European Agency for Safety and Health at Work

EUROPEAN RISK OBSERVATORY

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LITERATURE REVIEW

Maintenance and Occupational Safety and Health: A statistical picture

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MAINTENANCE AND OCCUPATIONAL SAFETY AND HEALTH – A STATISTICAL PICTURE

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Executive summary

Maintenance is a generic term for a variety of tasks in different sectors and all kinds of working environments. This report aims to provide an overview of maintenance workers in Europe with regard to their exposure to hazards and the main risks, health problems and accidents. It also gives some indication as to appropriate prevention measures.

Maintenance influences the safety and health of workers in two ways. Regular maintenance that is correctly planned and carried out is essential to keep both machines and the work environment safe and reliable. Maintenance itself has to be performed in a safe way, with appropriate protection of maintenance workers and others present in the workplace.

Two different types of maintenance can be distinguished:

- **Corrective maintenance** – when actions are intended to restore a system from a failed state to a working state (e.g. repair or replacement of broken components). This type of maintenance is also known as 'reactive maintenance' because the action is initiated when the unscheduled event of an equipment failure occurs;
- **Preventive maintenance** – when actions are carried out at predetermined intervals or according to prescribed criteria intended to reduce the probability of failure or the degradation of the functioning of an item. In this case, actions are scheduled, proactive and intended to control the deterioration process leading to failure of a system (e.g. replacement, lubrication, cleaning or inspection).

There is also a third type of maintenance which concerns large-scale maintenance. This is carried out to allow an item to accomplish new or additional functions, or the same function in better conditions. It is frequently carried out during shutdown (an outage scheduled in advance) of the item.

The data included in this report are merely indications of the European situation as only a few countries are discussed. The first chapters are based on data from Spain and France only. Alongside a literature review, the exposure of maintenance workers to different risks is shown using information from the National Spanish Survey of Working Conditions. Although based only on data from Spain, the analysis is unique and carried out especially for this report; we can assume that the situation in other European countries may be similar.

A subsequent chapter contains unique data on occupational accidents from EUROSTAT, which are not published elsewhere and are based on the European Statistics on Accidents at Work (ESAW) methodology. Although these data also cover only a few European countries, they demonstrate the high level of accident statistics for maintenance workers.

Maintenance workers

Maintenance covers a number of occupations and concerns all types of activity. It is therefore difficult to identify the exact number of workers involved in maintenance activities. Data from France and Spain indicate that about 6% of the working population is involved in maintenance tasks. The majority of maintenance workers are men (around 90% in France and 65% in Spain) and, within this category of workers, the largest age group is 30–49 years old.

In France, 62% of maintenance workers in 2003 were in the tertiary (service) sector and about 33% in industry. Spain had a similar distribution (2003–2006) with about 70% of maintenance workers working in the service sector and about 19% in industry, though also about 10% in the construction. The large number of maintenance workers working in the service sector can be explained by the considerable outsourcing of maintenance work to service companies; according to a survey conducted in 2005 in France, maintenance is the most subcontracted function in industry.

In France in 2003, about half of all maintenance staff worked in companies with less than 50 employees. Nearly a third belonged to companies with 50–499 employees and 18.5% to companies with 500 employees and more. Nevertheless, there are considerable variations in relation to professional family (grouping used in the French survey).

Occupational safety and health risks related to maintenance

Because they carry out a wide range of activities, maintenance workers are exposed to many and varied hazards at work. There are physical hazards such as noise, vibrations (especially during maintenance of roads, tunnels or bridges), excessive heat and cold (outdoor maintenance workers), radiation, high physical workload and strenuous movements (carrying heavy materials, bending, kneeling, reaching, pushing and pulling, working in small places). Maintenance workers are also at risk of all types of accidents.

Maintenance workers often have contact with vapour or gases, particles (dust, smoke), fibres (asbestos, glass fibre) and mists. Typical maintenance tasks during which workers come in contact with chemical substances include:

- work with asbestos;
- working in confined spaces with dangerous atmospheres;
- electrical arc welding;
- maintenance of public swimming pools;
- working in car repair shops;
- work in solid waste treatment plants;
- maintenance of industrial installations;
- road maintenance;
- maintenance in paper mills.

Biological hazards (Legionella, Leptospira) are related to:

- maintenance of public swimming pools;
- maintaining laboratory instruments;
- maintenance in water supply installations or wastewater treatment plants;
- maintenance in solid waste treatment plants;
- maintenance of public buildings (pigeon droppings).

The characteristics of maintenance work also imply the presence of **psychosocial hazards**. During maintenance work, the productivity of an organisation is cut back and there is an urgency to restart activities as soon as possible. This can put considerable pressure on maintenance workers to complete their tasks. Time pressure and poor work organisation may lead to excessive stress. Moreover, working with contractors can sometimes lead to communication problems.

