as a simple product linked to a given cause (Chesnais 1990), but as the result of interactions between the different components of the of the system. This conceptual leap will open the way to the multi-causality of accidents, as well as the development of tools and methods of analysis, such as the "root cause analysis tree" (Monteau 1998). The underlying hypothesis is that the accident is linked to variations in one or more of the elements determining the work (Garrigou, et al. 2004). All the data is then summarized in a graph presenting a tree of causal relations whose conjunction makes it possible to explain the occurrence of the accident. This technique remains a good support to make interact the different points that will subsequently attempt to explain its occurrence.

Hale (1998) stresses that important advances have been made thanks to the development of cognitive psychology, which has contributed to highlighting that people were « information processors, responding to their environment and its hazards by trying to perceive and control the risks that are present. The emphasis was also shifted in this models away from blaming the individual for failures or errors, and towards focusing on the mismatch between the behavioral demands of the task or *system and the possibilities inherent in the way behavior is generated and organized ».*

FICHE D'ANALYSE D'EVENEMENT SECURITE / ENVIRONNEMEN

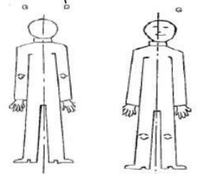
PARTIE 1 / IDENTIFICATION & DESCRIPTION

TYPOLOGIE DE L'EVENEMENT				
SECURITE	☐ Accident de Travail Avec Arrêt (ATAA) ☐ Accident de Travail Sans Arrêt (ATSA) ☐ Maladie Professionnelle (MP) ☐ Accident de Trajet Avec Arrêt (ATjAA) ☐ Accident de Trajet Sans Arrêt (ATjSA) ☐ Exposition Accidentelle Amiante (EAA) ☐ Incident Amiante (IA)	☐ Exposition Incidentelle Amiante (EIA) ☐ Accident Bénin (ATB) ☐ Accident de Trajet Bénin (ATjB) ☐ Presqu'accident (PRAT) ☐ Incident (INC) ☐ Situation Dangereuse (SD) ☐ Incident Chimique (IC)		ENVIRONNEMENT

IDENTIFICATION				
Société				
Dans le cas d'un accident corporel	**Nom**		**Prénom**	
	Salarié	☐ Salarié	☐ Intérimaire	☐ Autres (à préciser) :
Lieu détaillé / Service / Poste				
Date			**Heure**	☐ Horaire journé
1[ère] personne avisée			**Nom de la personne/SST ayant pris en charge la victime**	

DESCRIPTION			
		Nom du témoin(s) de l'accident	
		L'accident a-t-il été causé par un Tiers ?	☐ Oui
		L'accident a-t-il fait d'autres victimes ? *(indiquer le(s) nom(s))*	☐ Oui
		L'accidenté a été transporté par les services de secours ?	☐ Oui
		Supérieur hiérarchique prévenu	☐ Oui
		Situation de travail	☐ Trava ☐ Coac
		Si incident amiante :	Référence

Equipements de Protection	**Equipements de protection individuelle**	**EPI portés ?**	☐ Non concerné ☐ Oui (*indiquer lesquels et indiquer leur état*) ☐ Non (*indiquer pourquoi*)
		EPIs disponibles au poste de travail ?	☐ Non concerné ☐ Oui (*indiquer lesquels*) : ☐ Non (*indiquer pourquoi*)
	Equipements de protection collective	**EPCs disponibles au poste de travail ?**	☐ Non concerné ☐ Oui (*indiquer lesquels et indiquer leur état*) : ☐ Non (*indiquer pourquoi*) :

Conséquences	**Nature des lésions**		**Siège des lésions** (*Entourer la / les zor* 
	Durée de l'arrêt de travail		
	Conséquences ?		

PARTIE 2 / ANALYSE & PLAN D'ACTIONS

ANALYSE DE L'ACCIDENT : ARBRE DES CAUSES	
Noms des participants à l'élaboration de l'arbre des causes	
Pour chaque cause racine, identifier une action numérotée à transmettre dans le plan d'actions en faisant référence au numéro attrib	
N° — Action définie — Cause racine —	

Figure 16: Document for analyzing accident represents a the document for analyzing accidents. In the first part different types of accidents are listed: regarding asbestos or chemicals, injuries or pollution. The second section gives information about the people involved in the fictional accident, who are the victim, the witness and the *SST* (in French “saveteur secouriste du travail”, which means “first-aid rescue operators”). Then, it describes the accident and the situation in which it occurred. The fourth section inquiries about properly wearing PPE. The last section of the first page describes the physical consequences for the victim. The second page contains a space for the root cause tree and the actions identified by this analysis. The causes of the accident are analyzed in the root cause tree with the corresponding identified corrective and preventive actions in Figure 15: Cause tree analysis (Arbre des causes).

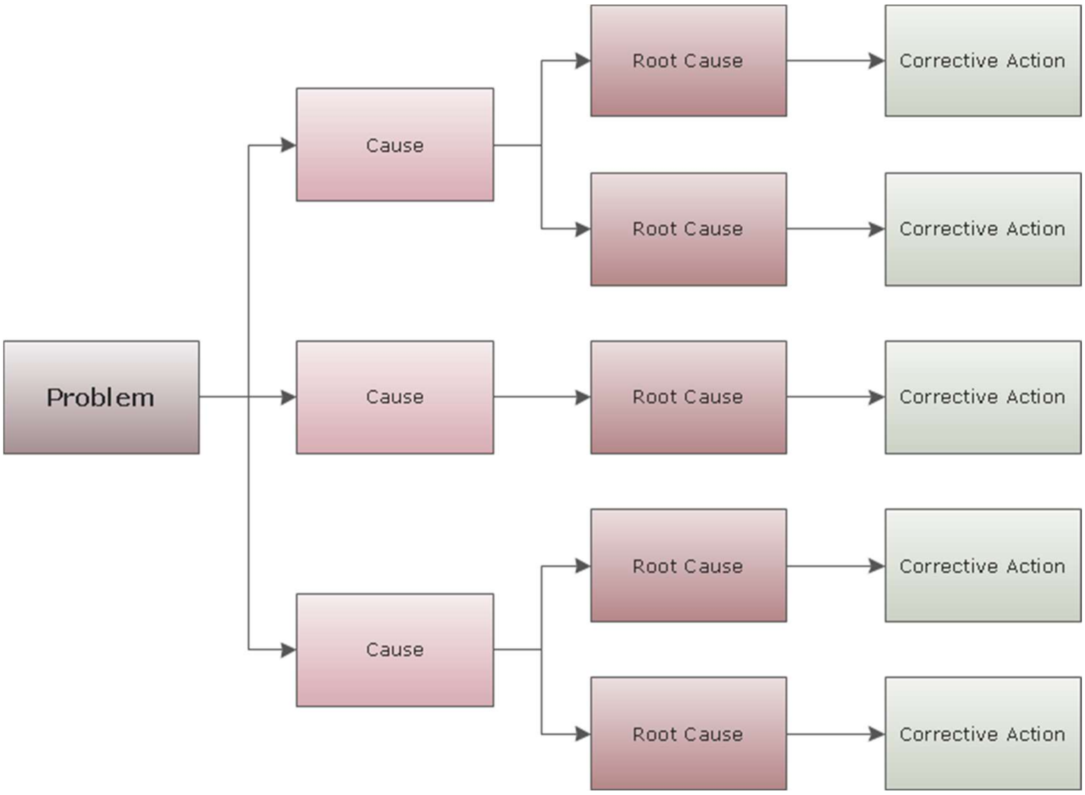
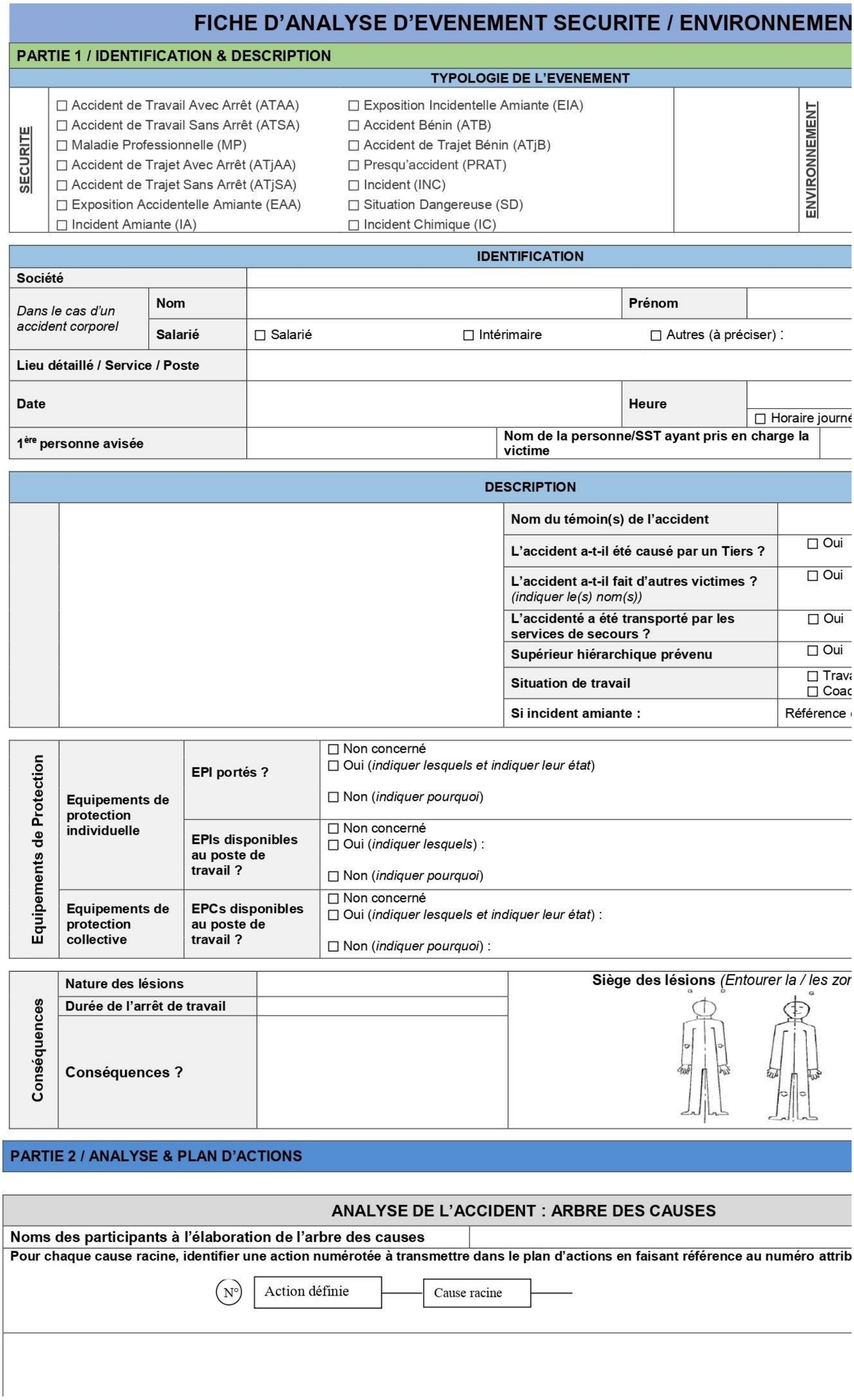


*Figure 15: Cause tree analysis (*Arbre des causes)



FICHE D'ANALYSE D'EVENEMENT SECURITE / ENVIRONNEMEN

PARTIE 1 / IDENTIFICATION & DESCRIPTION

TYPOLOGIE DE L'EVENEMENT

SECURITE	☐ Accident de Travail Avec Arrêt (ATAA) ☐ Accident de Travail Sans Arrêt (ATSA) ☐ Maladie Professionnelle (MP) ☐ Accident de Trajet Avec Arrêt (ATjAA) ☐ Accident de Trajet Sans Arrêt (ATjSA) ☐ Exposition Accidentelle Amiante (EAA) ☐ Incident Amiante (IA)	☐ Exposition Incidentelle Amiante (EIA) ☐ Accident Bénin (ATB) ☐ Accident de Trajet Bénin (ATjB) ☐ Presqu'accident (PRAT) ☐ Incident (INC) ☐ Situation Dangereuse (SD) ☐ Incident Chimique (IC)		ENVIRONNEMENT

IDENTIFICATION

Société				
Dans le cas d'un accident corporel	Nom		Prénom	
	Salarié	☐ Salarié	☐ Intérimaire	☐ Autres (à préciser) :
Lieu détaillé / Service / Poste				
Date			Heure	☐ Horaire journe
1ère personne avisée			Nom de la personne/SST ayant pris en charge la victime	

DESCRIPTION

		Nom du témoin(s) de l'accident	
		L'accident a-t-il été causé par un Tiers ?	☐ Oui
		L'accident a-t-il fait d'autres victimes ? *(indiquer le(s) nom(s))*	☐ Oui
		L'accidenté a été transporté par les services de secours ?	☐ Oui
		Supérieur hiérarchique prévenu	☐ Oui
		Situation de travail	☐ Trava ☐ Coac
		Si incident amiante :	Référence

Equipements de Protection	Equipements de protection individuelle	EPI portés ?	☐ Non concerné ☐ Oui (*indiquer lesquels et indiquer leur état*) ☐ Non (*indiquer pourquoi*)
		EPIs disponibles au poste de travail ?	☐ Non concerné ☐ Oui (*indiquer lesquels*) : ☐ Non (*indiquer pourquoi*)
	Equipements de protection collective	EPCs disponibles au poste de travail ?	☐ Non concerné ☐ Oui (*indiquer lesquels et indiquer leur état*) : ☐ Non (*indiquer pourquoi*) :

Conséquences	Nature des lésions		Siège des lésions (*Entourer la / les zor*
	Durée de l'arrêt de travail		
	Conséquences ?		

PARTIE 2 / ANALYSE & PLAN D'ACTIONS

ANALYSE DE L'ACCIDENT : ARBRE DES CAUSES

Noms des participants à l'élaboration de l'arbre des causes	

Pour chaque cause racine, identifier une action numérotée à transmettre dans le plan d'actions en faisant référence au numéro attrib

N° — Action définie — Cause racine

Figure 16: Document for analyzing accidents

4.2 MSD prevention

This part aims at illustrating the most common approaches to MSD prevention by companies presented in a report by Caroly et al. (2008). Actions are grouped under strategies targeting 4 types of transformations.

- Actions oriented towards the work station
- Actions oriented towards the control of effects of diseases
- Actions oriented towards the work organisation
- Actions oriented towards the individual

Target of the actions	Undertaken actions
Actions aimed at workstation layout and design	Configuration of workstation and fitting of the equipment
	5S, Kaizen or other continuous improvement tools
Actions aimed at the work organisation	Establishment of rotation system
Actions aimed at the worker	Interventions in the workplace by physical therapists or educators
	Gestures and postures training
Actions oriented towards the control of consequences of illnesses	Termination of employment
	Bonuses for presence
	Health surveys

Table 1: Actions undertaken from companies, grouped by type of target strategy

4.2.1 Actions aimed at workstation layout and design

The first type of prevention approach concerns the adaptation of workstations and of equipment. It mainly consists of changing the workstation design and layout and bringing new equipment. In the case of a technical approach to risk prevention, this action is also the most common. It is also an approach that does not impact on the other dimensions of production, and since it does not interfere with other departments, it is frequently adopted.

In this type of approach, the use of a tool to quantify the exposure to risk factors is common. It has the advantage of making the prioritization of actions to be implemented easier, but also to facilitate communication with other parties by means of qualitative data. However, these tools present some pitfalls or difficulties that can be identified in the following terms:

- They are by definition reductive because they take into account only the physical risk factors (handling, postures and repetitiveness) in which they are interested
- The conditions of use, and therefore of validity, defined by the designers of these tools are not always respected
- The quantification of the risk does not lead to any concept likely to constitute effective solutions.

5S is one of those tools for continuous improvement that are used directly on the field by companies. Together with Kaizen, they are used to identify and improve processes. While 5S is more focused on organizational means (such as a clean workspace, standardized rules etc.), Kaizen is more used to change the methodology of processes. If the concept or philosophy of 5S and Kaizen is clear and interesting, the ways in which it is applied are very numerous and different. According to Caroly et al. (2008), the concrete implementation of Kaizen approaches leaves little or no room for health issues due to the fact that Kaizen projects are largely oriented by productivity gains.

4.2.2 Actions aimed at reorganizing work

One of the most common actions aimed at reorganizing work is rotation, which is often used as a provision for dealing with difficulties caused by MSDs. Contrary to what is often thought, the use of this organizational arrangement for prevention purposes appears to be complex (Vézina 2003). Indeed, some possible difficulties companies might encounter:

- Actors are not as versatile as they would need to be
- Rotation is also perceived as a factor of disorganization of the work of operators
- Rotation is also an additional difficulty for those who manage this rotation: knowledge of the operators, management of the teams (leaves, absences, aptitude restrictions, etc.)
- In some cases, the rotation generates quality defects that were not present before, and which lead to a return to a specialization of certain positions. The cost of this process is high for employees.

The conditions to implement an effective rotation system are as follows (Vézina 2003):

- Workers must be properly trained for the different positions to be held
- The most difficult positions must be transformed. As a matter of fact, the risk is not proportional to the time spent on the workstation that affect health the most. The fact that all workers are put on these workstations leads to an increase of risk for everyone.
- The workstations must be sufficiently different from each other
- Apprenticeship at each workstation must be gradual

In addition to these four basic principles, there are some other conditions that should be met before implementing a rotation system. In the opposite case, rotation could entail an over exposition of workers to risk factors, that could produce the opposite effect.

4.2.3 Actions aimed towards the worker

This action aims at adapting the worker at the job and not the job at the worker as it was done before. The approach then becomes individual and it does not analyze the work itself. In addition, it implies that MSD are caused by a lack of adaptation of the operator to the work.

One common practice is the gestures and postures training. Overall, it is a matter of teaching workers which postures are the most favorable for the realization of the work according to conditions that favor the preservation of their physical integrity. This removes the room for maneuver necessary for the operator to face the variability of the work. In addition, when MSD manifest themselves anyway, the blame falls on the operators that did not execute what they were taught. It is clear that the conditions in which the "good gestures" and "good postures" are taught are very far from the real conditions of work. Indeed, the variabilities in the work situation, originating from equipment, materials, colleagues, work orders and many other variables, only too rarely allow the prescribed operating methods to be followed: the prescription is too costly physiologically to be maintained over the working day, the work rate does not the pace of work does not allow to follow the prescriptions which take more time, the workstations have not been designed to allow posture changes, etc.

This type of training is still very traditional and common in companies. Some public prevention organizations provide them, as do many consultants. For the company, they have two main advantages:

- They are inexpensive compared to other types of actions that could be implemented
- The focus is on the individual responsibility of the workers: their pain occurs because they do not follow the instructions.

Less frequent but growing, interventions by physiotherapists or physical activity specialists are another identified recourse. The remarks that can be made are relatively similar to those in the previous paragraph. The occurrence of MSDs is linked to the insufficient attention they pay to their lifestyle (physical activity, hydration, diet, warm-up and stretching, etc.). Group exercises are then set up during the so-called "active" breaks.

These relatively new practices offer little hindsight to evaluate their effectiveness in concrete terms. Nevertheless, specialists agree that if such an approach can constitute an interesting complement, it is not sufficient by itself and it does not allow profound changes without deep changes in the work situation itself.

4.2.4 Actions oriented towards the control of consequences of illnesses

Another action carried out by companies is directly targeted at controlling the consequences of MSD, such absenteeism, unsuitability declarations and insurance claim. Layoffs are one way for some companies to combat the reporting of MSDs. Used more or less consciously, the mechanism is simple: after an initial case of dismissal for unfitness, no employee will accept being declared unfit. Other companies appoint doctors to check that employees who have been dismissed are at home and ill. The layoff that punish the culprits are an explicit way of combating absenteeism and to reduce the number of complaints.

Another measure, for example, is a compensation system that is largely made by bonuses that are attached to a task to be performed, whether it is individual or collective. This bonus is not paid if the employee is absent, whatever the reason. The sum of the bonuses is equivalent to 20% of the salary. This bonus for presence questions the possibility of setting up preventive actions. It is also contradictory with the possibility for employees to recover from initial injuries before the pathology.

Health surveys are also used by companies, but here again the results are often lacking. Two major pitfalls have been identified (Caroly, et al. 2008):

- The conditions for using this tool are not met:
    - The preliminary and necessary social construction

- The conditions of the survey, the conditions of data entry and processing
  - The analysis and interpretation of the results
- These different steps require specific and consequent skills that the company lacks. Thus, the process is often not completed.

The implementation of this tool sometimes replaces any approach to prevent the onset of MSD in the company. The use of a tool without a clear plan or laid out project will not improve the situation or automatically draw a roadmap. The tool must be used in a context to provide usable results.

4.3 Limits of traditional approaches on prevention

4.3.1 The issues arising from these approaches

The majority of MSD and occupational risk prevention approaches focus on movement. Many firms still adopt models that almost exclusively take into account the biomechanical dimension, even if organizational approaches (such as work rotation) are well known to be risk factors. These models are focused on the physical or physiological dimension, where the person is considered as a system transforming energy (Garrigou, et al. 2004). It is usually considered that workers are exposed just to concrete and visible hazards that are dangerous to the body (harmful chemicals and materials, postures, falls et cetera), while the risks that can be classified as virtual (noise, stress, monotony et cetera) are rarely considered in prevention.

These representations of man and danger lead to consider damage to health only in terms of damage to the body, whether in the form of occupational diseases or accidents. The cognitive dimensions underlying any activity are therefore greatly underestimated; it is known that situations of overload in the processing of information or of time pressure are likely to produce various dysfunctions with regard to the efficiency or reliability of the person, but also, in the longer term, damage to health. In the longer term, this can lead to physical and psychological damage.

The new market requirements and the concern of companies for profitability favor the emergence of new organizational modes such as lean manufacturing. These new production methods lead to shorter production runs, frequent production changes, emergencies that must be met and new standards. The operator is more and more solicited, he is asked to be versatile and autonomous, which sometimes leaves him alone to face his suffering. On the other hand, the increasing speed of execution and the simplification of the task translate into biomechanical and mental pressures (Clot 1999).