An analysis of the results of the Spanish National Survey of Working Conditions (2007) revealed interesting data on the exposure to hazards among Spanish maintenance workers. For this project two groups were created in order to exploit the data: maintenance workers (n = 1280) and other workers (n = 9793). The following occupations were considered as related to maintenance:

- bricklayer or bricklayer's mate;
- painter, varnisher/lacquerer, paperhanger;
- plumber, heating operator;
- electrician;

- parquetry worker, tile or floor layer, glazier, roofer, installer of insulating material, installer of air conditioning;
- cleaners of building façades;
- machinist, machine adjuster;
- electrical or electronic equipment repairer.

The results indicate greater exposure of maintenance workers to:

- loud noise (16% compared to 8%);
- very loud noise (3% compared to 2%);
- hand–arm vibrations (24% vs. 9%);
- whole–body vibrations (12% vs. 5%);
- ultraviolet light (8% vs. 4%);
- radiofrequencies (4% vs. 2%).

Maintenance workers are also more exposed to:

- heat in summer (44% compared to 19% among other occupations);
- cold in winter (44% compared to 17%);
- humid atmosphere (25% compared to 13%);
- dangerous substances, vapours and fumes.

Outcomes related to occupational safety and health

Scientific studies indicate that occupational diseases and work-related health problems (e.g. asbestosis, cancer, hearing problems and musculoskeletal disorders) are prevalent among workers involved in maintenance activities. Industrial maintenance employees have an 8–10 times greater chance of developing an occupational disease than the average population.

Analysis of EUROSTAT data based on the ESAW methodology helped to identify accidents related to maintenance operations in a number of European countries. Within the variable 'working process' used by ESAW for the classification of causes and circumstances of accidents, four subcategories relate to **maintenance operations**:

- setting up, preparation, installation, mounting, disassembling, dismantling;
- maintenance, repair, tuning, adjustment;
- mechanised or manual cleaning of working areas and machines;
- monitoring, inspection of manufacturing procedures, working areas, means of transport, equipment – with or without monitoring equipment.

The number of accidents for these subcategories was compared to the total number of accidents related to any other subcategory within the variable 'working process'. The data show that around 20% of all accidents in Belgium (in 2005–2006) were related to maintenance operations, as well as around 18–19% in Finland, 14–17% in Spain, and 10–14% in Italy (in 2003–2006). In addition, figures from a number of European countries indicate that around 10–20% of all fatal accidents in 2006 were related to maintenance operations.

EUROSTAT data from five EU countries indicate that the majority of maintenance-related accidents occur in manufacturing, construction and 'real estate, renting and business activities',[*] and in Austria also in hotels and restaurants. In addition, in the electricity, gas and water supply sector in 2006, 50% of accidents in Finland and Belgium, 34% in Spain, and 23% in Italy were related to maintenance operations. In the real estate, renting and business activities sector, 40% of accidents related to maintenance in Finland, 34% in Spain, and 26% in Belgium. In Belgium, 41% of accidents in the education sector were maintenance-related. In other sectors, depending on the country, 10–20% of accidents related to maintenance operations.

The scientific literature indicates that most of the accidents occur during **corrective maintenance** activities. Moreover, an analysis of a French work accidents database shows that, in 2002, maintenance employees were the second most frequent victims of accidents related to subcontracting, followed closely by construction workers.

Lack of maintenance or inadequate maintenance can also lead to dangerous situations, accidents and health problems. This may be related to lack of, or poor maintenance of, vehicles, industrial or agricultural machines, electrical facilities, fire extinguishers, buildings or water facilities. Maintenance failures may contribute to large-scale disasters with extremely damaging consequences for humans and the environment.

Prevention measures

The process of maintenance should start at the design and planning stage, i.e. before maintenance workers even enter the workplace. It is essential to implement appropriate risk assessment procedures for maintenance operations, as well as employing adequate preventive measures to ensure the safety and health of workers involved in maintenance activities. After maintenance operations are complete, special checks (inspections and tests) should be carried out to ensure that maintenance has been properly carried out and that new risks have not been created. During the whole process, good maintenance management should ensure that maintenance is co-ordinated, scheduled and performed correctly as planned, and that the equipment or workplace is left in a safe condition for continued operation.

[*] 'Real estate, renting and business' activity consists of subcategories such as 'maintenance and repair of office, accounting and computing machinery' as well as 'industrial cleaning'.

1. Introduction

- Maintenance is a generic term for a variety of tasks in different sectors and all kinds of working environments. This report aims to provide an overview of maintenance workers in Europe with regard to their exposure to hazards and the main risks, health problems and accidents. It also gives some indication as to appropriate prevention measures.
- Chapter 2 presents a definition of maintenance work and general employment figures in this field. Chapter 3 is dedicated to the risks to which maintenance workers are exposed and occupational diseases, while chapter 4 examines maintenance-related accidents. The data given are based on the findings of a literature review, as well as information from EUROSTAT and the Spanish National Survey on Working Conditions. Chapter 5 offers guidance on prevention measures.
- When reading this report it is important to bear in mind that the figures given are merely indications of the European situation, as only a few countries are discussed. The first chapters are based on data from Spain and France only. Alongside the literature review, the exposure of maintenance workers to different risks is shown using information from the National Spanish Survey of Working Conditions. Although based only on data from Spain, the analysis is unique and carried out especially for this report; we can assume that the situation in other European countries may be similar.
- Chapter 4 on occupational accidents contains unique data from EUROSTAT that are not published elsewhere and which are based on the European Statistics on Accidents at Work (ESAW) methodology [1]. Again these data cover only a few European countries, but they demonstrate the high level of accident statistics for maintenance workers.

2. Maintenance – contextual features

2.1. Definitions

According to European Standard EN 13306 [2], maintenance concerns 'the combination of all technical, administrative and managerial actions during the life cycle of an item[1] intended to retain it in, or restore it to, a state in which it can perform the required function'. A maintenance function is critical to:

- ensure continuous productivity;
- produce products of high quality;
- maintain a company's competitiveness.

It also contributes significantly to occupational safety and health [3,4]. Maintenance influences the safety and health of workers in two ways. First, regular maintenance that is correctly planned and carried out is essential to keep both machines and the work environment safe and reliable. Second, maintenance itself has to be performed in a safe way, with appropriate protection of maintenance workers and others present in the workplace.

Two different types of maintenance can be distinguished:

- **Corrective maintenance**, i.e. maintenance carried out after fault recognition and intended to put an item into a state in which it can perform a required function [2]. In this case, maintenance actions are intended to restore a system from a failed state to a working state, i.e. to restore the functional capabilities of failed or malfunctioned systems. This involves, for example, repair or replacement of failed components [5]. This type of maintenance is also known as 'reactive maintenance' because the action is initiated when there is an unscheduled event of equipment failure [6];

[1] EN 13306 defines an item as 'any part, component, device, subsystem, functional unit, equipment or system that can be individually considered' (p. 14).

- **Preventive maintenance**, i.e. maintenance carried out at predetermined intervals or according to prescribed criteria intended to reduce the probability of failure or the degradation of the functioning of an item [2]. In this case, actions are scheduled, proactive and intended to control the deterioration process leading to failure of a system. They are carried out to either reduce the likelihood of a failure or prolong the life of the component [5] by, for example, performing replacement, lubrication, cleaning and inspection [6].

A third type of maintenance can also be added to this list. This concerns large-scale maintenance. This type of maintenance is carried out to allow an item to accomplish new or additional functions, or the same function in better conditions. It is frequently carried out during shutdown (an outage scheduled in advance) of the item [7]. The actions performed concern, for example, modification, rebuilding, modernisation or renovation of the equipment or system [8].

2.2. Maintenance workers

2.2.1. General employment

It is difficult to obtain statistics on the employment of maintenance workers for various reasons:

- Maintenance does not correspond to just one occupation but to several. Mechanics, electricians, car mechanics, electronics engineers, maintenance supervisors and other workers might perform maintenance tasks as a part of their job;
- Maintenance concerns all sectors of activity. The type of maintenance will be different depending on the sector in which the maintenance worker is employed;
- Maintenance is a role that can be assumed by different operators in a principal or subsidiary way. Maintenance organisations are various and have undergone profound modifications (e.g. total productive maintenance; autonomous maintenance; shared, integrated or specialised maintenance; subcontracting maintenance; and remote maintenance) leading for example to the allocation of maintenance tasks to production operators [9]. Thus, maintenance operations may be carried out by a specialised operator, a user or an operator who is external to the company owning the items being maintained.

The data presented below relate to employees whose occupation is explicitly related to maintenance. As no data were found for Europe in general, data from France and Spain are presented as an indication of employment of maintenance workers in Europe.

According to AFIM (Association of Maintenance Engineers and Technicians),maintenance (which includes industrial and tertiary[2] maintenance as well as private services) represents more than 450,000 jobs in France, including 15,000 managers [10–13].

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[2] The tertiary sector covers activities such as trade, administration, transport, financial and property activities, services to companies and people, education, health and social action.

The SUMER 2003 survey[3] [14] also allowed the number of maintenance employees in France to be estimated. The professional families[4] distinguished in the survey and related to maintenance are as follows:

- 'Skilled maintenance workers'. They undertake maintenance work, and the repair and renovation of mechanical, electromechanical, electrical and electronic equipment;
- 'Automotive repair workers'. These employees are mainly (about 75%) car mechanics and electronics workers, and (to a lesser extent) coachbuilders;
- 'Maintenance and organisation technicians and supervisors'. This group includes middle managers, who plan maintenance work, and qualified technicians, fitters and temporary repair workers in electricity, electronics and mechanics. Environmental engineers, managers and technicians are grouped with maintenance technicians and supervisors, which may affect the results as their activities are different.