The appearance of MSDs reveals a reduction in the room for maneuver necessary for the operator to form her own gesture in the activity. The organization will not think of the gesture as an activity, which is nevertheless a necessary condition for reconsidering its contribution to performance and to provide the means for MSD prevention (Bourgeois et Hubault 2005). For effective prevention of MSDs, an organization is needed that does not oppose the development of movement, but which encourages the operator to construct new regulations, to allow the genesis of new gestures in order to constitute a system of instruments to prevent suffering at work**.**

4.3.2 Status of safety requirements and instructions

The question of procedures or safety instructions is at the heart of prevention approaches. The general assumption is that it is sufficient for operators to "execute" and follow instructions to the letter in order to meet safety, reliability and efficiency requirements (Garrigou, et al. 2004). Drafting such documents is a particularly difficult exercise (Leplat, About implementation of safety rules 1998). In order to design safety procedures, the occupational health and safety officer must foresee a number of risk situations and combine different levels of safety standards derived from general regulations, etc. In many cases, the different states of a system are defined in the context of nominal situations.

This results in a strong underestimation of incidental or degraded situations, even though they are at the origin of risk-taking. In addition, instructions are not always usable, especially when the work situations are subject to highly variable.

4.3.3 Accidents and their causes

The legal logic of compensation for damage caused by caused by accidents at work often leads the company's actors to consider the individual to consider the individual responsible through negligence or lack of vigilance, insofar as a deviation from the rules is observed that is detrimental to the performance of the system or to health. The legal logic of compensation for damage caused by accidents at work often leads company players to consider the individual responsible for negligence or lack of vigilance, insofar as a deviation from the rules is observed that is detrimental to the system's performance or to health; prevention or training approaches are then focused on the acquisition of individual safety behavior. This "traditional" logic, classically carried by engineers and technicians, focuses on highlighting negligence, unawareness, lack of discipline, inattention, loss of a sense of responsibility, loss of motivation, etc.

It is true that the cause-tree approach has led to important advances, but even if this approach remains suitable for assessing the overall level of safety in an organization, it is insufficient to explain the why and how of an accident and inadequate to propose prevention measures that take into account that take into account the needs of the operators. The cause tree is produced by deterministic model that takes little account of the regulatory function of man nor the cognitive processes that are brought into play in the work situation, and particularly in a and more particularly in the context of an accident; the challenge is to better understand the circumstances triggering the accident and the operator's role (De la Garza et Weil-Fassina 1995).

4.4 Contributions of ergonomics to prevention

The exposure to occupational risks is multi-causal, bringing into play the characteristics of the person, the technical system and the organization (Daniellou et Béguin 2004). The multiple causes have to be defined in order to act on prevention. Different domains have to be considered and different actors have to collaborate. Actions aimed at preventing risks have to mobilize:

- The operator and her resources: her experiences, competences, her representations of the situation or of the risks, her physical abilities etc.
- The technical system and its environment: the technology and the materials used, physical environments;
- Work organization: hours, team composition, safety procedures etc.

The interpretations of this problem are often contrasting, if not judgmental: « The operators are annoyed by the PPE, they do not respect the obligation to wear PPE even if they are formed and continuously reminded to wear them, they cannot be trusted etc. » Every contribution to prevention, from engineers, occupational physician or ergonomists, has to come from an interpretation of this problem, which will depend on the context and on the issues.

To rightfully represent the complexity of work activity is necessary to take into account a human model (Daniellou et Béguin 2004) which integrate the 4 aspects illustrated in Figure 17, adapted from Garrigou et al. (2004). A person carrying out tasks in his occupation will, indeed, mobilize all these factors.

There are many forms of variability, in work activities, that impact the 4 aspects of the previous model, from which occupational risks arise. The origins of these risks are often not taken into account by those who designed work situations as well as its organization (Garrigou, et al. 2004). Ergonomics can help in identifying these forms of variabilities to solve the root problem of the exposition to risks.

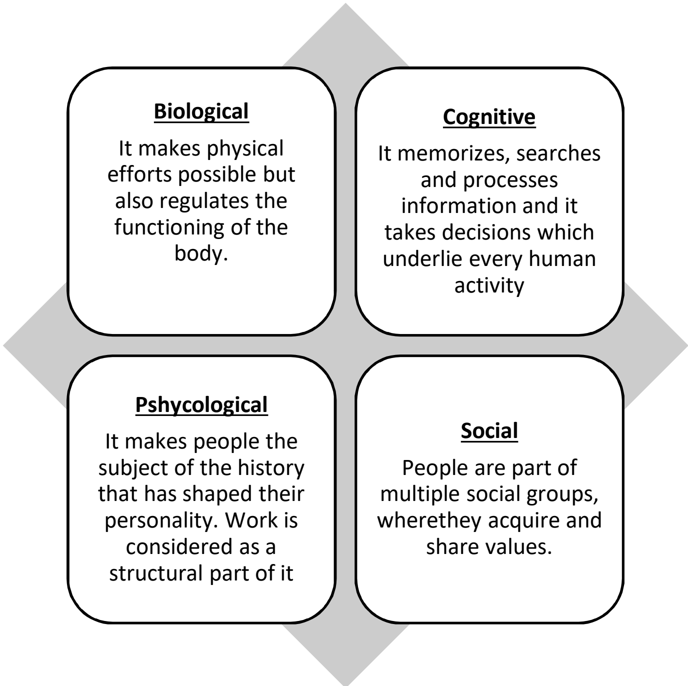


Figure 17:The 4 human dimensions

4.4.1 Individual variations

Ergonomic approach tries to take into account variations that concern individuals. It is possible to distinguish between intra-individual and inter-individual variations (Garrigou, et al. 2004).
Intra-individual variabilities Indicate the psychophysical variations of the same person, e.g. during one day a person goes through different mental and physical states. This allows to consider the apparition during the work day of fatigue generated by the work activity itself as well as fluctuations of the level of vigilance or attention due to different requirements. This aspect always has to be taken into account because very often accidents are attributed to a lack of attention by the operators (Garrigou, Tannière et Carballeda 2001), even when using in-depth analysis like the root cause tree.
Inter-individual variations, on the other hand, allow to highlight the diversity of the characteristics of a group of operators. They can be physical, the height or sex, regarding their experience, education or previous job experience or their history of occupational accidents. These characteristics are going to explain why every operator have a different perception and representation of occupational risks or why they take decisions differently.

4.4.2 Contextual variations

It has been shown in the literature (Wisner 1989) that even everyday occupational situations present operators with multiple forms of variability. Most often these variations are *irreducible*, in the sense they cannot be solved or avoided. In the industry this can concern variations in raw materials, in finished products or in temperature, humidity or vibrations. In this context, matter cannot be considered inert as it undergoes multiple transformations and processes that changes its physical structure. A sample in a laboratory for asbestos analysis is fractioned, cooked at high temperatures, mixed with strong acids and then diluted to be analyzed under a microscope. In addition, some

processes that are aggressive or wear and tear equipment can compromise the *nominal* function of the system and be the cause of degraded modes of working (Garrigou, et al. 2004).
In the case of a service activity, these irreducible variations are represented not in the matter but on the number of clients in the queue at a certain moment during the day, on the diversity of experience with the service itself of users, on the diversity of information to be asked for each case etc. The degradation of service quality or conditions of work can be caused by a misunderstanding or some form of perceived aggression between the two parties.

4.4.3 Organizational variations

For the organization, there are numerous factors that can create a difference between the actual functioning and the nominal desired one. Some categories have been created for organizational variabilities (Garrigou, et al. 2004): absences (due to illness, accident, seminar, education, paid time-off); variations in the compositions of teams (high employee turnover, growth in the workforce, rotation, differences of contracts and statuses); different timetables for some periods of the year or teams etc. Under these constraints, the enterprise must be able to rebuild itself in an ever-changing environment by relying on core competences that can be individual or collective.

4.4.4 The know-how of regulation and prudence

The interactions between the different forms of variabilities presented above can disrupt the normal functioning of facilities. In some cases, such disruptions can exacerbate and lead to major dysfunctions, creating risks for operator if not accidents. However, operators do not have a passive role with regard to these (Llory e Llory 1994, Laville e Teiger 1972, J.-M. Faverge 1970). With their own experience, they implement the know-hows to prevent these unwanted events, or even to treat them (Garrigou, et al. 2004). In some cases, while being effective at keeping the production or service running, these regulations can entail negative consequences on health in the long term: they are, indeed, at the very heart of the complex problem which is the exposure to occupational risks. Some examples of these individual regulations: exploration of the environment, research of information, making decisions, very often under strong time constraints.
Collective regulations, instead, are implemented after communication and coordination between the multiple involved actors. These actions are carried out not only in the cases of accidents or major events. They integrate also other know-hows related to prudence (Garrigou, et al. 2004). They are defined as attitudes, behaviours and ways of working that has the purpose of security and health preservation in work situations (Llory e Llory 1994). These know-hows implement security requirements; they complete them or they fortify them. Cru (1995) states that these know-hows are learnt on field watching those with more experience, then applying and articulating them according to one's requirements. These abilities are established as part of the work rules (Garrigou, Carballeda e Daniellou 1998) and concern multiple individual and collective aspects: ways of carrying out tasks; maintaining attention and vigilance; anticipation of variations in work situations; surveillance on other operators, especially if inexperienced; retrospection on completed tasks.
In this part the traditional approaches of prevention of occupational risks were presented. Then their limits were analysed and the possible contributions that ergonomics could bring are illustrated.

5 Methodology and context

This part will present the context in which this Master's thesis has been developed, as well as the methodology used.

5.1 Industrial context

This work has been conducted in the framework of a six-month internship within the company Eurofins Analyse pour le Bâtiment Sud-Est.

5.1.1 The company

The company Eurofins Analyse pour le Bâtiment Sud-Est (EABSE) is one of the laboratories of the Eurofins group. It belongs to the cluster of analyses for buildings, together with other 9 laboratories in France. It is specialized in the research of asbestos in construction materials, air and dust samples. Based in Saint Etienne, a city in the region of Auvergne-Rhône-Alpes not far from Lyon, it employs 40 operators. The company enjoys a certain independence from corporate: only HR and finance departments are managed at corporate level. This allows a wider range of action for the business unit managers.

The company is certified ISO 45001 for the safety management system and ISO 14001 for the environment management system. The site is assigned a QHSE manager for 30% of her time and an intern, with the role of HSE correspondent, is recruited. The team leaders and production manager, as well the Business Unit Manager, are also responsible for the animation of the safety and environment management system. Each team, in addiction, has an HSE referent who is formed on safety and environment matters.

In the perspective of continuous improvement, the company set multiple objectives concerning safety:

- Zero serious work injuries
- Reduction of minor injuries (cuts and scratches),
- Reduction of asbestos hazard
- Improvement of working conditions by means of an ergonomics project.

Our role as an HSE correspondent and our ergonomic project are within the scope of achieving these goals. Eurofins wishes to make the workplace better for its employees by taking into account their health, particularly in terms of musculoskeletal disorders.

The analysis processes and organization of the laboratory are standardized for all laboratories. The operators are divided in 3 teams, one of which always work nights, while the others alternate between morning and afternoon. The spatial division of the laboratory corresponds to the series of processes performed on the sample:

- ❖ Reception and coding: Samples are received from sampler companies, who are the upstream actors who collect samples and also the clients who receive the analysis result. At this step the samples are coded into the system with the client's demand and sorted for the type of analysis
- ❖ MOLP: This is the first step of the analysis of solid materials. Samples are analyzed under a special microscope and if asbestos is found, the client receives the report. If instead it is not found, samples go through a preparation in order to be analyzed under a more powerful microscope.
- ❖ Solid state preparation: Here the solid state samples that were not shown to contain asbestos, are prepared in various steps for the analysis under a more powerful microscopy.

- ❖ Air preparation: Here air samples directly go through a preparation process for the analysis under the MET microscope.
- ❖ MET: The samples here are analyzed under a more powerful microscope.

The laboratory has received the accreditation of the ISO 17025 standard about the "general requirements for the competence of testing and calibration laboratories" delivered by the "Comité français d'accréditation (COFRAC)".

5.1.2 Asbestos and the sector

The word derives from the Greek "ἄσβεστος", which means "inextinguishable", reflecting its use for candle wicks that would never burn up. Asbestos is a natural fibrous mineral. There are six types, all composed by long and thin fibers that can become airborne by abrasion. It has notable physical properties: electrical, thermic and sound insulator, highly fire-resistant, easily weavable and cheap. Its use traces as far back as the Stone Age and large-scale mining began in 19th century to supply manufacturers and builders.

It is classified as a carcinogen of type 1. It is the second cause of occupational illnesses and the first cause of occupation-related cancers. It is harmful to health in case of inhalation because a single fiber is 10 000 times smaller than a human hair. When inhaled, such a small fiber can penetrate all the way to the lower part of the lungs where it is not expelled or phagocyted, thus becoming bio persistent and directly toxic. The diseases that can arise are non-cancerous, asbestoses and pleural diseases, or cancerous, bronchopulmonary cancers or mesotheliomas.

The first cases of asbestos-related illnesses have been detected in the early 20th century: in 1906 an autopsy of an asbestos worker revealed large amounts of fibers in the lungs. Despite the growing scientific evidence, the first ban came only in 1986 in Sweden. The strong opposition from lobbyist has delayed the ban for many countries in western Europe, while in many others, as shown in the Figure 18: Legality of asbestos around the world , it is not banned yet or not even regulated. Italy banned all use of asbestos in 1992 and France did so in 1997.

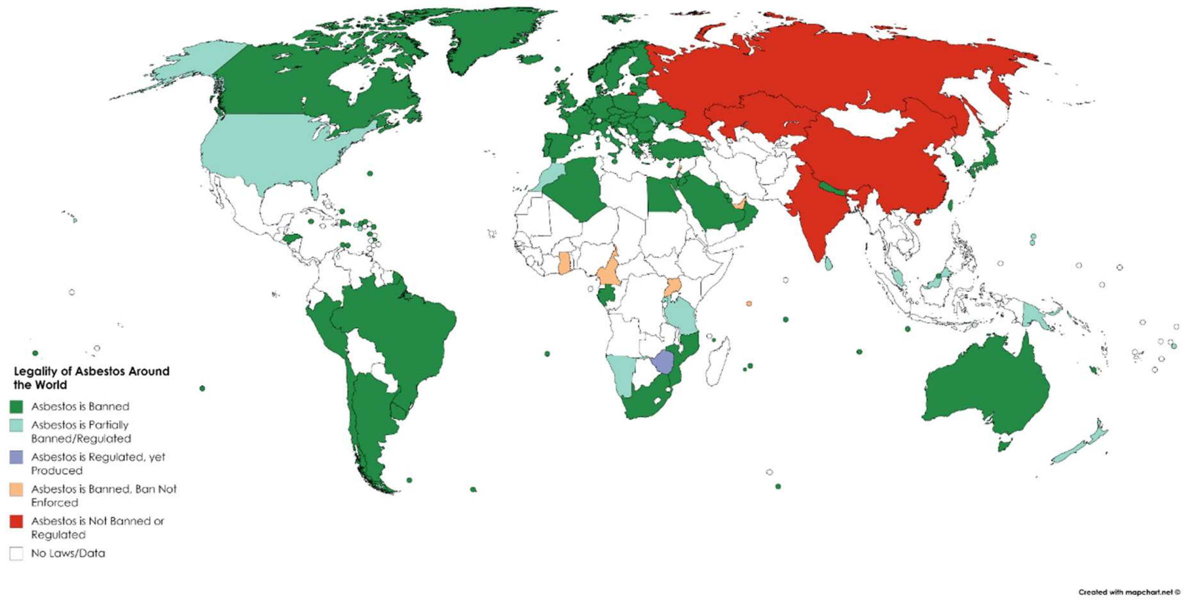


Figure 18: Legality of asbestos around the world (International Ban Asbestos Secretariat 2022)

The French regulation in 2011 has determined three groups of materials according to their propensity to release asbestos fiber (MINISTÈRE DU TRAVAIL, DE L'EMPLOI ET DE LA SANTÉ 2011).

A. The list A includes all materials that can release asbestos fibers through normal wear and tear. This list contains the flockings, the insulations and certain types of false ceilings as in Figure 19: List A materials: false ceilings, tube insulation and flocking.
B. List B includes all materials accessible "without destructive work" that can release asbestos fibers when they are subjected to an action such as rubbing, drilling, sanding, cutting. It may be asbestos-cement pipes, fiber cement roofs and vinyl floor tiles as in Figure 20: List B materials: garbage chute, walls and rooftops..
C. List C materials are those that are "inseparably incorporated into the building". They are accessible only by carrying out destructive works (destruction of masonry sheaths, etc.). A few examples are the roofing and waterproofing parts, facades, interior vertical walls and coatings, ceilings and fake ceilings, conduits, pipes, floor and wall coverings.

Considering its extensive use and the hazard that asbestos poses to health, regulation has been produced to preserve the health both of the general public and of operators. Funds are distributed at European and state level to remove asbestos from buildings, especially schools and gyms. To identify asbestos, companies specialized in sampling, take samples of various part of a building and send them to be analyzed at laboratories like Eurofins. In other situations, air and material samples have to be analyzed before starting works in the following domains: buildings, railways, ships, aircrafts and other types of installation. For airborne concentration of asbestos, the occupational exposure limit in Europe is set at 0,1 fibers per cm3 as an eight-hour time-weighted average (TWA).

Figure 19: List A materials: false ceilings, tube insulation and flocking

Figure 20: List B materials: garbage chute, walls and rooftops.

5.1.3 The mission

At the beginning of 2022, the hierarchy made a proposal about an ergonomic project for the laboratories. It consisted of an ergonomic analysis of workstation with the purpose of identifying, and then improve, the most demanding workstations. The site of Saint-Etienne accepted the proposal and recruited an intern with this mission and the role of HSE correspondent. The company has also scheduled construction works in the laboratory for the end 2022 which will change the layout of many workstations. It is seen as an opportunity to improve many stations, therefore the results from the ergonomic evaluation will be used in the new design plan. The mission has also been launched after the declaration of MSD from an employee, which urged the company to act.

The project has been conceived to reduce the number of MSD cases in the company. The HSE department of each laboratory has been designed as the responsible for the project and given the resources to carry it out. It has been set as an HSE objective for the year 2022, with the final deadline for the completion of the project as the end of the same year.

The project consists of three main steps, with a fourth added throughout the project:

1. The identification of the tasks and activities carried out by the operators in every analysis process
2. The ergonomic evaluation of these activities
3. The improvement of the most physical demanding workstations
4. The improvement of the risk evaluation tool

For the firsts step, it was decided to identify the tasks and activities at the cluster level. The engineer in charge of HSE projects at the cluster level defined a biweekly meeting to identify the tasks of a different process each time. The shared identification was seen as a way to ease the lengthy task of identification and also a way to share good practices or differences between each laboratory. In addition, sharing information about an action or an activity found to be critical in terms of ergonomic risks would be really easy.

For the second step, the HSE engineer developed an ergonomic evaluation tool and the method of observation, which will be presented in the Results section. They have been introduced by the HSE engineer assistant to each business unit in a 2-day demonstration. The third step is up to define to each business unit.

The actors concerned in the projects are all HSE managers who have competences in risk identification, including MSD, improvement of work stations but very often no formal education in ergonomics.

The fourth step has been added throughout the project, as we acquired more competences in ergonomics through the study of the literature. The tool showed some pitfalls, which will be discussed in the Results section. With the HSE manager, it was decided to propose some possible improvements for the tool.

5.2 The conduct of the internship

This section focuses on the conduct on the internship, thus including not only the ergonomic project but also our role as HSE correspondent inside Eurofins.

5.2.1 Role

Our internship started on the 1st of June at EABSE in Saint-Etienne with a contract expiring on the 30th of November. The tutor and instructor was the QHSE manager of the same site, who is based in Saint Etienne despite being responsible for other business units. She has almost 10 years of experience in various HSE positions and has formed multiple colleagues and interns with similar positions.

In the company the HSE correspondent realizes various activities:

- HSE reception training and formation
- Communicating and raising awareness on safety and environmental matters
- Monitoring the compliance of both personal and collective protection equipment
- Analyzing accidents and HSE events
- Managing HSE non-conformities: report anomalies and realize corrective actions
- Follow-up of asbestos and chemical waste
- Occupational risk evaluation
- Reporting to team leaders and managers
- Internal HSE audits

5.2.2 University and company' feedback

This MSc thesis project has been conducted in the framework of an Erasmus exchange between the school of Génie Industriel at the Institute Polytechnique of Grenoble in France and the Politecnico di Torino in Italy. The 18-month double degree program includes the first year of studies in Turin, the second year in Grenoble and an additional 5th semester of internship and thesis. It gives students the chance to obtain a double MSc degree in the domain of Industrial Engineering and Management. It started in Grenoble in August 2021 in Grenoble. Since in France engineering school is a 5-year school with the last semester devoted to the final internship, we first followed courses from the first semester of the 5th year, mainly in English. The second semester we followed courses from the second semester of the 4th year mainly in French.

The tutor from Grenoble INP is a doctoral student in ergonomics and the tutor from Politecnico is a professor whose course of analysis of production systems we had already followed in 2021. The school of Génie Industriel requires from students a presentation about their final internship project and a report of up to 30 pages. Differently, students at Politecnico have to present a thesis on a subject agreed upon with the tutor, which could come from an internship or a literature analysis. The thesis does not have a maximum number of pages and it requires a more complex development.

The project was presented early on in June by a colleague who trained us and the HSE manager for its use. The plan for its implementation was laid out with the HSE manager, who was currently updated. It did not progress much in the first two months since most of the time was spent to integrate in the company and to understand the role of HSE correspondent. It resumed in august and was the observations were carried out until the end of October for the meeting and the feedback. Overall, the feedback and support from the company was sufficient but not extensive. The blame also falls on us for a bad organization, due to struggles in adapting to company.

5.3 Methods

5.3.1 The general methodology

The question of the improvement of the approach towards prevention has to be treated by taking into account the actors involved. This work deals with three types of actors:

- ❖ The operators working on workstations
- ❖ The HSE manager
- ❖ Managers and team leaders whose decision can affect the operator

The industrial field that will be used to develop the project is that of the company Eurofins Analyse pour le Bâtiment Sud-Est, an asbestos analysis laboratory. The report also has to discuss the perimeter of the validity of the obtained results, i.e. the applicability to other work situations. This work is an ergonomic project for the improvement of workstations and general working conditions. It follows three main phases:

- The observation and analysis of work situations
- The identification and implementation of improvement actions
- The improvement of the risk evaluation tool

5.3.2 Evaluation of work situations

This is the first main step that serves the purpose of identifying the activities that are more physically taxing for the operators in order to prioritize action and improve working conditions. The first step is the selection of the activities to be analyzed and then the analyses of the activities.