On the basis of the results of the SUMER 2003 survey, the number of maintenance employees coming under these three maintenance professional families (the maintenance domain) in France can be assessed at 889,400 (see Table 1). Hence, they represent some 5% of the salaried employees of the general social security system and of the public hospitals, French post office, French electricity board, French railways, French air transport (Air France) and the agricultural social insurance system [14]. However, the three maintenance families examined here probably do not represent all maintenance employees. Moreover, these numbers are related to the occupations of the employees and not to their role.

Table 1: Number of professional families in France in the 'maintenance domain', SUMER 2003 survey [14]

Professional family	Number*	Percentage**
Skilled maintenance workers	304,600	1.76%
Automotive repair workers	202,000	1.17%
Maintenance and organisation technicians and supervisors	382,800	2.21%
Total	**889,400**	**5.13%**
All professional families (76 families)	17,334,200	100%

* Extrapolated numbers of salaried employees from the survey sample.

** Ratio of the employees of the professional family concerned to the total number of employees of the survey (i.e. employees of the 76 professional families, bearing in mind that 10 were not included because their number was insufficient or because they were too heterogeneous).

Two groups from the Spanish social security database were considered as maintenance workers:

- maintenance, repair, adjustment and working out (code 52);
- industrial or manual cleaning of spaces and machines (code 53).

The data show that, in 2006, about 6% of the working population in Spain was concerned with maintenance tasks. From 2003 to 2006 the percentage of workers involved in maintenance fell

[3] The SUMER (SUrveillance MEdicale des Risques professionnels) survey is an evaluation tool of the exposure of employees to the main workplace risks in France. It is organised by the French Ministry of Labour and was conducted in 2003 in conjunction with the French Department of Work Relations and the Ministry's Research and Statistics Department (DARES, Direction de l'Animation de la Recherche, des Etudes et Statistiques). The survey is based on interviews conducted by company doctors and questionnaires to a representative sample of 56,345 randomly chosen salaried employees.

[4] 'Professional families' is one of the main occupational nomenclatures based on the grouping used by INSEE (French National Institute of Statistics and Economical Studies) and ANPE (French National Agency for Employment). Professional families relate to occupations which require common knowledge and similar physical strains [15].

slightly (from 8% in 2003 to 6,1% in 2005, see Table 2) [17]. However, these figures do not necessarily cover all maintenance workers.

Table 2: Employment in maintenance work in Spain, Ministry of Labour and Immigration, 2003–2006 [17]

Maintenance					
Year	Yes		No		Total
	No.	%	No.	%	
2003	76,152	8.0	878,695	92.0	954,847
2004	61,880	6.5	893,864	93.5	955,744
2005	61,146	6.2	920,649	93.8	981,795
2006	61,367	6.1	942,073	93.9	1,003,440

2.2.2. Employment by gender

The data from the French SUMER 2003 survey indicate that almost all maintenance employees are men (Table 3); this is the case for 95% of all such employees, ranging from 91% for maintenance and organisation technicians and supervisors to 99% for automotive repair workers. Women represent 5% of these three professional families.

Table 3: Distribution of maintenance employees in France as a function of gender, SUMER 2003 survey

Gender	Skilled maintenance workers	Automotive repair workers	Maintenance and organisation technicians and supervisors	Total maintenance domain*
Male	97%	99.3%	91.2%	95%
Female	3%	0.7%	8.8%	5%
Total	**304,600**	**202,000**	**382,800**	**889,400**

* Data recalculated by taking into account the numbers of each of the three maintenance professional families.

In Spain the percentage of female maintenance workers is higher than in France; in 2006, 63% were men compared to 37% women (Table 4). This is comparable to the total employment figures, although the total percentage of male workers in 2006 was 77% making the percentage of women undertaking maintenance work higher than the average percentage of women in employment. This is quite a remarkable situation.

Table 4: Employment of maintenance workers by gender in Spain, Ministry of Labour and Immigration, 2003–2006 [17]

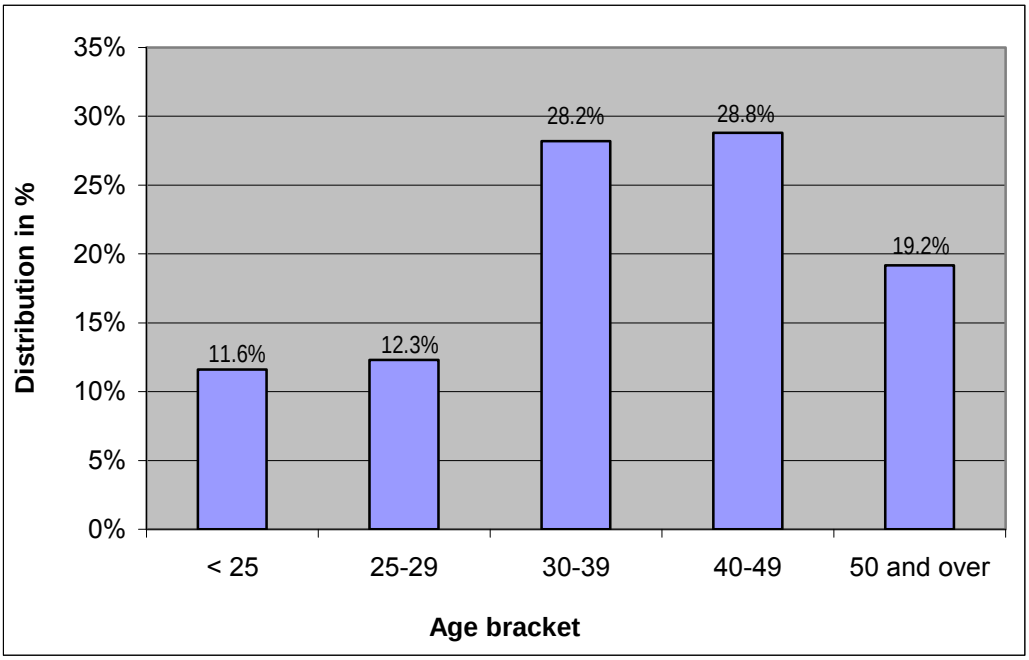
Year	Maintenance					Total				
	Men		Women		Total	Men		Women		Total
	No.	%	No.	%		No.	%	No.	%	
2003	49,167	64.6	26,985	35.4	76,152	745,265	78.1	209,582	21.9	954,847
2004	39,691	64.1	22,189	35.9	61,880	741,162	77.5	214,582	22.5	955,744

Year	Maintenance					Total				
	Men		Women		Total	Men		Women		Total
	No.	%	No.	%		No.	%	No.	%	
2005	38,846	63.5	22,300	36.5	61,146	761,032	77.5	220,763	22.5	981,795
2006	38,877	63.4	22,490	36.6	61,367	773,991	77.1	229,449	22.9	1,003,440

2.2.3. Employment by age

According to the SUMER survey [14], 57% of employees in the maintenance professional domain in France in 2003 were between 30 and 49 years old (see Figure 1).

Figure 1: Distribution of maintenance employees in France as a function of age bracket, SUMER 2003 survey [14]



However, there are large variations in this distribution in relation to professional family; 21% of the automotive repair workers were under 25 in 2003, whereas this percentage is only 6.6% for the maintenance and organisation technicians and supervisors. On the other hand, employees aged at least 50 represented more than one skilled maintenance worker in five (23%), but only 12% of the automotive repair workers. Furthermore, the SUMER 2003 survey does not allow comparison with all French employees (data are only relative to age per professional category).

According to the SUMER 2003 survey, 5.5% of the maintenance staff had been doing this work for less than one year (variations between maintenance professional families were slight – from 4.9% to 7.1%), and 94.5% had been working for at least a year in the job.

In Spain the largest proportion (around 65%) of the maintenance workers in 2003–2006 were between 25 and 49 years old (Table 5). This is comparable to the figures for total employment in Spain, though compared to the total employment, there are less young workers involved in maintenance work and a larger proportion of older workers.

Table 5: Employment of maintenance workers in Spain, by age, Ministry of Labour and Immigration, 2003–2006 [17]

(a) Maintenance							
Year	15–24		25–49		50 and more		Total
	N	%	N	%	N	%	
2003	11,496	15.1	47,620	62.5	17,036	22.4	76,152
2004	8,801	14.2	39,607	64.0	13,455	21.7	61,863
2005	8,160	13.3	39,292	64.3	13,694	22.4	61,146
2006	7,898	12.9	39,558	64.5	13,911	22.7	61,367

(b) Total							
Year	15–24		25–49		50 and more		Total
	N	%	N	%	N	%	
2003	218,132	22.8	593,616	62.2	143,099	15.0	954,847
2004	208,079	21.8	614,011	64.3	133,426	14.0	955,516
2005	202,362	20.6	639,242	65.1	140,191	14.3	981,795
2006	196,431	19.6	662,976	66.1	144,033	14.4	1,003,440

2.2.4. Employment by sector

Table 6 shows the distribution of maintenance employees as a function of four activity sectors – agriculture, industry, building, tertiary (service) – in the SUMER 2003 survey [14]. In 2003, maintenance staff worked essentially in the service sector (62%). They were also well represented in the industry sector (34%), but seem to be less numerous in the building and agricultural sectors.