5.3.2.1 Selection of the activities

Like in every job, a person performs a wide range of activities, some of which are performed less frequently or the composition of the task itself changes. Therefore, it is not possible to analyze every single activity and tasks performed by operators, due to time requested for the operation. Because of this reason a selection of activities has been made. The statutory document for the evaluation of occupational risks contains a long list of operations that have been identified in the course of many years not only in the company but also in the other asbestos analysis laboratories. It is updated at least once a year and at each change in process or activities. In this document every type of risk, including chemical, psychosocial or physical, for an activity is evaluated. From the list of activities, a selection has been agreed upon by HSE managers in the asbestos analysis cluster at different levels. It has been made based on information about previous analyses, time spent by operators on each activity, constraints and other various types of information. The ergonomic project included.

The ergonomic project launched by the company included also detailing the actions and tasks for each activity. This was done by observing the work of the operator and taking videos of what they were doing. The information collected was then exchanged in a biweekly meeting with other HSE managers in order to standardize the outcome and easily share information.

5.3.2.2 Analysis of work situations

To analyze the work activities, it is necessary to identify ways of collecting information and process the information to fill the ergonomic risk evaluation grid.

5.3.2.2.1 Collecting information

The first step of the analysis of the selected activities is the observation of the work situation. Prior to this it is necessary to understand what is the process under analysis, its inputs, outputs, resources and constraints. As a matter of fact, the observations started only after one month in the company, as this time was spent to understand the context and the processes by means of learning and interacting with employees in the company.

Learning about the work of employees and employees themselves did not stop the first month but progressed thanks to the other activities included in the role of HSE correspondent. The internal HSE audits were a useful way to see other dynamics in work situations and ask useful questions about ergonomics, general safety and constraints. These audits also included testing operators on their knowledge about safety and ergonomics, which helped understanding their knowledge and stance towards the matter.

The sessions of observation were conducted with the operator working at the workstation and performing the tasks, with the help of videos and notes. Each workstation has been visited multiple times to understand the process and try to eliminate the variability from the operator and the sample and to improve the understanding of their activity and work. The sessions included questions to the operator about their task but also about the other tasks they were assigned to do. The session tried to collect, within the limits, information about perceived pain or discomfort and propositions of improvement of their work stations. The ergonomic project was explained and introduced them during the observation as a way to improve their working conditions and bring up issues that might have not otherwise been detected.

One common problem of direct observation is that it is not always possible to find every bit of useful information by directly observing or questioning employees. A fundamental *a posteriori* tool to find hardships and areas of improvement of work situations was the form to signal the HSE non-conformities or hazardous situations in Figure 22: The form to signal HSE non conformities. The principle of this form is that of the Heinrich's safety pyramid in Figure 21: Heinrich's safety pyramid: the most severe accidents are those that happen less often and are the result of hazards and dangerous behaviors that were not corrected or prevented. It tries to change the safety prevention that mainly takes into account the most severe accidents, which suffers from a survivorship bias, by acting in a preventive way towards situations from which an accident can arise. This form is used by employees to bring up an HSE problem and also propose actions. Once filled, it is presented to the team leader but the responsible for their treatment is the HSE correspondent. Two HSE objectives are 180 actions realized and 350 forms completed. These forms bring up issues that can improve working conditions:

- Improving hygiene in the workspace by raising awareness and changing the organization
- Perceived pain and discomfort
- Malfunctioning equipment

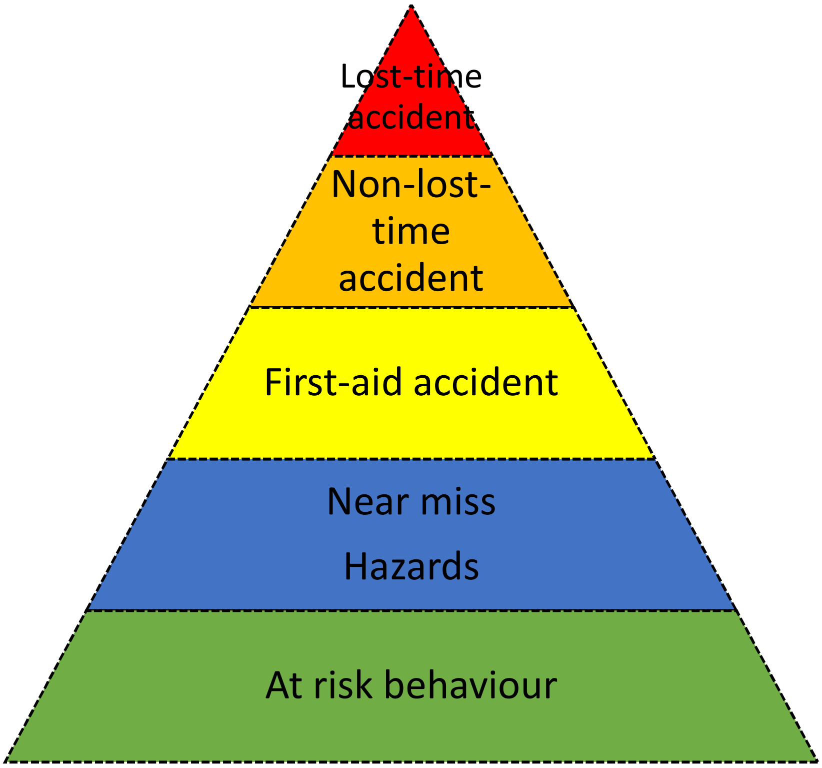
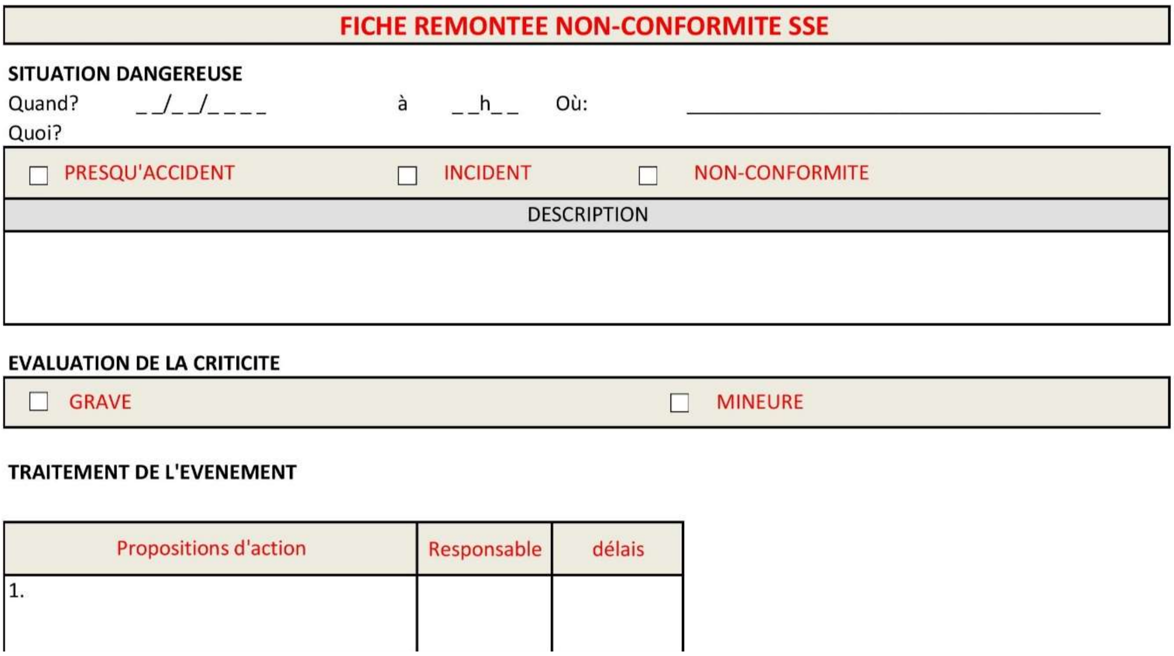


Figure 21: Heinrich's safety pyramid



FICHE REMONTEE NON-CONFORMITE SSE

SITUATION DANGEREUSE

Quand? _ _/_ _/_ _ _ _ à _ _h_ _ Où: ____________________

Quoi?

☐ PRESQU'ACCIDENT ☐ INCIDENT ☐ NON-CONFORMITE

DESCRIPTION

EVALUATION DE LA CRITICITE

☐ GRAVE ☐ MINEURE

TRAITEMENT DE L'EVENEMENT

Propositions d'action	Responsable	délais
1.		

Figure 22: The form to signal HSE non conformities

5.3.2.2.2 Using the ergonomic risk evaluation grid

The data collected were then analyzed to fill an ergonomic risk evaluation grid. This grid had been developed by the HSE engineer and shared to all the asbestos testing laboratories. It requires little to no experience in ergonomics and it is easily applicable to many work situations. Its purpose is to evaluate the physical risk factors for the onset of musculoskeletal disorders. It is an excel tool that takes ergonomic data and returns a level of risk for each activities. It focuses on three factors and on the exposition to each of them:

- Gestures and postures:
  - It includes 7 possible postures (sitting with back support, standing with buttock support, stand up, sitting with lateral rotations, sitting with arms above head, leaning stand, kneeling bent over) as presented in Figure 23: Part concerning postures.
  - It defines the amplitude of gestures performed on the work plan in a bi-dimensional perspective, considering how far from the torso the hands reach. Three levels, based on measures are defined: good as the surface facing the operator at the height of the work surface on which he handles of 1000mm width, 250mm depth and a radius of 300mm from each shoulder; acceptable as 16000mm width, 500mm depth and radius of 500mm from each shoulder; out of area as the rest Figure 24: Part concerning the amplitude of gestures with the three areas. In some workstations it has been possible to apply a tape on the counter to identify the percentage of time spent by operator in each zone, as in Figure 25: Green and red tape for the evaluation of the amplitude of gestures. This technique has not been implemented everywhere since there are fume hoods with fixed dimensions and tasks where the operators is standing and frequently changing their position.
  - As each posture and gesture has a value, when the percentage of time spent in each is entered, it simply multiplies the value of percentage for the value of gesture, then it does the same for the value of posture and it sums them. The value is used to return a color as one of four levels of risk for this risk factor and activity. The four possible ranges are the 4 intervals of 25 from 0 to 100.
- Repetitiveness: it considers the risk and its mitigation. It considers three levels for the number of technical actions per minute, the cycle time and percentage of total working time. It takes the highest between the first two and it multiplies it for the percentage of total working time. For the mitigation, it considers the presence of unfavorable factors in the execution and organization of the task (time imposed by machine, extreme or uncomfortable gestures etc.) and in the environmental conditions (temperature, noise etc.). It takes into account the number of unfavorable factors and the number computed before to obtain a final evaluation that has 4 levels of risk (blue, green, yellow and red) as in Figure 27:Evaluation of repetitiveness.
- Load: It considers the weight of the load and how the person handle the load. It considers the maximal height at which the person handles the weight, the maximal depth, the grip quality, the torso twist and the time exposition. The height has 4 intervals of measure; the depth has three intervals while the other indicators are qualitative as good or bad or present or not. The table combines each value of depth and height to obtain a maximum recommended weight (MLRI) as presented in Figure 28: The values for the maximum recommended weight for a measure of depth and height. This value is multiplied for the severity index X, which takes the value of (1; 0,9; 0,8) depending on the number of negative factors present: the result is the final recommended weight (MLR), which is less than or equal to the initial recommended mass. Then the ratio of the actual weight and the MLR is analyzed and the load is given a risk value between 4 different colored intervals as represented in Figure 29: The severity index X, the recommended mass MLR and the level of risk for the load part.

The data related to the activity for every indicator has to be entered and then each activity is assigned a level of risk for repetitiveness, load and postures. This allows to represent the analysis process with the activities and highlight what are the most physically demanding activities and macro-processes.

While this grid has the advantages of requiring very little training for its users and spotting activities at risk, it narrowly focuses on a few physical dimensions. It does not take into account movements at the wrist level, nor the back or neck posture when sitting down. This adds to the fact that some actions that are performed hundreds of times a day are not considered repetitive and so they are represented as safe when in fact they do have a physical impact. Furthermore, it does not consider stress, freedom of action when working or any type of fatigue (visual, mental, physical) nor it contains any question to assess the physical state of the operator. Given this lack of information, the evaluation was carried out also with the help of other tools.

Posture							
	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
Fréquence de temps passé %							

Figure 23: Part concerning postures

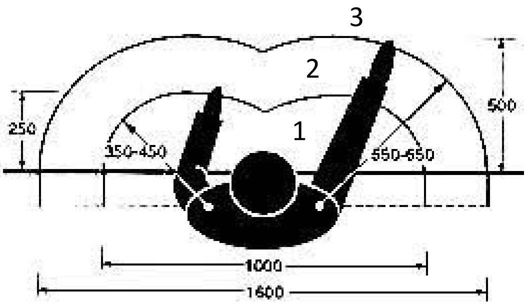


Figure 24: Part concerning the amplitude of gestures with the three areas

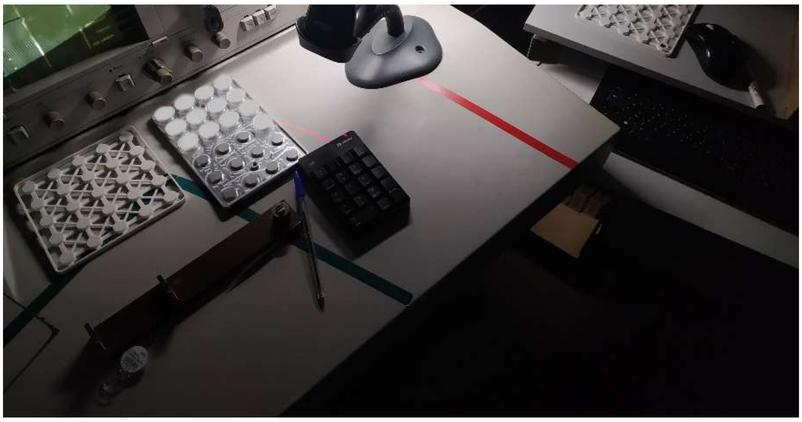


Figure 25: Green and red tape for the evaluation of the amplitude of gestures

Hazard level (H)	1	2	3	4

Number of actions per minute	0-20	21-40	>40	
Cycle time (s)	>30	16-30	0-15	
Total time spent (%T)	0-25% of work time	26-50% of work time	51-75% of work time	75-100% of work time

Figure 26: Part concerning repetitiveness

(%T*H)					
12	Y	R	R	R	R
9	Y	Y	R	R	R
8	G	Y	Y	R	R
6	G	G	Y	Y	R
4	G	G	Y	Y	Y
3	B	G	G	Y	Y
2	B	B	G	G	Y
1	B	B	B	G	G
	0	1 & 2	3	4	5 & 6
	Nombre de facteurs unfavourabes				

Figure 27:Evaluation of repetitiveness

MLRI (Masse limite recommandée initiale)		**Hauteur**			
		0 à 30 cm ou 111 à 140 cm	31 à 60 cm ou 91 à 110 cm	61 à 90 cm	> 140 cm
Profondeur	0 à 20 cm	**19 Kg**	**21 Kg**	**22,5 Kg**	**18 Kg**
	21 à 40 cm	**16 Kg**	**17 Kg**	**18 Kg**	**14,5 Kg**
	> 40 cm	**9 Kg**	**10 Kg**	**11 Kg**	**8 Kg**

Figure 28: The values for the maximum recommended weight for a measure of depth and height

Indice de sévérité = X = (0.8; 0.9; 1)
MLR = MLRI * X

M/MLR <= 0.6	**Risque mineur**
0.6<M/MLR<=0.8	**Risque moyen**
0.8<M/MLR<=1	**Risque important**
M/MLR>1	**Risque prioritaire**

Figure 29: The severity index X, the recommended mass MLR and the level of risk for the load part

Process	Activity	Details
Solid sample Coding	Coding	Order form scan + production time selection (seated) Data validation on the software (seated) Order form stamping (seated) Labels printing (seated) Take a zip (seated) Label zip + order + sample (seated) Put samples in zip (seated) Storing the order form (seated) Storing the zip in a specific box (seated)

Figure 30: Evaluation grid: Process, activities and detailed actions

Activity	Load					
	Load weight (Kg)	Height (cm)	Depth (cm)	High frequency (Yes/No)	Trunk torsion (Yes/No)	Grip quality (Good / Bad)
Coding	x					

Figure 31: Evaluation grid: each activity is evaluated concerning the load (port de charge)

Activity	GESTURES AND POSTURES									
	Frequency (%) : Time spent for each posture							Amplitude of gestures (% time spent)		
								GOOD	ACCEPTA BLE	bad
Coding	95			5				60	30	10

Figure 32: Evaluation grid: each activity is evaluated for the posture part

Activity	Repetitiveness					
	Numbe rof technical actions (min-1)	Cycle time (sec)	Time spent (%)	Environmenta l conditions : vibrations, temperature	Task organization : Time, Short rest time	Task execution : extreme articular angles, gestures under constraints
Coding	1	1	1	0	0	0

Figure 33: evaluation grid: each activity is evaluated for the repetitiveness part

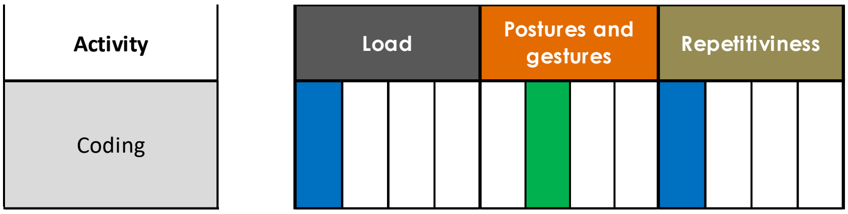


Figure 34: Evaluation grid: each activity has a final evaluation out of four ranks for Load, Postures and Repetitiveness

5.3.2.2.3 Other tools

Other tools have been used to widen the range of factors to be considered during the analysis. Other grids were not filled for the analysis but rather used to take into account other factors and how to measure them. The additional factors considered in the analysis extrapolated from other tools are:

- The wrist, neck and trunk position are detailed with explicative figures in the RULA tool (McAtamney et Corlett 1993), present in Annex 2 .
- The visual demand and level of the stress of the task in the Quick Exposure Check Tool in Annex 3 .
- The Nordic Style Questionnaire (1987) for an epidemiological study to collect data on perceived pain and physical problems among workers, in Annex 4 from Descatha et al. adapted from .

Other factors such as noise, lighting, possibility of communicating with other, space to work and many other have been identified by the literature review carried out in the theoretical section.

5.4 The identification and implementation of improvement actions

At the end of October, we had a meeting with the HSE manager and the HSE engineer to present the results from the ergonomic analysis. The results included the evaluation from the risk evaluation tool but also other relevant considerations from the observation and conversations with the operators on the field. Therein, it was decided how to pursue with the actions and the content of the final delivery of the project for the company. The presentation is attached in the Annex 6.

The purpose of the project resides more in identifying activities at risks and the actions to improve them rather than actually implementing the actions. It has been possible to complete some shorter actions, such as sharing good practices or buying new tools. Other actions require a longer intervention, the participation of multiple actors and a relevant budget. Due to this, the solutions to some risks might be identified, for example, as a new equipment or a new station layout from another business unit, but it will not go further than that.

5.5 The improvement of the risk evaluation tool

With the study of the scientific literature on etiological models of MSD and on different risk evaluation grids, the weaknesses of the tool have become clear. The experiences on the field confirmed the fact when the evaluation was not able to identify some activities that operators were indicating as detrimental and more dangerous. The evaluation has been carried out through observation on the field, questions to operators, data from previous accidents and MSD and other sources. During the presentation at the end of October, the results from the tool and those from the other evaluation were compared. It was decided to include a fourth part of the project as suggestions for the improvement of the tool, based on the information from the evaluation and the review of the scientific literature.

5.6 The resources involved

The resources involved are the people and the information: different people have been involved at different times during the project; multiple sources of reliable information were used.

5.6.1 The people involved

The project has been carried out in different business units by the respective HSE managers. In Saint-Etienne, both us and the HSE manager were trained for the project, while we carried out the analysis and evaluation of work situations. The HSE manager got involved again in the second part for the identification of improvement actions. Since this part was not planned and it required analysis of data and identification of targeted actions, the intervention of the HSE manager was seen as necessary. The HSE engineer that created the tool also provided help in analyzing the data from evaluation. The validation of improvement actions involved the operators themselves, team leaders, the production manager and the business unit manager to evaluate their feasibility. Clearly, the simpler actions bringing changes to pieces of equipment or slight changes to workstation design were immediately prioritized and implemented. Other actions, aimed at changing the organization of work or impacting the production, were evaluated with their collaboration.

The analysis of work situations involved the majority of workers. Through the use of direct ergonomic observation, colleagues' collaboration, deferred questioning, the use of RSD form and data about occupational accidents and illnesses it was possible to get to know all workers and the working conditions inside the laboratories. However, since direct questioning and observation has not been performed with the night shift team for organizational reasons, it is clear that some information might have gone undiscovered.

5.6.2 The information retrieved

The information about occupational risks has come not only from preconceived knowledge and direct analysis, as explained in the Paragraph 5.3.2.2.1, but also from accident and occupational illnesses reports. These sources have been useful not only in highlighting the most physically demanding workstations, but also in getting to know the approach of the enterprise towards these complex situations.

The obligation for the employer to register and report to the French Public Health Insurance Fund (CPAM) has existed for more than 20 years so all the accidents since the creation of the company in 2013 were available. Every accident is also analyzed by means of the cause tree tool, presented in the paragraph 4.1.1. Within this register, it was directly possible to find cases of MSD. For example, the analysis done by the company about the declaration of occupational illness from an employee or of an accident who caused a long-term MSD on an employee. This source was also useful as the analysis associates each cause with an action to address it and puts a person in charge of it. The data of the MSD occurred in the company was retrieved from archives or directly from the person, without asking the HR or the occupational physician.

Another source of information about accidents was the collaboration and exchange with other HSE services of other companies of Eurofins. The most frequent and direct exchanges have taken place with the other asbestos testing companies in France, but also, indirectly through frequent reports, about other companies in the environment national business line.

It was also possible to have access to two previous ergonomics intervention realized in the company in 2016 and 2018. The first intervention was realized by two ergonomists who analyzed all the workstations in the laboratory. The more recent intervention analyzed all the workstations as well and was carried out by an ergonomist and the occupational physician who is still in charge of the company. It has been useful to compare the working conditions and the state of the laboratory at two different points in time. Both the reports from the interventions contained the recommendations from the professionals about improvement at each workstation, with the corresponding remark and comment from the company. This has allowed to know the previous approach of the company towards this kind of intervention and how it has evolved in the last years.

6 Results

This chapter presents the results of the ergonomics evaluation. The 5 major processes are explained and then are evaluated with the use of the valuation grids and the outcome of the ergonomic evaluation. Then the improvement actions for each problem are introduced. An additional part contains the evaluation of the specific activities, performed less frequently. The last part contains the propositions of improvement for the evaluation grid, derived from the literature and the observation on the field.

6.1 Reception and coding

Here multiple times a day samples are received from sampler companies, who are the upstream actors who collect samples and also the clients who receive the analysis result. The number of samples is around 1500-2000 per day, whereas the number of analyses to perform can change depending on the client's requests. Parcels are opened under the hood and plastic packages inside are brought under another hood where the bags are individually decontaminated on both sides with a wipe. Then the samples from the same file are grouped into a new larger bag which is sorted in a container for a certain type of analysis. At the end the operator registers the number of samples, the name of the client and the type of sample on a nearby whiteboard. Then the containers, are brought next door where they are coded. This part is done at the desk in front of screens, where the samples are coded into the system with the request from the client and labeled with a tracking number. The containers are then brought to the MOLP room.

Here three people work during the day and two receive and sanitize samples then two code the samples (only one person performs both tasks). The ergonomic analysis in Figure 35: Risk evaluation results for the decontamination/reception process has identified two activities at higher risk: the handling of the parcel and the decontamination. As a matter of fact, parcels containing samples are deposited by couriers on a counter through a window. From here they are moved a few meters to the decontamination area. A parcel can weigh up to 15-20 kg, therefore operators use a cart but they are nonetheless obliged to make efforts and this represents a risk of overload. The second activity at risk is the decontamination, since each sample is wiped on both sides. This operation is performed as many times as the number of samples and it takes around 3 hours for the two operators on busy days. In addition, this operation is performed under a hood which limits movement and oblige the flexion of the neck to properly visualize the work surface, as in Figure 36: Operator at the decontamination hood. The available space under the hood is 40 cm deep and 200 cm large.

The three operators that work in this part of the laboratory have all more than 5 years of experience in this role and they enjoy some degree of independence in the organization of their work. During the analysis it was possible to exchange with them about the hardship and strain of this process as well as the perceived pain sensations and the possible improvements on the workstations. The risk associated with handling heavy parcel is mitigated by the use of a cart and available assistance in the case of excessive weights. In addition, the risk due to stress on the upper limbs for decontamination is reduced thanks to collaboration between the two employees as well as some adjustments, such as placing the instruments used closer to the station. The first two employees do not report pain and have not suffered from it for years after some improvements in work organization, as then they had more tasks to perform and more pressure. This fact reiterates what the scientific literatures has proved: not overloading employees with work (less stress) and allowing them to organize their work (more freedom of action) can avoid the manifestation of MSD.

The third employee works exclusively on the desk taking samples from one cart, coding them and putting them in another cart. The person has suffered an injury at the wrist and cannot make efforts with it. The use of a wrist brace impedes any movement of the wrist and supports it. The adapted ergonomic workstation includes a chair with armrests, vertical mouse and two close carts. The organization for coding has also been adapted according to their need and the person is able to work the whole day. The person perceives pain in the wrist during the day and even after leaving work. At certain times during the day they are able to take some rest to diminish the pain but with a great volume of samples that is not possible and it is necessary to “push through”. A possible action would be to allow the person to take some brief pauses (10/15 minutes) to alleviate the pain. Another person should replace the operator during this time. In total 3 other employees are trained to code samples therefore this could be put in place.

Process	Activity	Details	Load				Postures and gestures				Repetitiveness			
Reception/ Decontamination	Opening of a parcel	Opening the package with a cutter (standing) Removal of all the files (standing) Storing the package or putting it in the trash (standing) Storing the files under the decontamination hood (standing)												
	Decontamination	Opening a ZIP + emptying the folder ZIP (sitting) Putting the ZIP in the trash (sitting) Take a wipe (sitting) Cleaning the order form + sample + counter (seated) Write the details of the file on a whiteboard (standing).												

Figure 35: Risk evaluation results for the decontamination/reception process

Figure 36: Operator at the decontamination hood

Process	Activity	Details	Load	Postures and gestures	Repetitiviness
Solid sample Coding	Coding	Order form scan + production time selection (seated) Data validation on the software (seated) Order form stamping (seated) Labels printing (seated) Take a zip (seated) Label zip + order + sample (seated) Put samples in zip (seated) Storing the order form (seated) Storing the zip in a specific box (seated)			

Figure 37: Risk evaluation results for the coding process

6.2 MOLP

This is the first analysis that solid-state samples undergo. Then they are observed under a binocular loupe to analyze the type of material and decide whether to proceed with the MOLP (polarized-light microscope) analysis for finer results. Prior to the microscopy small bits are taken from samples by means of tweezers, cutting pliers, a hammer or a hot plate. Then two little pieces of the material are put on a glass slide with two drops of refractive index oil. Around 20% go through this process and are analyzed with this tool. If asbestos is found, no further analysis is needed. If it is not needed, then some bits are put in a glass tube. The operator proceeds to enter the data, sanitize the plastic bag and put them away for archiving. Every glass tube, called analysis layer, is sent to the solid-state preparation and then separately analyzed at the MET. The objective for each operator is around 150 analysis layers per day, which is around 110 samples. For the work organization, all laboratory operators have a 10-minute pause after 2,5 hours of work and 30-minute break after 5,5 hours.

The workstation is composed of a hood (64cm deep and 75 cm wide), where the loupe is positioned and the sample is operated on, with the MOLP and a screen positioned on the side. Workstations are built as for right or left-handed (more space on the dominant hand's part of the hood) as in Figure 38: Right-handed MOLP workstation. Operators often do not work in a hood adapted to their dominant hand, which can entail stress on the cervical spine and on the back. Operators are also constrained in their gestures by the front plastic cover of the protection equipment, its reduced width and the loupe. For example, when using the hammer to crumble hard samples, there is little available room for the movement. This might make repetitive actions, such as wiping the work counter and the samples as well as physically demanding actions as the use of the hammer, even more taxing for the body. A second problem related to the workstation setup are the positioning of the MOLP and the second screen to the side. Operators have to frequently change position by twisting the torso, by flexing the neck or arching the back. Considering the frequency of these changes (twice every 5 minutes if not more) and the 7 hour-long shift entirely at this workstation, it might cause MSD.

Figure 38: Right-handed MOLP workstation

The workstations also include a screen inside the hood and one outside, and keyboard outside. They are used by operators for visualizing and entering data from the analysis. The frequent changes between the view of the sample through the hood, then with the loupe, then the view of the screen and again the counter, requires a constant adaptation of the eyes and creates visual fatigue. Some operators work with the blind closed to avoid direct light and reflection on the plastic front cover.

The results from the risk evaluation tool in Figure 42: Risk evaluation results for the MOLP analysis highlights some medium risks for the postures and gestures in certain activities. This reflects the constraints imposed by the workstation setup explained before. Other activities have been identified to be at risk through the observation and exchanges with operators:

- The hammer is used around 20-30 times per day on concrete or asphalt samples, which often generate pain at the level of wrist, elbow and shoulder due to the recoil and vibrations.
- Cutting hard materials with the cutting pliers sometimes require a greater effort which produces pains in the hand.
- A particular type of analysis requires plastic tubes and caps, which are not available through a distributor, as the glass tubes are. In this process, operators have to reach out with an arm to the two distributors by the hood. Additionally, they have to screw and unscrew and hundreds of tubes. These activities create pain in the neck and shoulder.

The Figure 39: Time diagram for the MOLP analysis (1) and Figure 40: Time diagram for the MOLP analysis (2) show the time diagram for the MOLP analysis process and the level of ergonomic risk for each activity. This helps to measure the exposition to risks of operators, i.e. the time of each activity. It is also possible to see the variability in the whole process: the 25% of samples are observed through the MOLP and it requires more than 2 minutes. In addition, the preparation for the observation can increase with samples that require more manipulation, such as asphalt carrots, tiles, black glue or others. This makes it clear that the objective of 150 analysis layers per day is not easily reached and might pressure to operators to work faster.

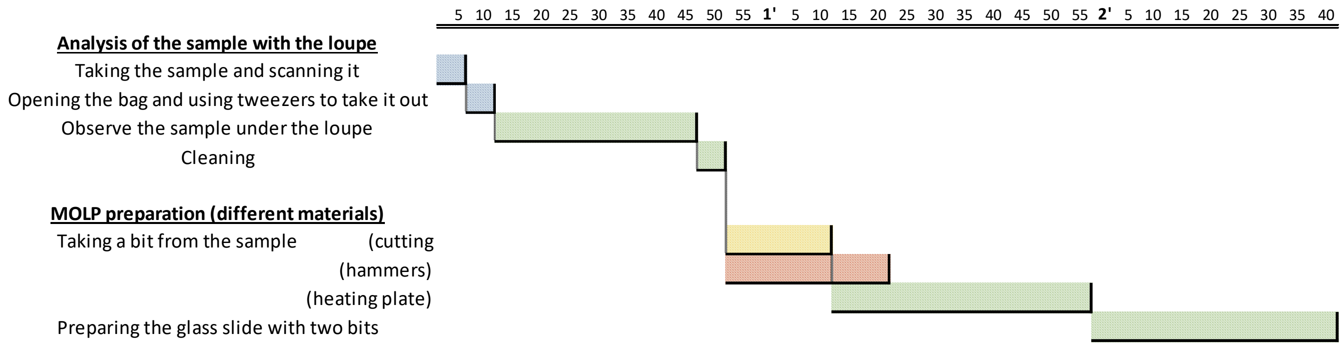


Figure 39: Time diagram for the MOLP analysis (1)

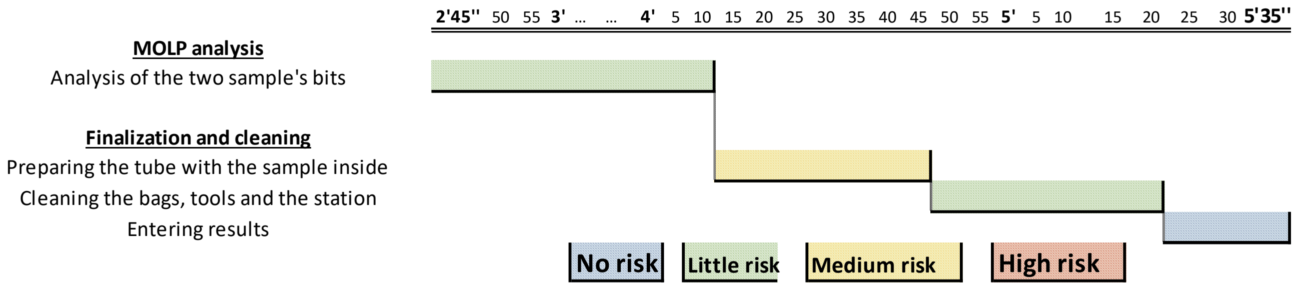


Figure 40: Time diagram for the MOLP analysis (2)

Figure 41: Pictures of multiple actions at the MOLP station

Process	Activity	Details
MOLP	Taking the sample	Taking the sample bottom (standing) Taking the sample (sitting) Scanning the sample (sitting) Opening the bag (x2) (sitting) Lowering the sample for observation (sitting) Taking tweezers to observe the sample in its zip (sitting) Cleaning the tweezers + wiping (sitting)
	MOLP preparation	Observation of the sample with tweezers under the loupe (sitting) Removing bits from the sample (if necessary, large pliers or other tools) (seated) Use of hammer or hot plate (if black glue) (sitting) Bino observation (sitting) Taking a glass slide and an oil drop (sitting) Collecting bits with tweezers + scratching (seated) Transfering bits on the slide (seated)
	MOLP analysis	Placement of the slide on the MOLP (seated) Choice of lens and polarization (seated) Additional preparation in case of other fibers or doubts (seated)
	Sending to solid-state preparation (no fiber)	IInsertion of a sample part in a tube (sitting) Putting aluminium paper on the tube (sitting) Picking up the ring (sitting) Putting the ring on the tube (sitting) Scanning the tube (sitting) Putting the tube on the rack (seated)
	Finalization and cleaning	Cleaning of tools and station (seated) Decontamination of zippers (x2) (seated) Close zippers (x2) (seated) Storing the sample (seated) Entering results on PC (seated)
	Putting in the oven	Taking the rack to the oven (standing) insertion in the oven (standing)

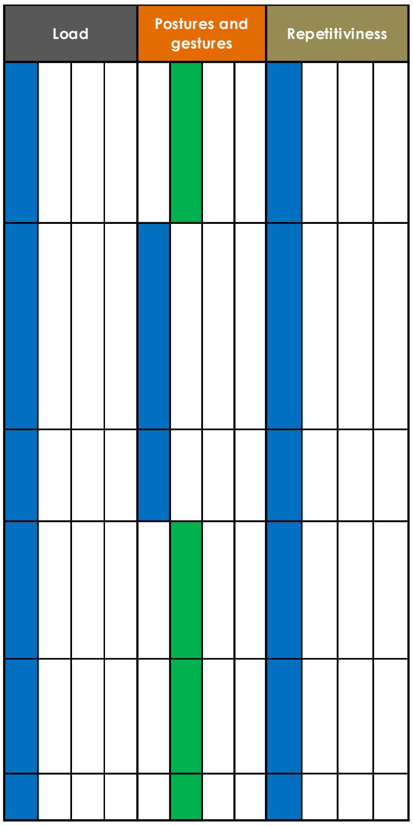


Figure 42: Risk evaluation results for the MOLP analysis

Improvement actions

Some actions have been proposed in order to improve working conditions for operators at this station. First, the hood should include the loupe and the MOLP, so that operators do not have to frequently change positions. This would allow to save some time and avoid harmful postures. This has already been implemented in some BUS, as in Figure 43: Hood with loupe and MOLP in another laboratory. With the change in layout, it would be possible to add a distributor for plastic tubes and plastic cap to avoid reaching out outside the hood. These distributors are already installed at the acid attack station in the solid-state preparation process. Since the same instalment would not be possible, another type of distributor has to be developed. In addition, the change in the hood might decrease the visual fatigue caused by changing views.

Figure 43: Hood with loupe and MOLP in another laboratory

Secondly, to deal with difficult samples there are rules for sample sizes for clients and new tools have been provided. It is now less frequent than recent years to have samples exceeding the dimensions, which are not larger than a fist. The tools adapted to deal with harder samples have been provided and validated by operators. The first is a lighter hammer with a rubber handle to diminish vibrations transmitted to the hand. The second are the tile pliers that are used especially on tiles which are too hard for cutting pliers.

Finally, for a particular analysis operators receive 4 plastic tubes all with caps but only one contains the actual sample. The 3 plastic tubes are filled by solid-state operators with aluminum little balls under a hood where also asbestos sample are treated. In other business units the three tubes are transported without cap: this practice has been validated at the quality level and the operating procedure does not require them to be closed since the risk of contamination is almost zero. The practice cannot be immediately implemented as operators have to agree and feel sure about the subject. In addition, to ease the burden of unscrewing and closing tubes, an operator who has previously worked in another sector has shared a good practice of a different hand gesture.

6.3 Solid-state preparation

This station receives the solid-state sample from the MOLP for which the analysis has been inconclusive. Here samples go through 9 processes that have the purpose of releasing the fibers from the material and put them into a liquid. Two drops of this liquid are put on a grid that is sent to the MET analysis. The operators have an objective of 300 samples per day and rotate on the stations. Figure 46: Risk evaluation for the solid-state preparation shows the ergonomic evaluation of the multiple activities of this process. One operator has filed a declaration of work-related illness after 7 years between solid-state and air preparation. The company has filed the response regarding the activities performed by the operator, who has done the same. An agent from the French national insurance fund has studied the two processes of preparation and issued a report. The information presented in the following comes from such reports in which I took part (summer 2022), the ergonomic observation and questions with the operators. In the following the activities carried out by operators and the ergonomic evaluation:

- Oven: The tubes containing the samples are put in the oven by the MOLP operators. The preparation operators bring them out with a special tool and let them cool. This operation is performed by different operators around 10-15 times per shift and lasts around 30 seconds. It is necessary to lift the shoulders under 90 degrees for a weight of less than 2kg, therefore the risk of MSD is very low.
- Acid attack: The samples are transferred under a hood and mixed with acid, water and aluminum tiny spheres. The operator work seated with the hands under the hood. The operation takes around 40 seconds for each tube and is the most time consuming of this process. The hood is 120 cm large and 60 deep, therefore it contains most things that are needed. Despite this, the operator has to lift the arms under 60 degrees to reach the automatic acid pump, the aluminum spheres distributor, the caps and the tubes under the hood. The operation takes around 40 seconds and it is the most time consuming, therefore operators are exposed to the effects of this action. The operator who performs this task usually take out samples from the oven, acidify them and put them in the micronizer. If there are three operators, another takes the samples from the micronizer, otherwise if there are just 2 operators, the same person goes from the oven to the first centrifuge. This whole task takes around 35% of the time for an operator who rotates between all the solid-state preparation stations.

- Micronizer and centrifuge: the samples are first put into a machine to reduce the size of the particles and then into the centrifuge to mix the compound in the tube. The operator inserts the samples, screw the bolt of micronizer and then closes it. This movement has recently caused one accident in another business unit, in which one person has suddenly felt a sharp pain in the thumb and hand while unscrewing the bolt. After micronization, the samples are put into the centrifuge, for which the operator lifts the arm at less than 90 degrees and shuts the lid.
- Draining and centrifuge: a tube is opened under the hood, put in a magnetic holder and the acid is drained in a bin. Distilled water is poured through a hand pump and then drained in the same bin. The whole operation is performed while standing, lasts 15 seconds and is repeated for each sample. The two movements are raising the shoulder and tilting the arm to pour the liquid from the tube, and pressing the distilled water hand pump. The tubes are then put in a centrifuge. This whole task takes around 15% of the time for an operator who rotates between all the solid-state preparation stations.
- Dilution: The liquid in the tube here is diluted until it is clear. The operator adds water with an automatic pump to the tube, then holds the tube on a vibrating tool that mixes the water and the material inside and then observes the turbidity with a light. If not clear enough, the operator pours the liquid in a bin with the magnetic holder around the tube and repeat the cycle until the water is clear enough. Each sample takes around 30 seconds and needs around 2 or 3 cycles of dilution. The operator lifts the shoulder and tilts the arm for pouring water and is subjected to the vibration from the tool. This whole task takes around 28% of the time for an operator who rotates between all the solid-state preparation stations.
- Deposit: Two drops of each sample are put on two grids and left to dry. The operator assembles the aluminum plate on the heating plate with the petri dishes with two grids for each. For each tube, the operator attaches a clean tip to the pipette and pour a drop for each grid of the liquid collected from the tube. The tube is put back and the tip is thrown away. The operation takes 20 seconds per sample and is performed by lifting the shoulder at less than 60 degrees. This whole task takes around 22% of the time for an operator who rotates between all the solid-state preparation stations.

Figure 44:Acid attack station

Figure 45: Multiple tasks in the solid-state preparation process

Process	Activity	Details
Préparation Massif	Preparation	Removal of racks at the end of the oven (standing) Moving the racks Picking up a sequence blade and applying a label with handwritten delay (standing) Positioning of the set (standing)
	Acid attack	Putting a tube in a tube magnet (sitting) Beeping a tube Removing the ring from the tube and putting it away Removing and disposing of the aluminum on the tube Pour glass tube into other plastic tube Put acid in the empty glass tube Pouring the filled tube (glass) into the other tube (plastic) Putting the bead in the plastic tube (sitting) Putting the empty glass tube in the garbage can Taking a cap and closing the plastic tube Stick a label on the tube and put it in the rack Validate the data into system
	Micronizer	Storage of the tube rack (standing) Deposit of the rack in the micronizer Placement of a blocker (standing) Screwing a nut by hand (standing) Tightening the nut with a wrench (standing) Closing the micronizer and starting up (standing) Taking a cup and placing it next to the micronizer Putting a weighted tube behind the micronizer (taken from the bucket) Unscrewing a bolt with a key (standing) Unscrewing a bolt by hand (standing) Installation of the blocker + key (standing)
	Passage US	Placement of tubes in two tube racks + retrieval of one tube at the back (loose) - standing Filling the ultrasonic bath with water (standing) Putting the cups in the bath (standing) Switching on the machine (standing) Take out the cups + tap on the US tray to empty the water Putting in the centrifuge or in a container while waiting for it to finish (standing) Closing the centrifuge and switching on (standing) Opening the centrifuge
	Draining	Moving the cups into a tray and placing them on a table (standing) Putting a tube in the tube magnet (standing) Opening the tube (standing) Emptying the tube and re-drying (standing) Putting water in the tube (standing) Taking a cap and closing the tube (standing) Putting the bucket in the vortex (standing) Shaking the well (standing) Putting the bucket in the centrifuge + interlocking (standing) Take the buckets out of the centrifuge and put them in a tray (standing)
	Dilution	Visu on the light turbidity for dilution evaluation (seated) Positioning a tube in a tube magnet (seated) Removing the cap (seated) Emptying the tube (seated) Insert distilled water into tube + close cap (seated) Vortexing the tube (sitting) Observe the tube under the light (x times to obtain correct dilution) - seated Put the tube on a rack and move the tray (sitting)
	Preparation of the sheets	Taking a plate (semi-standing) Placement of petri dishes on the plate (semi-standing) Grabbing a grid with a pair of forceps (semi-stand-up) Placement of the grid in the bottom of the petri dish (semi-standing) Stacking the plate on another one (semi-standing)
	Deposit	Beeping of a tube (standing) Shaking the tube (standing) Opening the tube (standing) Picking up a pipette and a tip (standing) Pipetting into the tube and placing on a grid (standing) Removing the tip from the tube + closing the tube (standing) Stick a label on the petri-lid (standing) Wait for drying on the hot plate (standing) Closing the petri dish (placing the petri dish on the bottom) - standing Take the plate to put on the tray + move the tray to the MET shelf (standing)

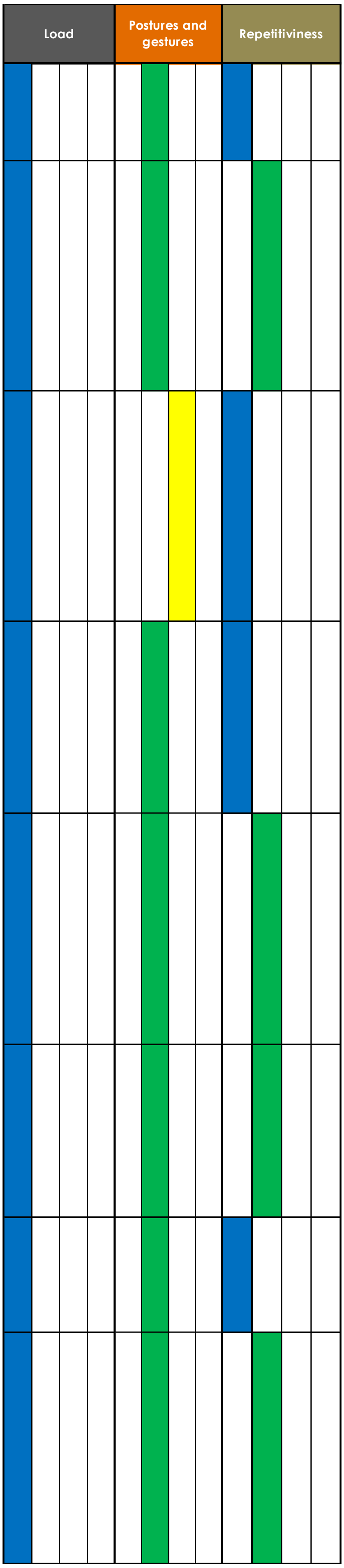


Figure 46: Risk evaluation for the solid-state preparation

Improvement actions

The first possible actions to improve workstations concern the tools. Regarding the micronizer, the operators do not perceive pain due to this operation. Regardless, a solution has been implemented in Saint-Etienne to prevent it: a more comfortable screwdriver for which it is not necessary to put pressure with the thumb. Another possible action is to use one part of the screwdriver to put less force when screwing, so that it is not necessary to make an effort to unscrew. This also happens due to the fact that one person usually inserts and screw the micronizer, while another unscrew. The other tool that should be improved is the hand pump for distilled water in the draining station, substituting it for an automatic one like in the acid attack workstation.