Some variations are observed in relation to professional family, as almost every automotive repair worker (97%) worked in the service sector, whereas a third of the maintenance and organisation technicians and supervisors (34%) and more than half of the maintenance skilled worker (54%) worked in industry.

The high proportion of maintenance staff in the service sector is noteworthy. This distribution of maintenance employees according to sector is likely to have undergone major change in recent years (from industry to service sector). As maintenance activities are increasingly subcontracted, maintenance staff who used to work for industrial companies may now work for companies specialising in maintenance (which are part of the service sector). Indeed, maintenance was the most subcontracted function in industry according to a survey conducted in 2005 in France [19].

Table 6: Distribution of maintenance employees in France as a function of four activity sectors, SUMER 2003 survey [14]

Activity sector	Skilled maintenance workers	Automotive repair workers	Maintenance and organisation technicians and supervisors	Total maintenance domain
Agriculture	0.6%	0.6%	0.1%	0.4%
Industry	54.1%	2.2%	33.8%	33.6%
Building	5.9%	0.2%	3.9%	3.7%
Service	39.3%	97.0%	62.2%	62.3%

* Data recalculated by taking into account the numbers of each of the three maintenance professional families.

In Spain maintenance workers are best represented in 2003–2006 in the service sector (70%), followed by industry (19%) and construction (10%). The service sector is also best represented (46%) in the total working population (see Table 7).

Table 7: Employment by economic activity in Spain, Ministry of Labour and Immigration, 2003-2006 [18]

Activity sector	2003				2004			
	Maintenance		Total workers		Maintenance		Total	
	N	%	N	%	N	%	N	%
Agriculture	864	1.1	34,830	3.6	709	1.1	36,246	3.8
Industry	15,901	20.9	247,050	25.9	12,362	20.0	244,411	25.6
Construction	7,084	9.3	238,360	25.0	5,498	8.9	236,475	24.7
Service	52,303	68.7	434,607	45.5	43,311	70.0	438,612	45.9
Total	76,152		954,847		61,880		955,744	

Activity sector	2005				2006			
	Maintenance		Total workers		Maintenance		Total	
	N	%	N	%	N	%	N	%
Agriculture	622	1.0	35,438	3.6	692	1.1	36,005	3.6
Industry	11,715	19.2	241,550	24.6	11,605	18.9	241,371	24.1
Construction	5,792	9.5	251,505	25.6	5,968	9.7	263,359	26.2
Service	43,017	70.4	453,302	46.2	43,102	70.2	462,705	46.1
Total	61,146		981,795		61,367		1,003,440	

2.2.5. Size of company

In 2003, almost half of maintenance staff (49%) in France worked in companies with less than 50 employees (Table 8). Nearly a third belonged to companies with 50–499 employees and 18.5% to companies with 500 or more employees. Nevertheless, there are considerable variations in relation to professional family (see Table 8). Indeed, over half the automotive repair workers worked for companies with less than 10 employees, and more than 80% for companies with less than 50 employees. On the other hand, the corresponding figures are 13% and 34% respectively for skilled maintenance workers (more than a quarter worked in companies with 500 employees and more), and 18% and 43% respectively for maintenance and organisation technicians and supervisors. The subcontracting of maintenance may result in increasing numbers of maintenance workers working in small companies, whereas maintenance technicians and supervisors tend to stay in user companies to prepare and plan subcontracted interventions.

Table 8: Distribution of maintenance staff in France according to size of company, SUMER 2003 survey [14]

No. of employees	Skilled maintenance workers	Automotive repair workers	Maintenance and organisation technicians and supervisors	Total maintenance domain
1–9	13.2%	52.8%	17.6%	24.1%
10–49	21.1%	31.4%	25.3%	25.3%
50–199	23.5%	11.1%	23.6%	20.7%
200–499	15.3%	1.6%	13.5%	11.4%
500 and over	26.9%	3.1%	19.9%	18.5%

2.3. Maintenance companies

As explained above (i.e. maintenance is a transverse activity which concerns all activity sectors), it is very difficult to evaluate the number of maintenance companies.

In France, numerous risk codes used by the CNAM (Caisse Nationale d'Assurance Maladie – National Health Insurance Fund) to characterise company activity are explicitly related to maintenance. This is the case in the following examples:

- 'reconstruction and repair of machine tools';
- 'repair of agricultural equipment';
- 'repair of household equipment'.

However, data concerning these companies are grouped together with data related to those whose main activity does not concern maintenance.