The problems detected in the acid attack station concern the organization of the space under the hood. The printer might not be necessarily placed under the hood, while other objects might be changed of place to make them more easily reachable. The space and objects should be rearranged so that the ergonomics can improve.

Other actions concern managing the appearance of MSD. The first time the operator perceived pain in the shoulder and mentioned it to a manager was 2019, but no actions were taken until 2021, with the first diagnosis. Then, the operator was assigned entirely to the air preparation, as it was thought to be less repetitive. However, as it is shown in the next paragraph, the air preparation requires the operator to move and maintain the shoulder at a degree equal or greater than 60 degrees and frequently even 90. The decision has worsened the situation and the worker had to start working at the air coding station. The situation could have been avoided at different stages: the worker could have been put before on rotation on easier tasks, such as the air coding and stock replenishment. The problem was not faced on time and putting the worker only in the air preparation reveal an improper knowledge of the risks and movement of the process. This ergonomic study will help building a common knowledge on MSD risks inside all the company. This is beneficial to both the operators and the company, which faces the costs of hiring new personnel, costs of reorganization and the poor internal and external brand as employer.

6.4 Air preparation

This is the station where all air sample are coded and prepared for the microscopy analysis. The volume received is much lower than solid-state samples, therefore only one operator per shift is assigned. In Figure 49: Risk evaluation for Air preparation (1) and Figure 50: Risk evaluation for air preparation (2) is possible to see the complex activities and actions that make up the process and the risk evaluation for each activity. The workers operate 6 different workstations that correspond to the steps of the process. In the following, a brief explication of every part and the results from the ergonomic evaluation:

1. Coding: it works almost the same as for the other samples but the weight is reduced and the volume, on average, ranges from 100 to 150 sample per day. The activity does not involve detrimental postures, weight or repetitive gestures, therefore the risk of developing a MSD, also according to operators, is very low. It is performed for the most part by the operator working therapeutic part-time work.
2. Cutting: the cartridge is open with a tool and the filter inside is cut and put into a beaker. The operation is performed under a hood which constraints normal arm movements. Each cartridge is open with a decapper, which requires an effort with the wrist. Operators describe this action as the worst at the level of physical consequences and often feel pain due to this.

This is the station where actions are the most repetitive and physically taxing. The objective is 40 samples for each operator, from the cutting to the deposit station.

3. Oven: The beakers are put in an oven for calcination. The weight is really low, the rack is taken by hand and the oven is at a safe height and distance so that no extreme gestures are made.
4. Filtering: the filter is washed with water which is then filtered with a second filter. This operation is performed standing and requires numerous technical actions to assemble and disassemble the different pieces of glass. The table is 90cm tall and the glassware used reaches around 145 cm. Because of this, the operators move and maintain the shoulder in abduction without support with an angle greater than 60 degrees for most of their time, and they even go beyond 90 degrees for grabbing certain tools. Three operators that are between 170 and 180 cm tall say they do not have problem with the station layout, since they do not bend over or lift the shoulder at an angle greater than 90 degrees too frequently. Two other operators, one much taller and the other shorter, have to respectively lean over the counter because it is too low and lift the shoulder at angle greater than 90 degrees. In addition, this operation takes 15 minutes and is carried out 5-6 times per shift, which makes the filtration 40% of the operator's time. The postures and gestures, as well as the longer exposition, might cause MSD at the shoulder and back level.
5. Carbonation: filters are put inside a machine that use a carbon lead to carbonize them. This operation takes around two minutes and a few seconds with arm lifted and it is performed two times per shift. The operator has to drill a hole inside the carbon lead and then insert it into the machine. The operator has to lift their arm high to both open the lid and place the filter, which may cause problem at the shoulder level. One person cannot reach the lid with her arms and has to use a step, which adds the risk of stumbling and falling.
6. Deposit: filters are cut and put on a grid and then bathed in chloroform. This operation is performed under a hood which constraints normal movements. In addition, the grids are minuscule, 3 mm of diameter, so it requires a high precision to handle them with tweezers. The operator pours chloroform by pressing a small hand pump under the hood which is not easy to reach. The operator has to reach out with arms outside the hood for multiple objects used each time: mouse, portable scanner and timer.

Figure 47: Postures and gestures for the carbonation and filtration operations

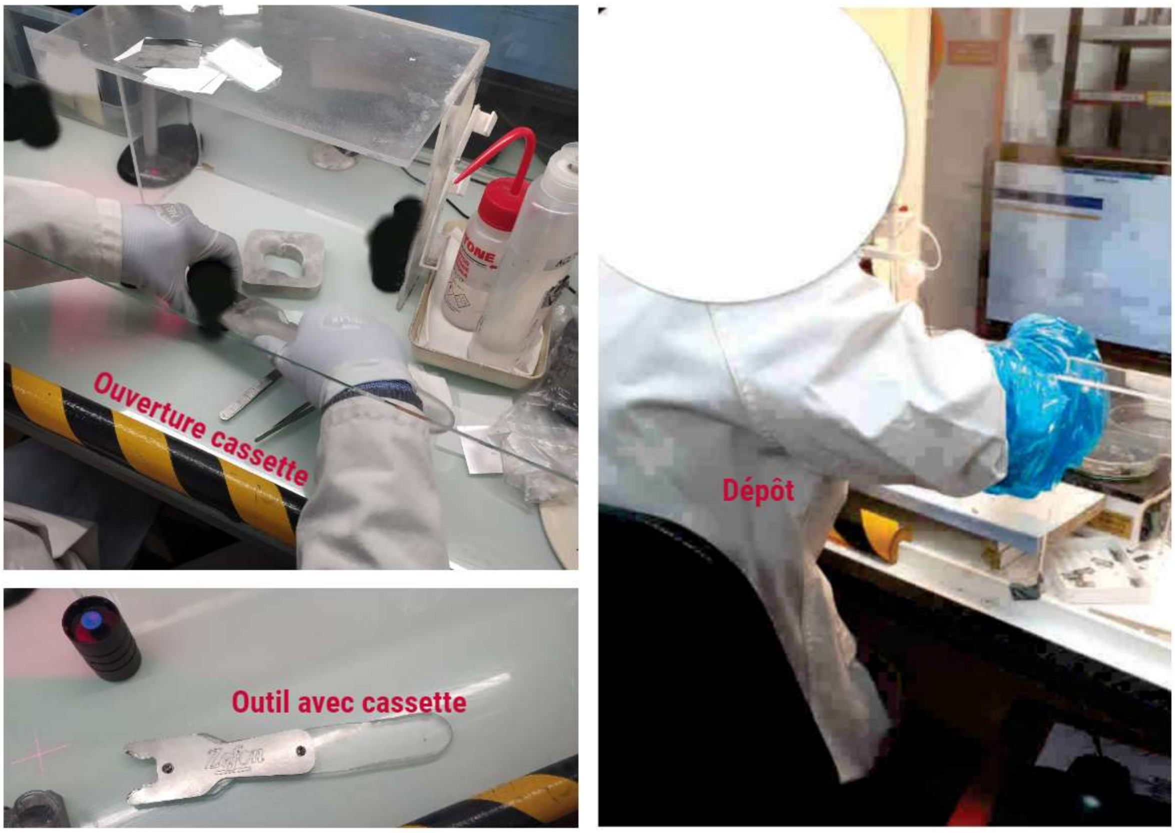


Figure 48: Deposit and opening of the cartridges

Process	Activity	Load				Postures and gestures				Repetitiveness			
Réception / décontamination - AIR	Contrat review												
	Sanitization												
Codage Air	Coding												

Process	Activity	Details	Load	Postures and gestures	Repetitiveness
Préparation Air	Cutting preparation	Installation of the sample cartridges to be prepared in the hood (seated) Picking up the 6 beakers (standing) Cutting of the labels on the cassettes with the tool (sitting) Pre-opening the cassettes with the tool (opener) - seated Picking up the 6 beakers to put under the hood (sitting) Adding a new blade to the scalpel (seated) Disposal of blade packaging (seated) Cleaning the tools (seated)			
	Cutting	Beep of a cartridge (sample) - sitting Cutting the filter with a scalpel (sitting) Place part of the filter in a beaker (sitting) Closing the cartridge (sitting) Putting aluminium on the beaker (sitting) Beep the beaker (sitting) Tool cleaning (seated) Hole with needle cap (sitting) *Operations repeated for each sample* Putting in archive box the zip of the cartridges (separation cardboard op/static) - seated			
	Putting in the oven	Putting the beakers in a metal rack (standing) Putting the rack in the oven (standing) Turning on the oven (standing) Opening the kiln at the end of the calcination (the calcination lasts between 40 and 110min) - standing Immediate pouring of distilled water in each beaker Putting the rack on standby for filtration (standing)			
	Taking out of the oven and scraping	Taking a clean rack (standing) Removal of aluminum (standing) Rinse aluminum with distilled water (standing) Disposal of aluminum (standing) Scrape off beaker (standing) Rinse the scraper (standing) Disposal of scraper (standing) Clean hands with wipes (standing) Disposing of waste (standing) Cleaning the bench (standing)			
	Filtration preparation	Pre-carbonated filter pick-up with pliers (standing) Positioning of the filters on the sockets (standing) Place a column on each socket (standing) Fixing the columns on the sockets with pliers (standing) Putting the column holder in the sink (standing)			
	Filtration	Taking the distilled water droplet (standing) Inserting distilled water into the columns (standing) Putting down the washbowl (standing) Opening and closing the taps (standing) Position the beakers in front of the tulips (standing) Transfer the contents of the beakers to the columns (standing) Rinsing the beaker with the distilled water (standing) Open the tap (standing) Return distilled water to the columns for rinsing x2 (standing)			

Figure 49: Risk evaluation for Air preparation (1)

Process	Activity	Details
Préparation Air	Carbonization preparation	Picking up a pair of pliers (standing) Soak the tongs in water + soap then water and wipe (standing) Beep of a beaker (standing) Removing the column and tongs (standing) Putting the column in the sink (standing) Opening the petri dish (standing) Closing the tap (standing) Take the filter with the tongs and place it on the glass (standing) Gluing the label to the filter (standing) Putting the beaker in the sink (standing) *Operations repeated for each beaker*
	Carbonization	Opening of the carbon evaporator chamber cover (standing) Removal of the two used carbon mines Picking up a new lead and placing it in the drill (standing) Closing the drill and starting it (standing) Opening the drill and removing the mine (standing) Positioning in the carbonizer (standing) Repeat with second mine Depositing the glass with glued filters (standing) Close and switch on the evaporator (standing) Open evaporator lid (standing) Take the wafer to the deposition hood (standing)
	Deposit preparation	Taking a petri dish + bridge (standing) Put a bridge inside (sitting) Fill with chloroform up to the bridge (sitting) Put down lens paper (sitting)
	Deposit	Seizing and opening of the MET grid box (seated) Removal of grids with tweezers (seated) Cleaning the scalpel (seated) Cutting the filter (seated) Place the cut central strip on the lens paper (seated) Repeat these operations as many times as the number of samples (sitting) Closing the petri (sitting) Take the bridge after 45min (sitting) Place in another empty petri dish and wait for drying (sitting)
	Finalisation	Taking a plate (standing) Deposit of petri dishes on the plate (standing) Beeping of the cartridges (standing) Deposit of labels on the lids (standing) Picking up the petri dish (with bridge and MET grids) - standing Deposit carbonaceous grids in the petri dishes (sitting) Closing the petri dishes (sitting) Place the plate on the MET shelf (move to the MET room) - standing
	Washing up	Washing of beakers and columns (standing) Putting the beakers in the oven to dry (standing) Glass columns are placed on a rack (standing) Putting the plastic columns into an ultrasonic bath (standing) Removal of plastic columns from ultrasonic bath (standing)

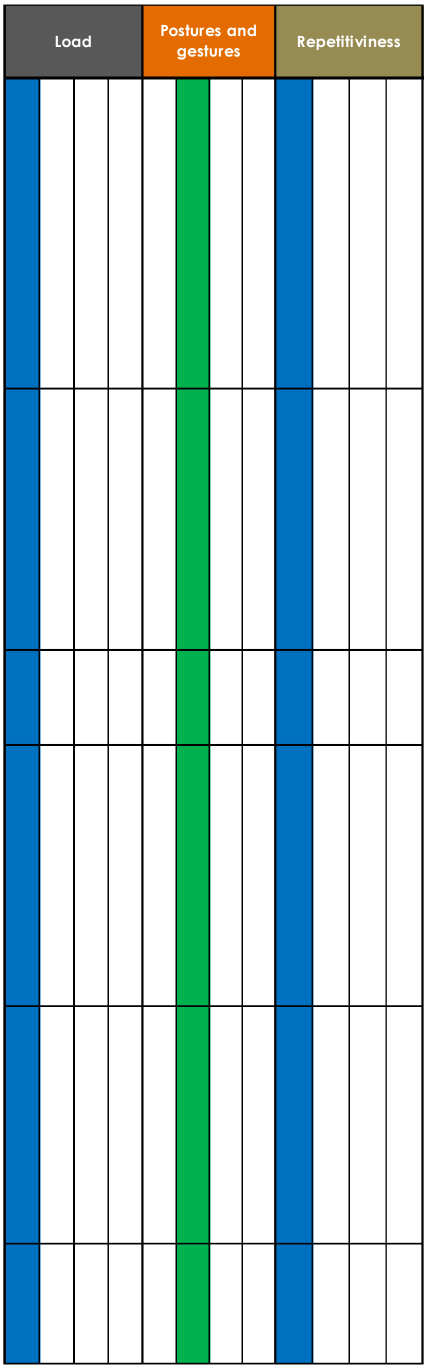


Figure 50: Risk evaluation for air preparation (2)

Improvement actions

Some actions have been identified to prevent the risk of MSD. For the carbonation and filtration station the instalment of a height-adjustable table is being evaluated. It would avoid lifting arms over the 90-degree angle and leaning over for tall operators. For the filtration is also under study the implementation of rack with 2 more places for filters, which would diminish by 25% the exposition of operators to this task. In addition, it is necessary to add some space for the tools, as they are stocked at around 170 cm and requires reaching out with a fully extended arm. For the deposit station, instead, the hand pump should be substituted with an automatic pump, as it is present in the solid-state preparation. the tools that are out of the hood would need to be placed inside if not as close as possible.

The activity that generates discomfort and pain the most is opening the cartridges. The movement is entirely done with the wrist and constrained by the front plastic cover of the hood. The process engineer in the company suggested to widen the opening of the tool with a milling machine. The problem did not occur in other business units, for which there are three possible causes: opening the cartridge with only one movement might entail a wider rotation of the wrist and a greater effort; the tool used in other companies is different; the cartridges are different. The first one seems unlikely since 4 operators out of 6 perceive discomfort as a result and the cartridges have been confirmed to be the same across business units. The tool is indeed different in other units and changing this tool is one of the major HSE action plan for the year 2022.

6.5 MET

All the previous processes prepare the sample for the transmission electron microscopy. The preparation, as shown, is complex and detailed and it ends with the grids. They are put on the carrier which is inserted inside the machine in the middle of the cannon. The image of the particles is projected and seen by the operators through the glass opening at the bottom. They thoroughly observe the grids by shifting the view with the use of the trackball or the handles, depending on the model, as represented in Figure 51: On the left the insertion of the grid carrier into the old MET, while on the right the new MET. They look for the particular shape and color of asbestos fibers between the other particles. The digital screens by the side are used to control some parameters and visualize data about samples. Since the image projected by the microscopy is fluorescent and prevalently green and black, operators need to work without light.

The ergonomic evaluation has identified the risks for each activity, as in Figure 52: Risk evaluation of the MET process. The analysis consists in using the trackball or handles to shift the view on the surface of the grid and changing the focus or other parameters through the cranks on the canon. The image is projected at the bottom and is seen as fluorescent green through the screen. One grid takes around 40 seconds for the analysis, and the carrier can fit 4 grids at a time. With the model on the right in Figure 51: On the left the insertion of the grid carrier into the old MET, while on the right the new MET, the operator moves with one or two hands the trackball at a very high speed, with one movement per second. The tool cannot be changed but operators can move the trackball in a more comfortable position and use cushion supports for the wrist and forearm. The other model, on the left in Figure 51: On the left the insertion of the grid carrier into the old MET, while on the right the new MET, has rotating handles at a distance of 35 cm from the tables.

One person is working at therapeutic half-time for a disease at the level of the shoulder. The operators have to frequently lift the shoulder at a degree greater than 90 degrees for reaching the controls on the canon and for the insertion of the retractable carrier, as shown in Figure 51: On the left the insertion of the grid carrier into the old MET, while on the right the new MET.

Figure 51: On the left the insertion of the grid carrier into the old MET, while on the right the new MET

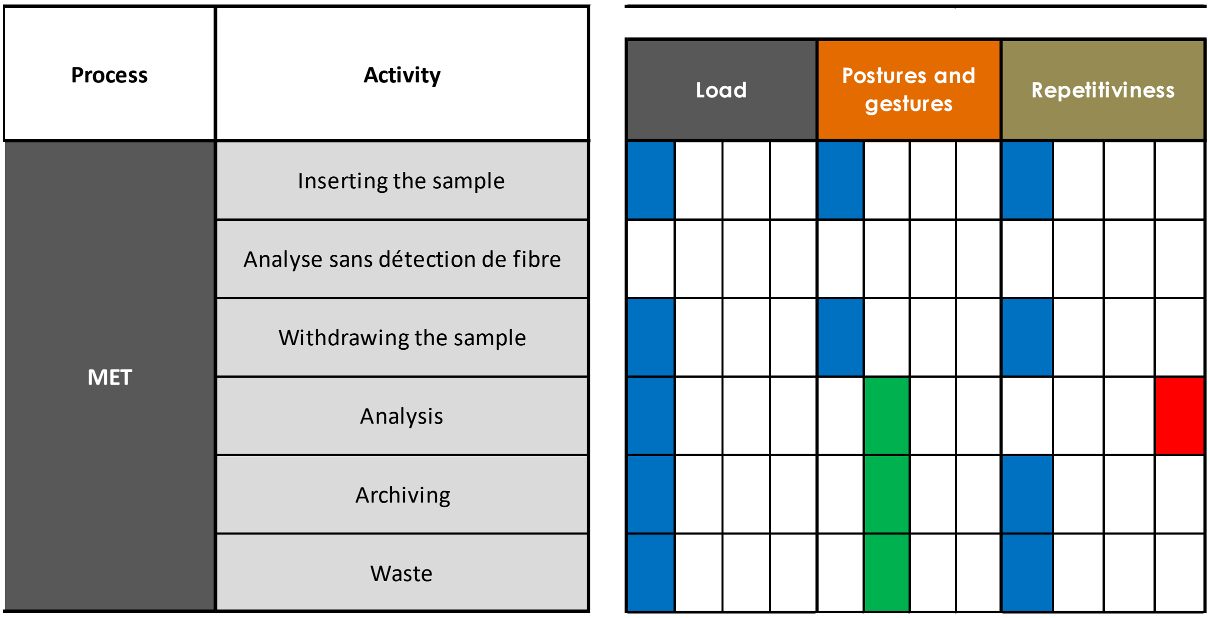


Figure 52: Risk evaluation of the MET process

<u>Improvement actions</u>

The analysis has shown that some risks arise directly from activities that are related to the machine and can be hardly changed, such as the trackball, the neck position, the absence of light and the carrier change. In the last three years the company has launched a project to improve the MET analysis by implementing a new workstation, called CoMET and shown in Figure 53: The MET workstation and the operator in front of the screen. It consists of a wooden frame for an elevated workstation with a larger desk to allow the operator to not make extreme gestures to insert the object holder. In addition, the images from the microscope are transferred to a larger digital screen on the desk. This greatly enhances the posture of the operator that can adjust the screen and does not have the lean forward by flexing the neck. The images on the screen also mean that there is no more need to work with low lights, which improves the overall perception and work environment. For the moment there is only one installed, since it is a long and expensive project. Two others are going to be installed and will be productive in the spring of 2023, by replacing other microscopes.

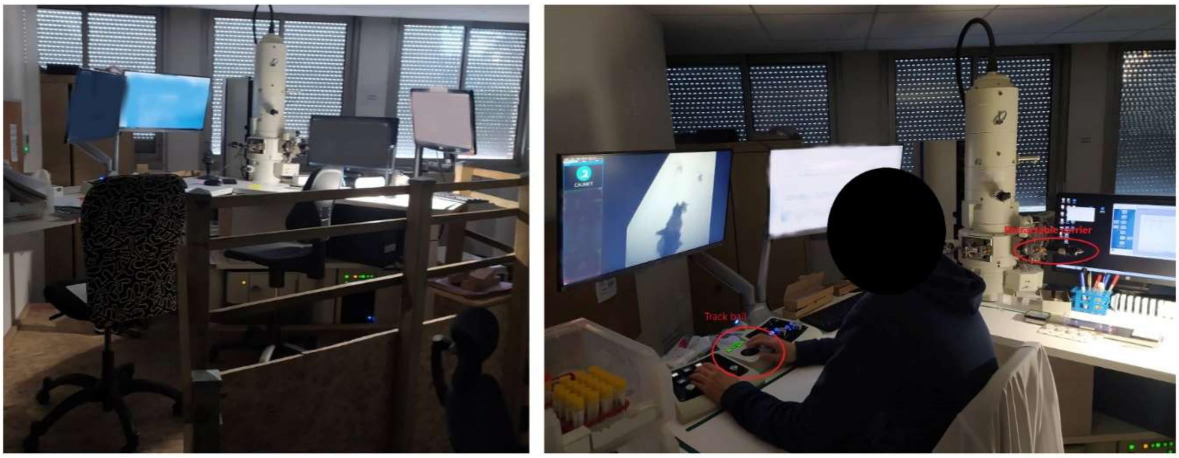


Figure 53: The MET workstation and the operator in front of the screen

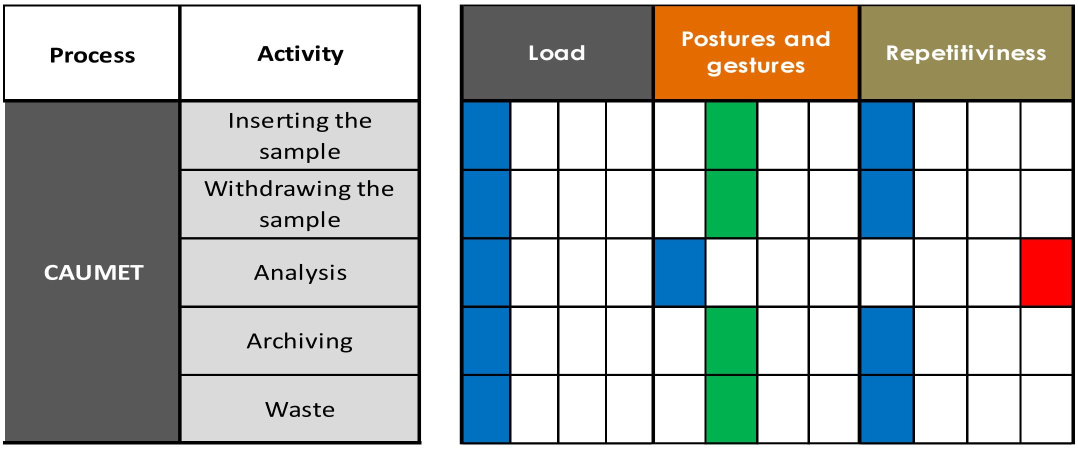


Figure 54: Ergonomic evaluation for the CoMET

While the problems related to postures and gestures are greatly improved, the operators still have to use the trackball with the same repetitiveness as the other MET stations. As shown in Figure 54: Ergonomic evaluation for the CoMET, the analysis still shows a high level of repetitiveness but it has improved in the postures and gestures, which is no longer green as before. Because of this, another project has been under study for some years and is now going to be implemented at the beginning of 2023. A new AI will scan the entire surface of the grid and return the results. The operator will have to validate the results and it will be possible to go through some points of the grid with little use of the trackball.

Given that the stations will not be implemented for a few more months, it is necessary to improve the current activities with actions in the short term. The rotation on the CoMET would allow the operator in therapeutic half-time, to continue working with less pain or even slowly take on the full-time role if desired. This requires some organization, as each equipment requires some short introductive training. Another project that is going to be implemented in December, is a new retractable carrier that holds more grids. This would allow the operator to extract and insert the carrier two times less frequently inside the canon, which decreases the number of extreme gestures for the shoulder.

These new technologies will surely reduce the existing ergonomic risk for operators. On the other hand, they will also bring greater productivity, therefore the production objective for operators will be increased shortly after. This means repeating the new gestures a greater number of times, which increases the exposition of operators to the risk of each task. In other words, even if new gestures carry little ergonomic risk but they are repeated more times, MSD can nevertheless arise. In conclusion, these new technologies are surely going to improve working conditions for operators, but managers should be cautious in setting much higher objectives as this could severely undermine the progress made.

6.6 Other activities

This part is dedicated to other special activities that are done less frequently but need nevertheless to be analyzed.

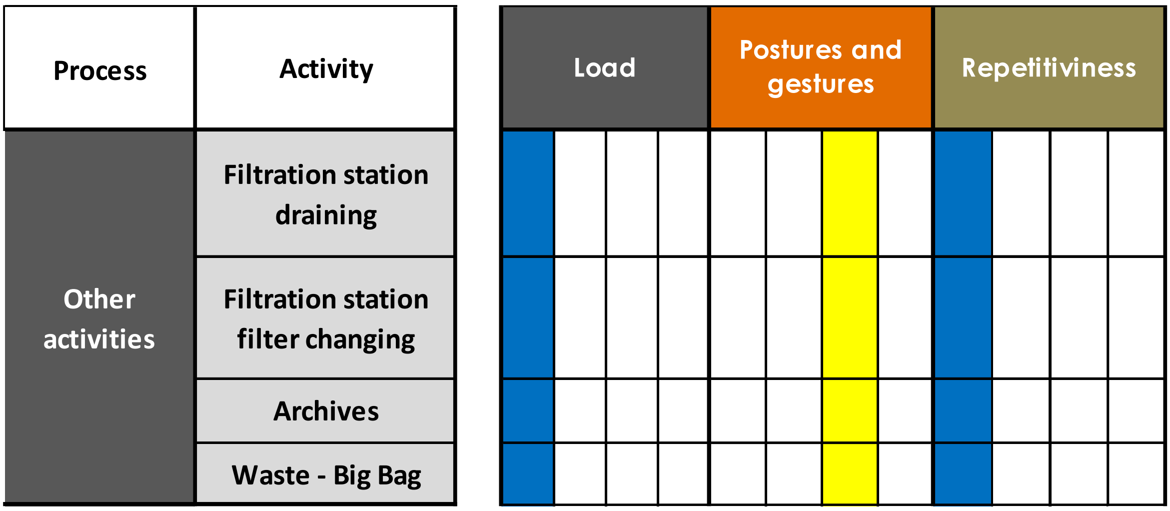


Figure 55: ergonomic evaluation for specific activities

6.6.1 Waste management

The waste management is crucial when dealing with asbestos. Plastic bags need to have the pictogram for asbestos and waste has to be put in a double bag. The bags need to be closed with a swan neck knot and put in a bigger special bags, called Big Bags, that are retrieved by waste collectors and processes. This operation does not involve load over 10 or extreme postures and is done approximatively at each shift's end. At the acid attack station, however, the bags are on the ground so the operator are kneeling bent over to close the bags and then lift it from the ground. This might sudden problems in the low back area and is not appreciated by operators.

The solution is not obvious as the bag is under the station and there is no space available for a proper bin. It is necessary to look for suggestions from other business units and the project engineer.

6.6.2 Archiving

This consists of taking cardboards containing samples from the archives and bringing them to waste zone. Here they are either thrown away in the Big-Bags or piled on a pallet for pickup. The cardboard does not weigh more than 10. The operator use ladders to take them from shelves and put them on carts that are transported to waste zone. The task is performed once every two weeks by different operators. As before, the task is not performed frequently and the exposition is really low. The actions for avoiding risks are designating operators that are have a minimum level of physical fitness for this physical tasks.

6.6.3 Filtration station

Here operators change filters and drain the station. These activities are performed every two days by different operators, so that the same operator might do it no more than 5-6 times per month. There is little physical effort and everything is at a safe distance and waist height. They are not seen as problems by operators.

6.7 Improvement of the grid ergonomic evaluation

The grid has been introduced in the Methodology chapter and its results presented for the evaluation of each process. It has been developed as a tool to evaluate the physical risk factors of the workstations of the Eurofins asbestos analysis laboratories. It has helped launching the risk evaluation process and it has been used as a starting point for the analysis. During the 6 months of this project, I was able to study the literature on ergonomics and consult multiple ergonomic tools. This paragraph is intended to propose changes to this tool that can bring value to ergonomic evaluation.

First, the grid is adapted to all kinds of physical work, therefore it tries to represent as many work situations as possible. Therefore, it includes a part on handling loads and one on postures. However, the postures in Figure 56: The postures included in the grid from the grid, represent only a small part of those in the laboratory that are a risk for health. Operators spend 95% of their time carrying out tasks using their upper limbs sitting on a chair or standing still. The grid does not allow to take into account the movement of the neck, upper back, shoulder, elbow, wrist and hand. As explained before, one case of MSD in the laboratory is due to moving or maintaining the shoulder at a degree equal or greater than 60 degrees in abduction, which is not represented in the figures.

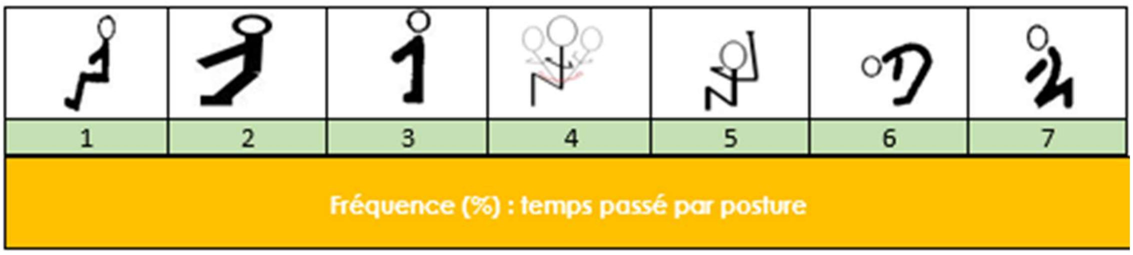


Figure 56: The postures included in the grid

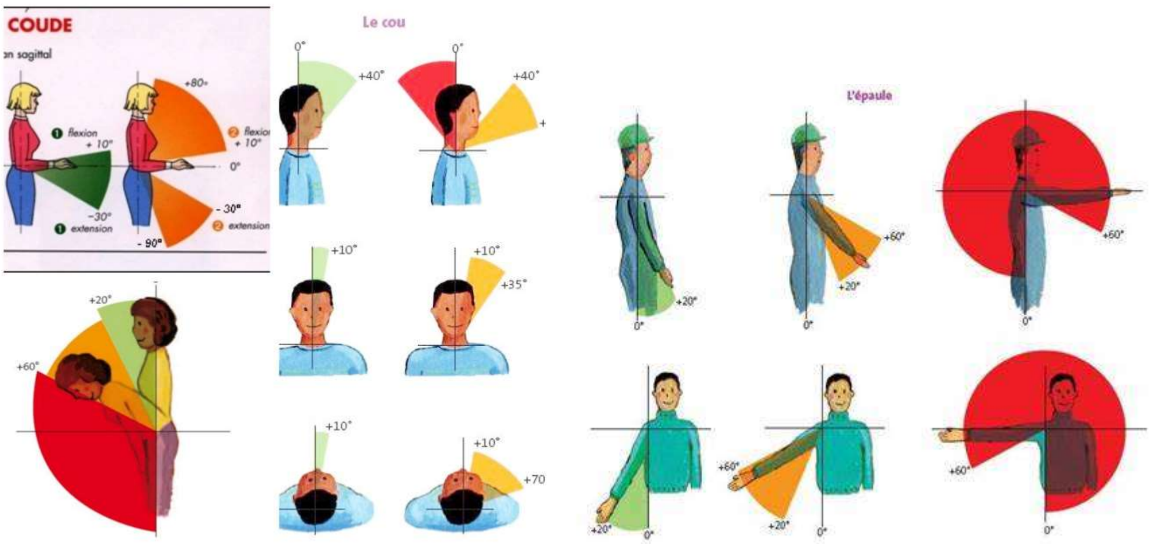


Figure 57: safety angles for the flexion of the neck, upper back, elbow, shoulder and wrist

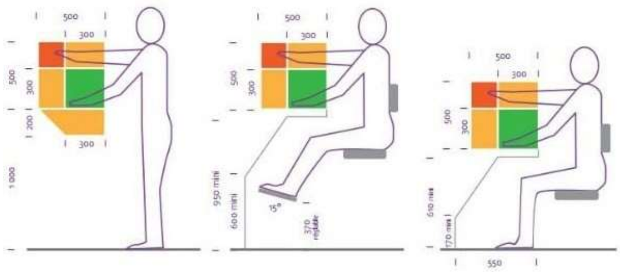


Figure 58:Risks related to reach zones

Figure 57: safety angles for the flexion of the represents some of the postures that are not accounted for in the tool. In 103 the RULA represents such movements and has three levels risk, while in Annex 3 the QEC just has two and uses a questionnaire. The French government lists the periarticular affections at the level of the wrist, elbow and shoulder and link them to work activities which can potentially cause them (Code de la sécurité sociale 2022, Tableau 57). Adding the information from this table would widen the range of risks evaluated.

Secondly, the grid rightly follows the definition of repetitiveness from the norm NF EN 1005-5 and defines a repetitive task as characterized from: a cycle time of less than 30 seconds, an activity repeated at least 50% of the work time and with more than 40 technical gestures per minute (Normes Françaises et Européennes 2007). This is obviously the correct definition that tries to protect workers from repetitiveness. However, as shown in the ergonomic evaluation and in the literature review, MSD can arise from activities that do not fall under the previous definition, but are nevertheless repeated hundreds of time each day. In the MOLP process, for instance, operators have to unscrew and then screw 4 tube caps during the analysis. The activity is repeated once every 5 minutes, does not require 40 technical actions per minute and is not performed 50% of the work time. Regardless, multiple operators feel pain in their shoulder and neck after an entire day of this particular analysis. This points out a more complex issue, highlighted in the literature review, which is the complexity and multi-causality of MSD. A tool that compartmentalize the repetitiveness, load and gesture, without taking into account all of them together to elaborate a more complex diagnosis, will fail at identifying some risks. Since accounting for the multi-causality might be not feasible at the analytical level, to avoid this pitfall the repetitiveness factor should be updated so that it includes other actions. It might be useful to shift the indicator to the number of times per day or per 10 minutes.

Another shortcoming is the fact that the analysis focuses on the activities, that are actions consecutive actions grouped by similarity for their purpose. However, many of these actions are different in terms of time length, movement and difficulty. In the preparation prior to filtration in the air process in Figure 49: Risk evaluation for Air preparation (1), for instance, the operator takes the filters and assemble the glassware. The first action consists of taking something like a sheet of paper at waist height, while for the second the operator moves the shoulder at 60 degrees for some minutes and reaches more than 90 degrees in some moments. Evaluating together these two actions will make the former appear more dangerous and the latter as less harmful. In addition, the division in activities does not allow to compound the evaluation of certain actions that are repeated in different activities. Cleaning the internal work surface of the hood, for example, is performed at various times during an analysis at the MOLP process. To solve this, in the next years it might be necessary to proceed with the analysis of every single action or to create group consecutive action only for similarity in the movements rather than purpose.

Another factor that is critical to successful ergonomic analysis, but is missing from the tool, is an epidemiological analysis of MSD in the company. It is necessary to collect information about the pain perceived by operators, as well as the history of accidents and occupational illnesses in the company. One part would be using a form, such as the popular Nordic questionnaire in Annex 4 from Descatha et al. adapted from , to repertory pathologies and pains. This can help prioritizing the improvement of some tasks that are detrimental to operators' health. The action of opening the air cartridges in the cutting operation, for instance, has been prioritized thanks to exchanges and active participation from operators. The other part of the investigation would be retrieving information about the health and safety at work (work accidents, declarations of inaptitude and MSD) and personnel management (absenteeism and turn-over). This would not only help prioritizing actions but also improving the way the enterprise manages MSD and its employees. As shown, the case of severe shoulder chronic pathology in the company could have been avoided by a proper risk analysis and a timely intervention. Bringing up this mistake can help the company establish a more effective procedure for managing MSD early on.

7 Conclusion

This work studies the complementarity of the ergonomic approach to the traditional approach. The ergonomic intervention was carried out with tools and knowledge retrieved from the literature. The results show that ergonomics can indeed enhance the identification of occupational risks. It broadened the scope of the analysis by accounting for other risks in addition to the three existing ones, i.e. repetitiveness, load and postures. In particular, it included the internal risk factors, e.g. the pain experienced and the age, as well as the physical risk factors with a wider range of postures and the factors related to the work environment, such as the noise and the vibrations. The evaluation also considered previous ergonomic intervention, MSD and accident declarations to collect data on symptoms and illnesses. In addition, the analysis links the risk factors to their determinants, as represented in the ergonomic intervention model in Figure 12: MSD model for ergonomic intervention adapted from Bellemare. This step allows to establish objectives of change for the improvement of working conditions, which can be technical, organizational or humans. The propositions and realized actions for improvement have targeted these objectives of change.

The effectiveness of the ergonomic approach is also shown in the second part of the results section, where the grid evaluation tool is revised. It is shown what it lacks in comparison to the factors and methods used in the analysis. The propositions, in fact, regard only what is shown to be necessary in the context of the analysis of this particular context and not for general work situations.

The findings of this work relate can be related to the existing knowledge presented in the chapter 3 and 4, respectively introducing the *state of the art* of MSD prevention practices and the most common companies' approaches. The current approaches of MSD are indeed those that impact production objectives the least, e.g. posture training, rotation system and actions aimed at workstation design. In particular, the gesture and posture formation is refreshed after accidents or other special events. This practice aims to teach workers their job, but it is thanks to experience that operators can build their own practice to protect against MSD. For instance, showing the postures to minimize the physical toll when lifting weight from the ground or how to reduce arm movement to minimize the lifting the shoulders. Regarding the change in the workstation layout and tools, the historical data has shown that such advancements have improved working condition by decreasing extreme gestures and exposure. Finally, the approach in the company is increasingly more preventative rather than reactive to accidents, which has diminished accidents in the last years.

The findings fit in the existing knowledge on effective prevention practices. Carrying out an ergonomic evaluation, divided in analysis of work, deferred questioning and through an evaluation grid, can allow to preventatively identify and improve occupational risks. Within the company both operators, manager and the HSE manager share some knowledge about MSD. Questioning operators and managers have revealed that some, not all, are aware that MSD arise not only from physical factors but also psychosocial and environmental factors. Knowing how MSD originate can allow operator to signal when a situation is a risk and to act preventatively. Furthermore, this confirms that prevention requires a participatory approach involving operators and managers. On the other hand, the lack of a clear organization of this ergonomic evaluation project has impeded to launch some important improvement actions, which shows the importance of project management elements, such as clear definition of needs, roles, expectations and deadline.

The occupational risks in this work have been identified through observation on the field. This attributes a major importance to the observer's competences, which might lead to some postures and gestures at risk to be missed. For example, the shoulder movements over 60 degrees have not been detected immediately, but rather after the study of the shoulder MSD case in the company. This is mainly due to the difficulty of detecting this movement, which is not blatantly clear as showed in the multiple pictures of operators. Another movement not immediately clearly dangerous was the torsion of wrist. These two initial shortcomings, urged to more closely analyze arm, elbow, upper back, neck and hand movements, with the help of pictures with risk zones. However, it cannot be excluded with absolute certainty that some movements might have gone undetected. To mitigate this risk several videos and pictures have been taken to be analyzed after the analysis, and several grids have been used to correctly identify gestures and weight.

Secondly, the improvement propositions for the tools are based on knowledge from the literature used in the analysis, which means that some factors, tools and questions have been excluded as considered not relevant for the analysis. This hypothesis depends on both the analysis and the literature review. It cannot be excluded that carrying out the two processes differently might lead to other propositions.

Finally, this evaluation proposes some actions to improve working stations. It is necessary, as the next step, to evaluate more carefully these actions in an ergonomic way. The implementation of new designs, layouts or entire new workstations brings out problems that were not existing before. As mentioned at the end of the MET improvement actions, the workstation improvements will bring an increased productivity, which, in turns, entail more actions and movements. This might cause pother problems that were not existing before. Therefore, new project should include a new ergonomic evaluation to prevent other unknown problems. This might require simulation or consultation with other business units or companies where it is already implemented.

The second recommendation concerns the revision of the evaluation grid. It should be decided whether to transform it in a tool with less analytical importance, thus transferring the task of interpreting the data more to the user. This road should be evaluated, since the tool is ready to use and directly presents risk evaluation results, but, as shown, it does not contain a correct variety of postures, an analysis of operators' health and how it considers repetitiveness.

In conclusion, this work evaluates the MSD risk of workstations in a Eurofins asbestos testing lab. It uses both a tool internally developed form the company and existing knowledge from the literature. The central question is the complementarity of the ergonomic approach and the traditional prevention approach. The results show how ergonomics can contribute to existing practices by mobilizing actors from all domains in the company, by taking into account individual and organizational factors. In addition, some improvement propositions about the grid were made. On the other hand, the completeness of the risks identified and propositions might be depended by competences in direct field observation. It is recommended to future works to upgrade the tool giving back some of the data interpreting power to the user. Furthermore, the workstations improvement projects should carry out a preemptive ergonomic evaluation to avoid some new unforeseen risks to arise.

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9 Annexes

9.1 Annex 1 (Occhipinti et Colombini 1996)

CHECKLIST OCRA

A SHORTENED PROCEDURE FOR THE IDENTIFICATION OF UPPER LIMB OVERLOAD IN REPETITIVE TASKS

COMPILED BY/I .... DAY............

PAGE 1

DENOMINATION OF THE WORKPLACE AND BRIEF DESCRIPTION OF THE TASK..

....

-how many workplaces are identical or very similar..
-how many shifts are present in a day..
-how many workers work in these workplaces during a day and considering all the identical workplaces..

	DESCRIPTION	MINUTES
SHIFT DURATION	official	
	real	
OFFICIAL PAUSES	contractual	
OTHER PAUSES (other than the official ones)		
LUNCH BREAK	official	
	real	
NON REPETITIVE TASKS (eg: cleaning, supplies, etc)	official	
	real	
NET DURATION OF REPETITIVE TASK/S		
No. Of UNITS (or cycles)	planned	
	real	
NET CYCLE TIME (secs.)		
OBSERVED CYCLE TIME		

TYPE OF WORK INTERRUPTION (WITH PAUSES OR OTHER VISUAL CONTROL TASKS) (max. score allowed = 10).
Choose one answer. It is possible to choose intermediate values.

[0] - there is an interruption of at least 8/10 minutes every hour in the repetitive work (also count the lunch break) or the recovery period in included in the cycle.

[2] - there are 2 interruptions in the morning and 2 in the afternoon (plus the lunch break), lasting at least 8-10 minutes on the 7-8 hour shift, or at least 4 interruptions per shift (plus the lunch break), or four 8/10 minute interruptions in the 6-hour shift.

[3] - there are 2 pauses, lasting at least 8-10 minutes each in the 6-hour shift (without lunch break); or, 3 pauses, plus the lunch break, in a 7-8-hour shift.

[4] - there are 2 pauses, plus the lunch break, lasting at least 8—10 minutes each over a 7-8 hour shift (or 3 pauses without the lunch break), or 1 pause of at least 8-10 minutes over a 6-hour shift;

[6] - there is a single pause, lasting at least 10 minutes, in a 7-hour shift without lunch break; or, in an 8-hour shift there only is a lunch break (the lunch break is not counted among the working hours).