Although existing sources do not allow an evaluation of the number of companies specialising in maintenance in France, some indicators are provided by AFIM (Association of Maintenance Engineers and Technicians). AFIM has identified 300 companies and training organisations certified in maintenance, including 169 maintenance service providers [12]. In addition, 5,485 French establishments containing the term 'maintenance' can be found by searching the website http://www.societe.com. Furthermore using a directory of French companies, 'France Prospect 2008',[5] the Chamber of Commerce and Industry of Meurthe-et-Moselle identified [84] companies specialising in maintenance in the Lorraine region alone. Thus, assuming that there is no difference between the 22 various French regions, there could be an estimated 1,848 companies specialising in maintenance in France.

2.4. Subcontracting maintenance

Maintenance is one of the most subcontracted functions in industry [18,19]. Indeed, many industrial companies have decided to focus on their core business and have outsourced some functions or departments that were previously integrated into their structure. For example, this is the case for transport and research, but also maintenance. The aim of transferring activities to external companies can be 'to set up a small network of interdependent companies that will make production, maintenance and services more flexible' [20] and consequently to reduce costs; in our case, maintenance costs.

According to SESSI (Department of Industrial Studies and Statistics), maintenance and general services represent 20% of the purchases of services by industrial companies in France [21], with

[5] See http://www.france-prospect.fr

some variations according to the size of the company and its sector of activity.[6] In 2005 according to SESSI [21]:

- 50% of French industrial companies with at least 20 employees bought maintenance and general services, but also had internal maintenance and general services;
- 44% only had external (subcontracting) maintenance and general services;
- 4% had no maintenance and general services at all;
- 2% only had internal maintenance as well as general services.

More than 60% of French service companies had recourse to a service provider for maintenance and cleaning activities in 2001. According to INSEE (National Institute of Statistics and Economical Studies), the reasons are primarily linked to the specific abilities needed and the cost of maintenance [22].

AFIM estimates that maintenance represents 2.5–3% of industrial turnover in France, i.e. EUR 22 billion of expenditure, of which EUR 7.1 billion is dedicated to subcontracting [12]. Hence, almost a third (32%) of maintenance expenditure may be dedicated to subcontracting. Internal subcontracting in France (i.e. user company allocating work to an external company on the user company's site and within the scope of its own business) is particularly concerned with industrial maintenance and accounts for a turnover of about EUR 6 billion [23]. This subcontracting maintenance covers different industries such as chemical, petrochemical, steel and nuclear [23].

The subcontracting trend in Spain seems to be less developed than observed in France. It even seems that the percentage of outsourcing of maintenance work in Spain is still declining; in 2003 25% of the maintenance work was outsourced while in 2006 it was only 14% (see Table 9).

Further studies are necessary to better estimate the importance of subcontracting maintenance in Europe.

Table 9: Subcontracting maintenance work in Spain, Ministry of Labour and Immigration, 2003–2006 [18]

Year	Subcontracting maintenance			
	Yes		No	
	N	%	N	%
2003	19,126	25.1	57,026	74.9
2004	12,852	20.8	49,028	79.2
2005	11,625	19.0	49,521	81.0
2006	8,430	13.7	52,937	86.3

[6] Industrial companies may offer their customers certain services. These services mainly concern maintenance and services related to installation and startup [21].

3. Occupational safety and health risks related to maintenance

In recent years, maintenance has been the subject of fundamental change and is now regarded as an essential function within companies. However, maintenance-related risks continue to receive limited attention and little research has been devoted to the impact of maintenance on the safety of those who work in maintenance and their co-workers [24]. Maintenance tasks can be carried out in permanent installations (i.e. maintenance workshops) with appropriate machines and tools, but also where a breakdown occurs. In this latter case, incidents and accidents are more frequent because workers may use inappropriate or improvised equipment, may be working under time pressure, etc. [25]. Moreover, maintenance activities are rarely taken into account in the design of equipment.

Maintenance workers are exposed to many and varied risks when carrying out their job due to very different activities of maintenance, maintenance environment, varied equipments concerned, etc. [26]. Maintenance covers different conditions:

- working outdoors exposed to changing climatic conditions (e.g. maintenance of radiotelephone antenna) or to vibrations, noise and chemical substances (e.g. maintenance of roads, bridges, tunnels, rail tracks);
- working indoors exposed to high levels of noise in industrial facilities (e.g. repair of machines, vehicles, etc.).

Thus, risks are related mainly to:

- environment where the work is carried out;
- machines and tools used;
- type of energy used (e.g. electric, pneumatic or hydraulic);
- working conditions;
- chemical and/or biological agents that workers handle during the work.

In most cases there is a combination of risks.

3.1. Physical hazards

3.1.1. Noise

Many maintenance workers do their job or remain for many hours in noisy environments. This is the case, for instance, for those maintaining roads/tunnels/bridges/railway tracks, aircraft mechanics, car mechanics, metal workers, etc.