[10] - there are no real pauses except for a few minutes (less than 5) in a 7 to 8-hour shift..

The first hour ... the last hour

Shif duration in min..................... draw the breaks in the shift.

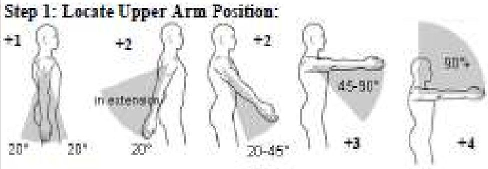
[ ] RECOVERY

9.2 Annex 2 (McAtamney et Corlett 1993)

RULA Employee Assessment Worksheet *based on RULA: a survey method for the investigation of work-related upper limb disorders, McAtamney & Corlett, Applied Ergonomics 1993, 24(2), 91-99*

A. Arm and Wrist Analysis

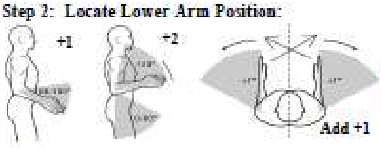
Step 1: Locate Upper Arm Position:



Step 1a: Adjust…
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

Upper Arm Score

Step 2: Locate Lower Arm Position:



Lower Arm Score

Step 2a: Adjust…
If either arm is working across midline or out to side of body: Add +1

Step 3: Locate Wrist Position:

Step 3a: Adjust…
If wrist is bent from midline: Add +1

Wrist Score

Step 4: Wrist Twist:
If wrist is twisted in mid-range: +1
If wrist is at or near end of range: +2

Wrist Twist Score

Step 5: Look-up Posture Score in Table A:
Using values from steps 1-4 above, locate score in Table A

Posture Score A
+

Step 6: Add Muscle Use Score
If posture mainly static (i.e. held>10 minutes),
Or if action repeated occurs 4X per minute: +1

Muscle Use Score
+

Step 7: Add Force/Load Score
If load < 4.4 lbs (intermittent): +0
If load 4.4 to 22 lbs (intermittent): +1
If load 4.4 to 22 lbs (static or repeated): +2
If more than 22 lbs or repeated or shocks: +3

Force/Load Score
=

Step 8: Find Row in Table C
Add values from steps 5-7 to obtain Wrist and Arm Score. Find row in Table C.

Wrist & Arm Score

SCORES

Table A: Wrist Posture Score

Upper Arm	Lower Arm	Wrist 1, Wrist Twist 1	Wrist 1, Wrist Twist 2	Wrist 2, Wrist Twist 1	Wrist 2, Wrist Twist 2	Wrist 3, Wrist Twist 1	Wrist 3, Wrist Twist 2	Wrist 4, Wrist Twist 1	Wrist 4, Wrist Twist 2
1	1	1	2	2	2	2	3	3	3
	2	2	2	2	2	3	3	3	3
	3	2	3	3	3	3	3	4	4
2	1	2	3	3	3	3	4	4	4
	2	3	3	3	3	3	4	4	4
	3	3	4	4	4	4	4	5	5
3	1	3	3	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	4	4	4	4	4	5	5	5
4	1	4	4	4	4	4	5	5	5
	2	4	4	4	4	4	5	5	5
	3	4	4	4	5	5	5	6	6
5	1	5	5	5	5	5	6	6	7
	2	5	6	6	6	6	7	7	7
	3	6	6	6	7	7	7	7	8
6	1	7	7	7	7	7	8	8	9
	2	8	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

Table C: Neck, trunk and leg score

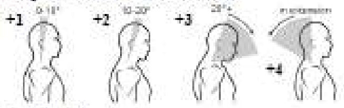
Wrist and Arm Score	1	2	3	4	5	6	7+
1	1	2	3	3	4	5	5
2	2	2	3	4	4	5	5
3	3	3	3	4	4	5	6
4	3	3	3	4	5	6	6
5	4	4	4	5	6	7	7
6	4	4	5	6	6	7	7
7	5	5	6	6	7	7	7
8+	5	5	6	7	7	7	7

Scoring: (final score from Table C)
1 or 2 = acceptable posture
3 or 4 = further investigation, change may be needed
5 or 6 = further investigation, change soon
7 = investigate and implement change

Final Score

B. Neck, Trunk and Leg Analysis

Step 9: Locate Neck Position:



Step 9a: Adjust…
If neck is twisted: +1
If neck is side bending: +1

Neck Score

Step 10: Locate Trunk Position:

Step 10a: Adjust…
If trunk is twisted: +1
If trunk is side bending: +1

Trunk Score

Step 11: Legs:
If legs and feet are supported: +1
If not: +2

Leg Score

Table B: Trunk Posture Score

Neck Posture Score	Trunk 1, Legs 1	Trunk 1, Legs 2	Trunk 2, Legs 1	Trunk 2, Legs 2	Trunk 3, Legs 1	Trunk 3, Legs 2	Trunk 4, Legs 1	Trunk 4, Legs 2	Trunk 5, Legs 1	Trunk 5, Legs 2	Trunk 6, Legs 1	Trunk 6, Legs 2
1	1	3	2	3	3	4	5	5	6	6	7	7
2	2	3	2	3	4	5	5	5	6	7	7	7
3	3	3	3	4	4	5	5	6	6	7	7	7
4	5	5	5	6	6	7	7	7	7	7	8	8
5	7	7	7	7	7	8	8	8	8	8	8	8
6	8	8	8	8	8	8	8	9	9	9	9	9

Step 12: Look-up Posture Score in Table B:
Using values from steps 9-11 above, locate score in Table B

Posture Score B
+

Step 13: Add Muscle Use Score
If posture mainly static (i.e. held>10 minutes),
Or if action repeated occurs 4X per minute: +1

Muscle Use Score
+

Step 14: Add Force/Load Score
If load < 4.4 lbs (intermittent): +0
If load 4.4 to 22 lbs (intermittent): +1
If load 4.4 to 22 lbs (static or repeated): +2
If more than 22 lbs or repeated or shocks: +3

Force/Load Score
=

Step 15: Find Column in Table C
Add values from steps 12-14 to obtain Neck, Trunk and Leg Score. Find Column in Table C.

Neck, Trunk & Leg Score

Task name: ______________________ Reviewer: ______________________ Date: ___/___/___

provided by Practical Ergonomics

9.3 Annex 3 (European Agency for Safety and Health at Work 1997)

Quick Exposure Check (QEC)

QEC has been designed to:

- assess the changes in exposure to musculoskeletal risk factors of the back, shoulders and arms, hands and wrists, and neck before and after an ergonomic intervention
- involve the practitioner (i.e. the observer) who conducts the assessment, and the worker who has direct experience of the task
- indicate change in exposure scores following an intervention

The QEC Guide gives more detailed information about each question and the background to QEC.

Worker's name: ____________________

Worker's job title: ____________________

Task: ____________________

Assessment conducted by: ____________________

Date: ____________________ Time: ____________________

Action(s) required: ____________________

____

____

Worker's name ______________________________ Date ______________

Observer's Assessment

Back

A When performing the task, is the back
(select worse case situation)

- A1 Almost neutral?
- A2 Moderately flexed or twisted or side bent?
- A3 Excessively flexed or twisted or side bent?

B Select ONLY ONE of the two following task options:

EITHER

For seated or standing stationary tasks. Does the back remain in a static position most of the time?

- B1 No
- B2 Yes

OR

For lifting, pushing/pulling and carrying tasks (i.e. moving a load). Is the movement of the back

- B3 Infrequent (around 3 times per minute or less)?
- B4 Frequent (around 8 times per minute)?
- B5 Very frequent (around 12 times per minute or more)?

Shoulder/Arm

C When the task is performed, are the hands
(select worse case situation)

- C1 At or below waist height?
- C2 At about chest height?
- C3 At or above shoulder height?

D Is the shoulder/arm movement

- D1 Infrequent (some intermittent movement)?
- D2 Frequent (regular movement with some pauses)?
- D3 Very frequent (almost continuous movement)?

Wrist/Hand

E Is the task performed with
(select worse case situation)

- E1 An almost straight wrist?
- E2 A deviated or bent wrist?

F Are similar motion patterns repeated

- F1 10 times per minute or less?
- F2 11 to 20 times per minute?
- F3 More than 20 times per minute?

Neck

G When performing the task, is the head/neck bent or twisted?

- G1 No
- G2 Yes, occasionally
- G3 Yes, continuously

Worker's Assessment

Workers

H Is the maximum weight handled MANUALLY BY YOU in this task?

- H1 Light (5 kg or less)
- H2 Moderate (6 to 10 kg)
- H3 Heavy (11 to 20kg)
- H4 Very heavy (more than 20 kg)

J On average, how much time do you spend per day on this task?

- J1 Less than 2 hours
- J2 2 to 4 hours
- J3 More than 4 hours

K When performing this task, is the maximum force level exerted by one hand?

- K1 Low (e.g. less than 1 kg)
- K2 Medium (e.g. 1 to 4 kg)
- K3 High (e.g. more than 4 kg)

L Is the visual demand of this task

- L1 Low (almost no need to view fine details)?
- *L2 High (need to view some fine details)?

* *If High, please give details in the box below*

M At work do you drive a vehicle for

- M1 Less than one hour per day or Never?
- M2 Between 1 and 4 hours per day?
- M3 More than 4 hours per day?

N At work do you use vibrating tools for

- N1 Less than one hour per day or Never?
- N2 Between 1 and 4 hours per day?
- N3 More than 4 hours per day?

P Do you have difficulty keeping up with this work?

- P1 Never
- P2 Sometimes
- *P3 Often

* *If Often, please give details in the box below*

Q In general, how do you find this job

- Q1 Not at all stressful?
- Q2 Mildly stressful?
- *Q3 Moderately stressful?
- *Q4 Very stressful?

* *If Moderately or Very, please give details in the box below*

* *Additional details for L, P and Q if appropriate*

*** L**

*** P**

*** Q**

Exposure Scores Worker's name ____________________ Date __________

Back

Back Posture (A) **& Weight** (H)

	A1	A2	A3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 1 ☐

Back Posture (A) **& Duration** (J)

	A1	A2	A3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 2 ☐

Duration (J) **& Weight** (H)

	J1	J2	J3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 3 ☐

Now do **ONLY** 4 if static
OR 5 and 6 if manual handling

Static Posture (B) **& Duration** (J)

	B1	B2
J1	2	4
J2	4	6
J3	6	8

Score 4 ☐

Frequency (B) **& Weight** (H)

	B3	B4	B5
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 5 ☐

Frequency (B) **& Duration** (J)

	B3	B4	B5
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 6 ☐

Total score for Back
Sum of scores 1 to 4 **OR**
Scores 1 to 3 plus 5 and 6 ______

Shoulder/Arm

Height (C) **& Weight** (H)

	C1	C2	C3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 1 ☐

Height (C) **& Duration** (J)

	C1	C2	C3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 2 ☐

Duration (J) **& Weight** (H)

	J1	J2	J3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 3 ☐

Frequency (D) **& Weight** (H)

	D1	D2	D3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 4 ☐

Frequency (D) **& Duration** (J)

	D1	D2	D3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 5 ☐

Total score for Shoulder/Arm
Sum of Scores 1 to 5 ______

Wrist/Hand

Repeated Motion (F) **& Force** (K)

	F1	F2	F3
K1	2	4	6
K2	4	6	8
K3	6	8	10

Score 1 ☐

Repeated Motion (F) **& Duration** (J)

	F1	F2	F3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 2 ☐

Duration (J) **& Force** (K)

	J1	J2	J3
K1	2	4	6
K2	4	6	8
K3	6	8	10

Score 3 ☐

Wrist Posture (E) **& Force** (K)

	E1	E2
K1	2	4
K2	4	6
K3	6	8

Score 4 ☐

Wrist Posture (E) **& Duration** (J)

	E1	E2
J1	2	4
J2	4	6
J3	6	8

Score 5 ☐

Total score for Wrist/Hand
Sum of Scores 1 to 5 ______

Neck

Neck Posture (G) **& Duration** (J)

	G1	G2	G3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 1 ☐

Visual Demand (L) **& Duration** (J)

	L1	L2
J1	2	4
J2	4	6
J3	6	8

Score 2 ☐

Total score for Neck
Sum of Scores 1 to 2 ______

Driving

M1	M2	M3
1	4	9

Total for Driving ______

Vibration

N1	N2	N3
1	4	9

Total for Vibration ______

Work pace

P1	P2	P3
1	4	9

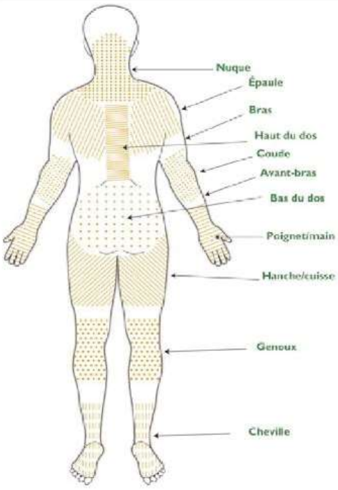
Total for Work pace ______

Stress

Q1	Q2	Q3	Q4
1	4	9	16

Total for Stress ______

9.4 Annex 4 from Descatha et al. (2007) adapted from (Kuorinka et al. 1987)



ANNEXE

Questionnaire de style nordique

(d'après Kuorinka et al. 1987, Kuorinka et al. 1994, Roquelaure et al. 2006)

À quelle date remplissez-vous ce questionnaire ?

|__|__| |__|__| 20 |__|__|
jour mois année

Avez-vous eu, au cours **des 12 derniers mois**, des problèmes (courbatures, douleurs, gêne, engourdissement) au niveau des zones du corps suivantes ? *Pour chacune des zones du corps, cochez la case correspondante*

1 ▸	**Nuque / cou**	**Oui…?**	**Non…?**	**Si oui,**	**du côté droit…?**	**du côté gauche…?**	**des deux côtés…?**
2 ▸	**Épaule / bras**	**Oui…?**	**Non…?**	**Si oui,**	**du côté droit…?**	**du côté gauche…?**	**des deux côtés…?**
3 ▸	**Coude/ avant-bras**	**Oui…?**	**Non…?**	**Si oui,**	**du côté droit…?**	**du côté gauche…?**	**des deux côtés…?**
4 ▸	**Main / poignet**	**Oui…?**	**Non…?**	**Si oui,**	**du côté droit…?**	**du côté gauche…?**	**des deux côtés…?**
5 ▸	**Doigts**	**Oui…?**	**Non…?**	**Si oui,**	**du côté droit…?**	**du côté gauche…?**	**des deux côtés…?**
6 ▸	**Haut du dos**	**Oui…?**	**Non…?**				
7 ▸	**Bas du dos**	**Oui…?**	**Non…?**				
8 ▸	**Hanche / cuisse**	**Oui…?**	**Non…?**	**Si oui,**	**du côté droit…?**	**du côté gauche…?**	**des deux côtés…?**
9 ▸	**Genou / jambe**	**Oui…?**	**Non…?**	**Si oui,**	**du côté droit…?**	**du côté gauche…?**	**des deux côtés…?**
10 ▸	**Cheville / pied**	**Oui…?**	**Non…?**	**Si oui,**	**du côté droit…?**	**du côté gauche…?**	**des deux côtés…?**

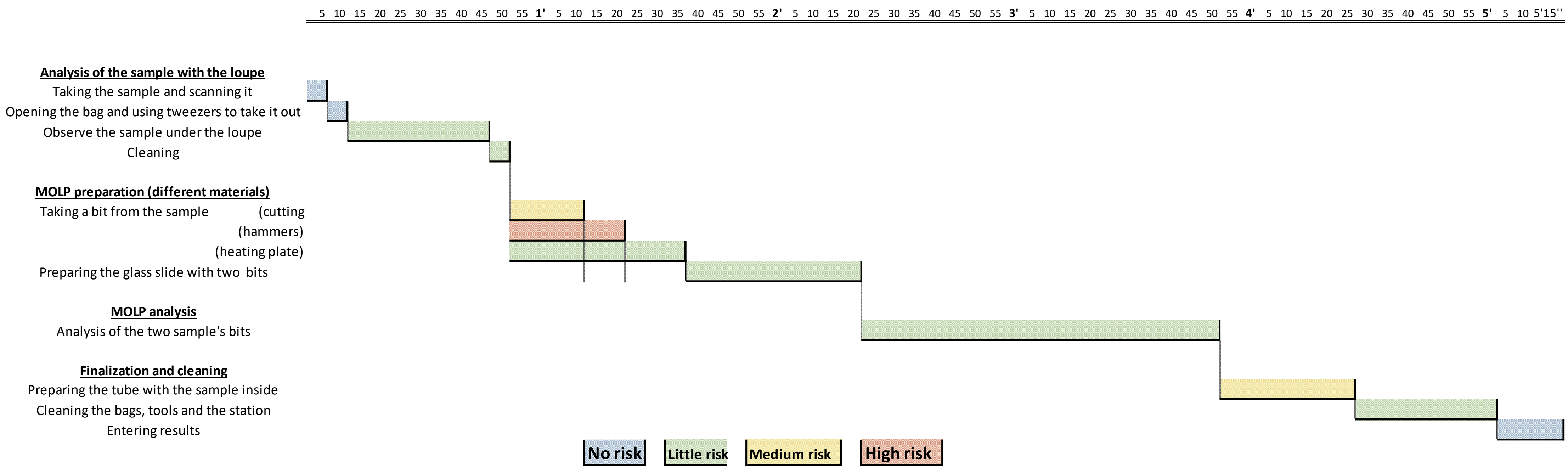
Avez-vous eu, au cours **des 7 derniers jours**, des problèmes (courbatures, douleurs, gêne, engourdissement) au niveau des zones du corps suivantes ? *Pour chacune des zones du corps, cochez la case correspondante*

1 ▸	**Nuque / cou**	**Oui…?**	**Non…?**	**Si oui,**	**du côté droit…?**	**du côté gauche…?**	**des deux côtés…?**
2 ▸	**Épaule / bras**	**Oui…?**	**Non…?**	**Si oui,**	**du côté droit…?**	**du côté gauche…?**	**des deux côtés…?**
3 ▸	**Coude/ avant-bras**	**Oui…?**	**Non…?**	**Si oui,**	**du côté droit…?**	**du côté gauche…?**	**des deux côtés…?**
4 ▸	**Main / poignet**	**Oui…?**	**Non…?**	**Si oui,**	**du côté droit…?**	**du côté gauche…?**	**des deux côtés…?**
5 ▸	**Doigts**	**Oui…?**	**Non…?**	**Si oui,**	**du côté droit…?**	**du côté gauche…?**	**des deux côtés…?**
6 ▸	**Haut du dos**	**Oui…?**	**Non…?**				
7 ▸	**Bas du dos**	**Oui…?**	**Non…?**				
8 ▸	**Hanche / cuisse**	**Oui…?**	**Non…?**	**Si oui,**	**du côté droit…?**	**du côté gauche…?**	**des deux côtés…?**
9 ▸	**Genou / jambe**	**Oui…?**	**Non…?**	**Si oui,**	**du côté droit…?**	**du côté gauche…?**	**des deux côtés…?**
10 ▸	**Cheville / pied**	**Oui…?**	**Non…?**	**Si oui,**	**du côté droit…?**	**du côté gauche…?**	**des deux côtés…?**

Comment évaluez-vous l'intensité de ce problème **au moment où vous remplissez le questionnaire**, sur l'échelle ci-dessous? *Pour chacune des zones du corps, cochez la case correspondante*

		Ni gêne ni douleur ▸	0	1	2	3	4	5	6	7	8	9	10	◂	gêne ou douleur intolérable
1 ▸	**Nuque / cou**	Ni gêne ni douleur ▸	0	1	2	3	4	5	6	7	8	9	10	◂	gêne ou douleur intolérable
2 ▸	**Épaule / bras**	Ni gêne ni douleur ▸	0	1	2	3	4	5	6	7	8	9	10	◂	gêne ou douleur intolérable
3 ▸	**Coude/ avant-bras**	Ni gêne ni douleur ▸	0	1	2	3	4	5	6	7	8	9	10	◂	gêne ou douleur intolérable
4 ▸	**Main / poignet**	Ni gêne ni douleur ▸	0	1	2	3	4	5	6	7	8	9	10	◂	gêne ou douleur intolérable
5 ▸	**Doigts**	Ni gêne ni douleur ▸	0	1	2	3	4	5	6	7	8	9	10	◂	gêne ou douleur intolérable
6 ▸	**Haut du dos**	Ni gêne ni douleur ▸	0	1	2	3	4	5	6	7	8	9	10	◂	gêne ou douleur intolérable
7 ▸	**Bas du dos**	Ni gêne ni douleur ▸	0	1	2	3	4	5	6	7	8	9	10	◂	gêne ou douleur intolérable
8 ▸	**Hanche / cuisse**	Ni gêne ni douleur ▸	0	1	2	3	4	5	6	7	8	9	10	◂	gêne ou douleur intolérable
9 ▸	**Genou / jambe**	Ni gêne ni douleur ▸	0	1	2	3	4	5	6	7	8	9	10	◂	gêne ou douleur intolérable
10 ▸	**Cheville / pied**	Ni gêne ni douleur ▸	0	1	2	3	4	5	6	7	8	9	10	◂	gêne ou douleur intolérable

9.5 Annex 5


5 10 15 20 25 30 35 40 45 50 55 1' 5 10 15 20 25 30 35 40 45 50 55 2' 5 10 15 20 25 30 35 40 45 50 55 3' 5 10 15 20 25 30 35 40 45 50 55 4' 5 10 15 20 25 30 35 40 45 50 55 5' 5 10 5'15''
Analysis of the sample with the loupe
Taking the sample and scanning it
Opening the bag and using tweezers to take it out
Observe the sample under the loupe
Cleaning
MOLP preparation (different materials)
Taking a bit from the sample (cutting
(hammers)
(heating plate)
Preparing the glass slide with two bits
MOLP analysis
Analysis of the two sample's bits
Finalization and cleaning
Preparing the tube with the sample inside
Cleaning the bags, tools and the station
Entering results
No risk
Little risk
Medium risk
High risk

9.6 Annex 6

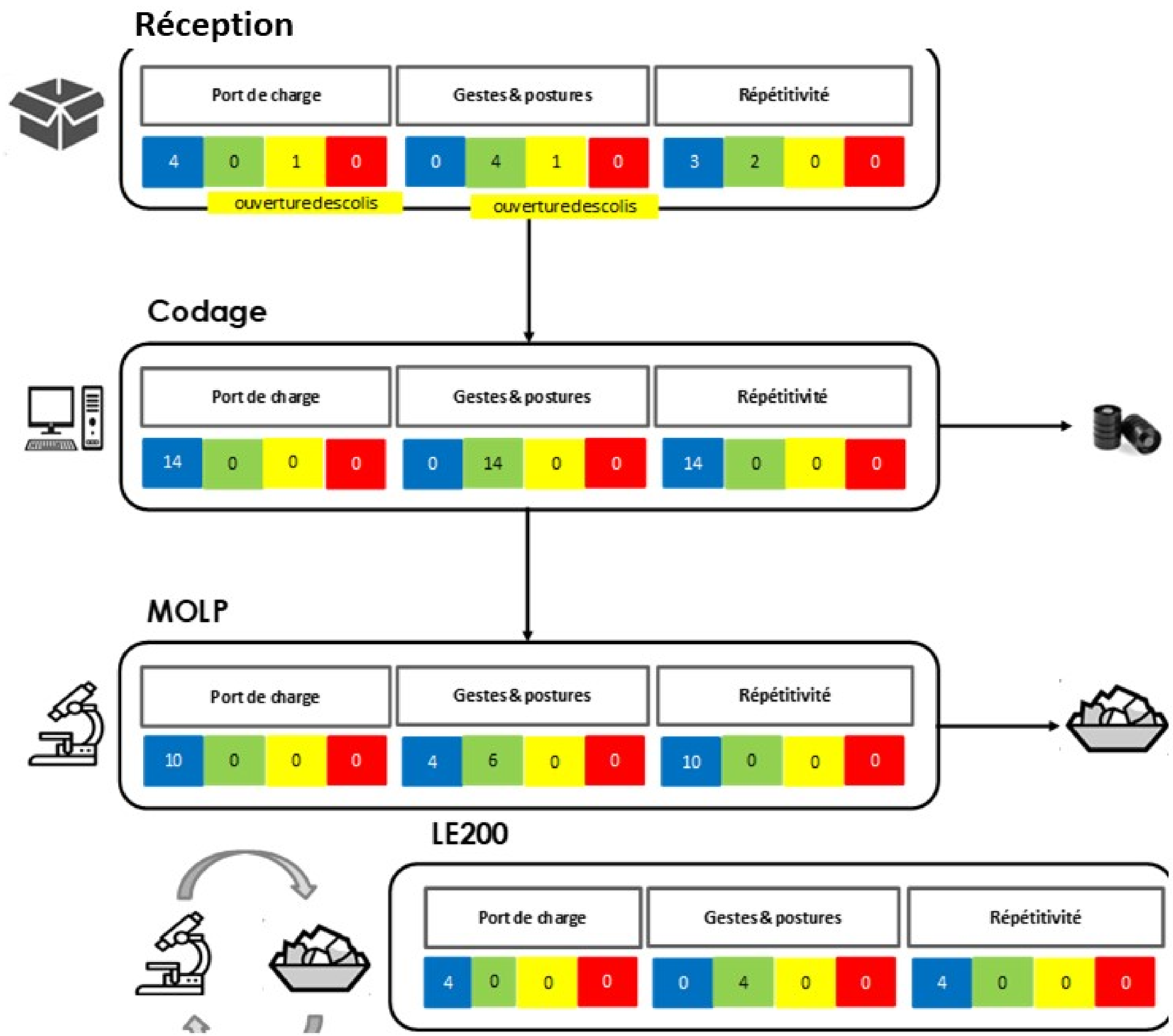
Evaluation ergonomique

EABSE – 2022

Gabriele Chelini

1

Résultats évaluation
Outil excel



Préparation Air

Port de charge				Gestes & postures				Répétitivité			
12	0	0	0	1	11	0	0	12	0	0	0

Préparation Matériaux

Port de charge				Gestes & postures				Répétitivité			
8	0	0	0	0	7	1	0	4	4	0	0
						microniseur					

MET

Port de charge				Gestes & postures				Répétitivité			
5	0	0	0	0	5	0	0	4	0	0	1
											analyse

CAUMET

Port de charge				Gestes & postures				Répétitivité			
5	0	0	0	1	4	0	0	4	0	0	1
				analyse							analyse

Tâches spécifiques (Filtration + Archives + Déchets)

Port de charge				Gestes & postures				Répétitivité			
4	0	0	0	0	0	4	0	4	0	0	0

3

Evaluation ergonomique à l'aide d'autres outils et connaissances

4

Codage

Tâches	Description	Par jour	Risques ergo	Mesures en place
Réception	Ouverture colis et sortie de l'ensemble des dossiers	30 minutes	Port de charge	Chariot et support
Décontamination	Ouverture des dossiers, déconta, revue de contrat, rangement	3h par deux personnes (1500-2000 éch)	Répétitivité: TMS coude, poignet, dos	Organisation du travail
Codage	Codage	Journée	Gestes extrêmes pour le tri dossier	Poste adapté Chariots

Difficultés

- Le poste est adapté ergonomiquement mais des gestes extrêmes sont encore faits pour ranger les dossier d'un bac à l'autre

Actions

- Evaluer la possibilité d'un adjoint en cas de journée chargée et donc des douleurs au poignet

MOLP

Tâches	Description	Risques ergo
Préparation	Prélèvement morceaux de l' échantillon (marteau ou pince coupante)	TMS bras, épaule, cou
Observation MOLP Observation loupe binoculaire	Binoculaire et MOLP	Torsion du buste, flexion du cou
Préparation LE200	Prise des tubes et bouchons en plastique hors de la hotte Vissage et dévissage	Gestes extrêmes Manipulation répétitive (>>100 fois) TMS épaule et cou

Difficultés

- Les Molpistes ont un objectif de 150 couches par jour, soit 110 échantillons par jour. Un objectif qui ne tient pas compte de la variabilité des échantillon (carottes, carrelages, multicouches, colle noire ...)
- Fatigue visuelle: changement entre échantillon, loupe, MOLP, écran interne et externe
- Poste gauchier et droitier pas bien assigné
- Presse: presse et plan difficiles à nettoyer; pompe loin de la hotte

Actions

- Virer les bouchons PrepMassif->MOLP (ok niveau qualité -> évaluer avec techniciens)
- Outil adaptés
- Distributeur bouchons et tubes comme en attaque acide
- Partage du bon geste de dévissage/vissage des bouchons
- Hotte plus large avec loupe et MOLP

PrepAir

Tâches	Temps totale (Position)	Par jour %	Par jour % sans codage	Risques ergo
Codage	3h (sur PC)	69%	-	-
Découpe	5min (assis)	4%	12%	Ouverture cassette avec décapsuleur –TMS poignet
Passage au four	50s (debout)	1%	3%	-
Filtration (5-6 fois par jour, le reste 2)	15 min (debout)	23%	72%	Soulèvement de l'épaule répété au-dessus de 60 degrés et fréquent au-dessus de 90 degrés
Carbonation	2 min (debout, en levant les bras)	2%	6%	Gestes extrêmes pour l'ouverture du couvercle
Préparation de la grille	5min entrée dépôt (assis) + 5min30s sortie dépôt (assis)	2%	6%	Gestes extrêmes lors du remplissage du bain avec le chloroforme Gestes contraignantes pour utilisation pompe manuelle chloroforme

Difficultés
- Verrerie de filtration difficiles à prendre (soulèvement épaule)
- Plusieurs outil hors de la hotte de dépôt

Actions
- Table à hauteur réglable pour la carbonation et la filtration
- Ajout d'espace pour verrerie de la filtration
- Nouveau décapsuleur
- Pompe (comme prepMassif) pour verser le chloroforme
- Portoir à 8 filtres pour diminuer fréquence filtration
- Installation pompe automatique chloroforme

PrepSolide

Tâches	Position	Par jour %	Risque ergo
Récupération des fours	(debout, en levant les bras)	1%	Gestes extrêmes
Attaque acide	(assis) Attaque acide et micronisation + centrifugation faites par la même personne	33%	Répétitivité Gestes extrêmes pour prendre tubes et bouchons au fond de la hotte Soulèvement de l'épaule pour utilisation distributeur billes et acide
Micronisation + Centrifugation	(debout)	2%	TMS main et poignet pour le vissage microniseur
Vidange acide	(assis)	15%	Mouvement pour la pompe manuelle d'eau distillé
Dilution	(assis)	27%	Soulèvement de l'épaule répété au-dessus de 60 degrés
Dépôt	(assis)	22%	Soulèvement de l'épaule répété au-dessus de 60 degrés et au-dessus de 90 degrés plusieurs fois

Difficultés

- L'inclination du bras avec soulèvement de l'épaule pour verser du liquide du tube est répétée plusieurs fois par échantillon à l'attaque acide, vidange et dilution ->

Actions

- Rotation sur les postes
- Réévaluer l'organisation de la hotte attaque acide
- Installation pompe automatique

MET

Tâches	Description	Risque ergo
Insertion – retrait échantillon	Debout pour insérer/retirer le porte-objet	Gestes extrêmes
Analyse	Utilisation trackball + boutons	Forte répétitivité (~1 geste per sec) TMS poignet, bras et épaule Flexion du cou

Difficultés
- Fatigue visuelle
- Ambiance de travail
- Changement fréquent du filament

Actions
- Evaluer possibilité d'effectuer plus de rotation sur CauMET
- Améliorer la coordination avec la cellule process (Sebastien &Co) qui travaillent sur porte-objet multi grille et moteurs
- Installation CauMET
- Mise en place IA pour éliminer répétitivité liée à l'analyse (poignées et trackball)

Tâches spécifiques

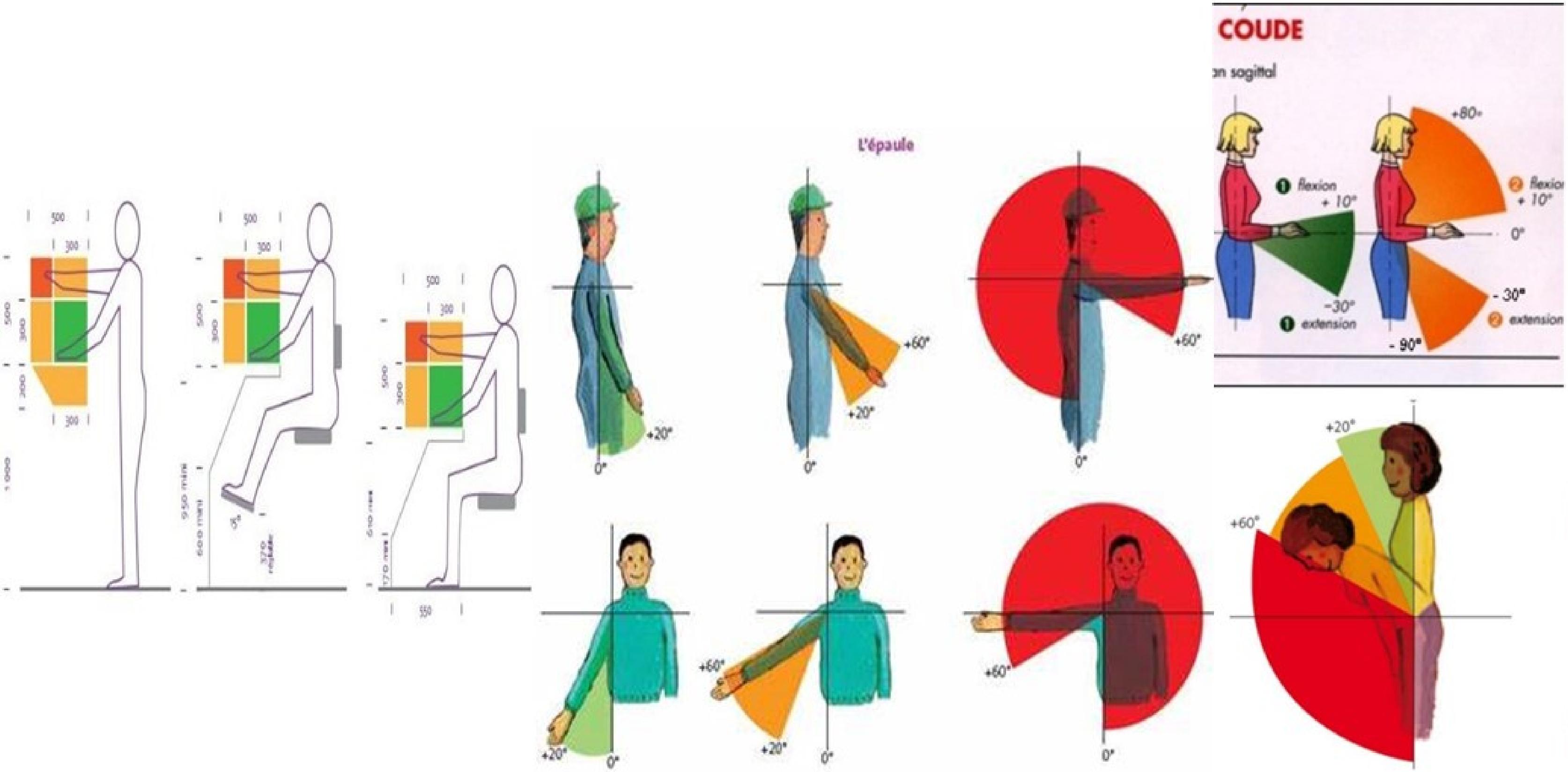
Tâches	Description	Risque ergo
Déchets bigbag	Fermeture grande poubelle (agenouillé penché pour attaque acide) Transport au local déchet	Postures contraignantes Port de charge (10kg
Archivage air/massif Désarchivage massif		Port de charge
Station de filtration	Changement filtres et vidange	

Actions

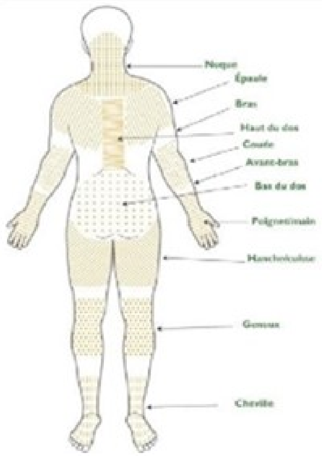
- Virer le double ensachage
- Améliorer la poubelle attaque acide (à évaluer avec operateurs et autres BU)
- Mise en place de poubelles plus petites pour le changer plus régulièrement

Amélioration de la grille ergonomique

Prise en compte de plusieurs postures (Epaule, coude, cou, dos)



Enquêter sur les douleurs et les TMS déjà présents dans l'entreprise



ANNEXE

QUESTIONNAIRE DE STYLE NORDIQUE

(d'après Kuorinka et al. 1987, Kuorinka et al. 1994, Roquelaure et al. 2006)

À quelle date remplissez-vous ce questionnaire ?

|__|__| |__|__| 20|__|__|
jour mois année

Comment évaluez-vous l'intensité de ce problème **au moment où vous remplissez le questionnaire**, sur l'échelle ci-dessous? *Pour chacune des zones du corps, cochez la case correspondante*

	Ni gêne ni douleur	▸ 0	1	2	3	4	5	6	7	8	9	10	◂ gêne ou douleur intolérable
1 ▸ **Nuque / cou**	Ni gêne ni douleur	▸ 0	1	2	3	4	5	6	7	8	9	10	◂ gêne ou douleur intolérable
2 ▸ **Épaule / bras**	Ni gêne ni douleur	▸ 0	1	2	3	4	5	6	7	8	9	10	◂ gêne ou douleur intolérable
3 ▸ **Coude/ avant-bras**	Ni gêne ni douleur	▸ 0	1	2	3	4	5	6	7	8	9	10	◂ gêne ou douleur intolérable
4 ▸ **Main / poignet**	Ni gêne ni douleur	▸ 0	1	2	3	4	5	6	7	8	9	10	◂ gêne ou douleur intolérable
5 ▸ **Doigts**	Ni gêne ni douleur	▸ 0	1	2	3	4	5	6	7	8	9	10	◂ gêne ou douleur intolérable
6 ▸ **Haut du dos**	Ni gêne ni douleur	▸ 0	1	2	3	4	5	6	7	8	9	10	◂ gêne ou douleur intolérable
7 ▸ **Bas du dos**	Ni gêne ni douleur	▸ 0	1	2	3	4	5	6	7	8	9	10	◂ gêne ou douleur intolérable
8 ▸ **Hanche / cuisse**	Ni gêne ni douleur	▸ 0	1	2	3	4	5	6	7	8	9	10	◂ gêne ou douleur intolérable
9 ▸ **Genou / jambe**	Ni gêne ni douleur	▸ 0	1	2	3	4	5	6	7	8	9	10	◂ gêne ou douleur intolérable
10 ▸ **Cheville / pied**	Ni gêne ni douleur	▸ 0	1	2	3	4	5	6	7	8	9	10	◂ gêne ou douleur intolérable

Avez-vous eu, au cours **des 12 derniers mois**, des problèmes (courbatures, douleurs, gêne, engourdissement) au niveau des zones du corps suivantes ? *Pour chacune des zones du corps, cochez la case correspondante*

1 ▸ **Nuque / cou**	**Oui…?**	**Non…?**	**Si oui,**	**du côté droit…?**	**du côté gauche…?**	**des deux côtés…?**
2 ▸ **Épaule / bras**	**Oui…?**	**Non…?**	**Si oui,**	**du côté droit…?**	**du côté gauche…?**	**des deux côtés…?**
3 ▸ **Coude/ avant-bras**	**Oui…?**	**Non…?**	**Si oui,**	**du côté droit…?**	**du côté gauche…?**	**des deux côtés…?**
4 ▸ **Main / poignet**	**Oui…?**	**Non…?**	**Si oui,**	**du côté droit…?**	**du côté gauche…?**	**des deux côtés…?**
5 ▸ **Doigts**	**Oui…?**	**Non…?**	**Si oui,**	**du côté droit…?**	**du côté gauche…?**	**des deux côtés…?**
6 ▸ **Haut du dos**	**Oui…?**	**Non…?**				
7 ▸ **Bas du dos**	**Oui…?**	**Non…?**				
8 ▸ **Hanche / cuisse**	**Oui…?**	**Non…?**	**Si oui,**	**du côté droit…?**	**du côté gauche…?**	**des deux côtés…?**
9 ▸ **Genou / jambe**	**Oui…?**	**Non…?**	**Si oui,**	**du côté droit…?**	**du côté gauche…?**	**des deux côtés…?**
10 ▸ **Cheville / pied**	**Oui…?**	**Non…?**	**Si oui,**	**du côté droit…?**	**du côté gauche…?**	**des deux côtés…?**

Avez-vous eu, au cours **des 7 derniers jours**, des problèmes (courbatures, douleurs, gêne, engourdissement) au niveau des zones du corps suivantes ? *Pour chacune des zones du corps, cochez la case correspondante*

1 ▸ **Nuque / cou**	**Oui…?**	**Non…?**	**Si oui,**	**du côté droit…?**	**du côté gauche…?**	**des deux côtés…?**
2 ▸ **Épaule / bras**	**Oui…?**	**Non…?**	**Si oui,**	**du côté droit…?**	**du côté gauche…?**	**des deux côtés…?**
3 ▸ **Coude/ avant-bras**	**Oui…?**	**Non…?**	**Si oui,**	**du côté droit…?**	**du côté gauche…?**	**des deux côtés…?**
4 ▸ **Main / poignet**	**Oui…?**	**Non…?**	**Si oui,**	**du côté droit…?**	**du côté gauche…?**	**des deux côtés…?**
5 ▸ **Doigts**	**Oui…?**	**Non…?**	**Si oui,**	**du côté droit…?**	**du côté gauche…?**	**des deux côtés…?**
6 ▸ **Haut du dos**	**Oui…?**	**Non…?**				
7 ▸ **Bas du dos**	**Oui…?**	**Non…?**				
8 ▸ **Hanche / cuisse**	**Oui…?**	**Non…?**	**Si oui,**	**du côté droit…?**	**du côté gauche…?**	**des deux côtés…?**
9 ▸ **Genou / jambe**	**Oui…?**	**Non…?**	**Si oui,**	**du côté droit…?**	**du côté gauche…?**	**des deux côtés…?**
10 ▸ **Cheville / pied**	**Oui…?**	**Non…?**	**Si oui,**	**du côté droit…?**	**du côté gauche…?**	**des deux côtés…?**

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Modification du regroupement des actions

- Actions consécutives regroupées par similitude de finalité -> Différences fréquentes en matière d'ergonomie
  - L'action *prise de filtre* ne nécessite pas de gestes extrêmes, alors que pour assembler la verrerie, l'opérateur soulève l'épaule à plus de 90 degrés.
  - Actions répétées dans plusieurs activités (e.g. nettoyage avec lingette au MOLP) – pas prises en compte

Préparation à la filtration	Prise de filtre pré-carboné à l'aide de pince (debout) Positionnement des filtres sur les tulipes (debout) Pose d'une colonne sur chaque tulipe (debout) Fixer les colonnes sur les tulipes avec une pince (debout) Mise du portant à colonne dans l'évier (debout)

Pose d'une colonne sur chaque tulipe (debout)
Fixer les colonnes sur les tulipes avec une pince (debout)
Mise du portant à colonne dans l'évier (debout)

→*Analyse de chaque action*

Ou

→*Regroupement des actions consécutives sur la base des mouvements*

Assemblage verrerie	Prise des outils (debout) Positionnement des filtres sur les tulipes (debout) Pose d'une colonne sur chaque tulipe (debout) Fixer les colonnes sur les tulipes avec une pince (debout) Mise du portant à colonne dans l'évier (debout)

Répétitivité

- La norme NF EN 1005-5 défini une tâche répétitive comme caractérisée par:
  - Temps de cycle inférieur à 30 seconds
  - Activité répétée au minimum 50% de travail
  - Fréquence gestuelle supérieure à 40 gestes technique par minute
- Toutefois, comme l'a montré l'évaluation ergonomique et l'enquête interne, les TMS peuvent résulter d'activités qui ne correspondent pas à la définition précédente, mais qui sont néanmoins répétées des centaines de fois chaque jour.
  - MOLP – LE200: vissage et dévissage des tubes ne sont pas considérés comme répétitives (Tcycle=5min, <40 act/min, <50% Ttravail) → Malgré cela, les opérateur ont des douleurs suite manipulation LE200

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- Cela met en évidence un problème plus complexe, qui est la complexité et la multi-causalité des TMS. Un outil qui compartimente la répétitivité, la charge et le geste, sans prendre en compte l'ensemble de ces éléments pour élaborer un diagnostic plus complexe, échouera à identifier certains risques.
- Étant donné que la prise en compte de la multi-causalité peut ne pas être possible au niveau analytique, pour éviter cet écueil, le facteur de répétitivité devrait être mis à jour de manière à inclure d'autres actions. Il pourrait être utile de déplacer l'indicateur vers le nombre de fois par jour ou par 10 minutes.