Noise can be caused by machinery, equipment or motor vehicles. The levels of noise can exceed the established limit values and continuous exposure to such high sound levels may have several undesirable impacts on the health of operators, causing them hearing loss and other non-auditory effects (see Table 10).

Table 10: Classification of noise effects [27]

Type	Effects of noise
Auditory effects	Temporary hearing loss
	Permanent hearing loss; Acoustical trauma; Hearing loss induced by noise.
	Effects of very intense noise

Non-auditory effects	Physiological non-auditory effects; Increase in blood pressure; Increase in respiratory frequency; Gastric ulcers; Sleep disorders.
	Difficulties in oral communication
	Difficulties in mental concentration
	Discomfort
	Reduction in performance
	Increase in work accidents

Maintenance employees working with heavy earth-moving machinery are considered particularly at risk, with the sound levels experienced by these workers reported to range from 95 to 105 dB [28].

Another study aimed to characterise respirable dust, crystalline silica, diesel and noise exposure of construction workers on a large highway construction project (including maintenance tasks) [29]. The study focused primarily on operating engineers and labourers, and to a lesser extent on ironworkers and carpenters during the tunnel finish and cut and cover stages. With regard to noise exposure, full and partial shift noise dosimeter measurements were collected. Of the 40 noise measurements, 80% were at or above 85 dBA, with the operating engineers averaging 91 dBA. The results indicate that high exposure to noise is common in the road construction industry.

Aircraft mechanics are also considered to be particularly exposed to impact noise [30] and fatigue has been shown to be an effect of noise exposure in this group of workers [31]. According to this latter study, mechanics would feel sleepier and less energetic during the week of work on the runaway after repair work at their base; this effect was most evident in the afternoon after work and increased during the week. The mechanics reported that, when working between two aeroplanes with engines running, they could not only hear the sound but also feel it as vibrations, especially in the chest. This effect might have contributed to the fatigue.

3.1.2 Vibration

- **Hand-arm vibration**

Many of the hand-held power tools used by maintenance workers (e.g. grinding, polishing or riveting tools, impact wrenches, percussion hammers, vibrating compactors, mowers, and chain saws) can transmit vibrations to the worker's hand [32]. The exposure to certain levels of hand–arm vibrations can cause different worker disorders (see Table 11) depending on the doses received, the environmental conditions and the individual characteristics.

Table 11: Disorders caused by exposure to hand–arm vibrations [27]

Type of disorder	Symptoms
Vascular	White finger or Raynaud's phenomenon
Neurological	Decline in touch, manual dexterity and sensitivity to heat
Musculoskeletal	Wrist or elbow osteoarthritis, arthralgia in hands or arms, muscular weakness

- **Whole-body vibrations**

Whole-body vibrations occur when a major part of the body rests on a vibrating surface. In most cases, this exposure takes place while sitting, and vibrations are transmitted through the seats, or while standing and then vibrations are transmitted through the feet. As a consequence, whole-body

vibrations are basically from driving commercial vehicles such as earth-moving machinery, tractors, fork-lift trucks, lorries and buses [32]. The exposure to certain levels of whole-body vibrations can cause different disorders depending on the doses received, the environmental conditions and the individual characteristics (see Table 12).

Table 12: Disorders caused by exposure to whole-body vibrations [27]

Type of disorder	Symptoms
Back	Backache, disc lesions, spinal degeneration
Digestive	Gastrointestinal problems
Female sexual organs	Menstruation disorders, internal inflammation, pregnancy disorders
Circulatory	Haemorrhoids, varicose veins
Hearing loss	Hearing loss due to noise exposure can be increased by simultaneous exposure to vibrations.

Many studies demonstrate the exposure of maintenance workers to vibrations. In particular these studies highlight the risk from machinery used during the maintenance of roads, bridges and tunnels. The main conclusions of a study conducted in the Asturias region of Spain were that [33]:

- in almost all civil engineering machines, vibration levels exceeded the action level fixed by Council Directive 2002/44/EC [34] at 0.5 m/s2 for an eight daily hours reference period;
- in some of the machines, measured vibration values were higher on the seat than on the base.

A study [35] based on a systematic literature review to assess risk factors for carpal tunnel syndrome (CTS) summarised 38 primary reports, with analyses based either on a comparison of job titles (22) or of physical activities in the job (13) or both (3). The study found:

- reasonable evidence that regular and prolonged use of hand-held vibratory tools increases the risk of CTS two-fold;
- substantial evidence for similar or even higher risks from prolonged and highly repetitious flexion and extension of the wrist, especially when allied with a forceful grip.

3.1.3. Heat atmosphere

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Studies show the particular hazard of maintenance workers in nuclear power stations due to their exposure to heat [36]. The hazard is particularly present in maintenance operations during the nuclear reactor rundown. The circuit is then under high temperature (300ºC) and pressure (150 bar). Work teams are normally made up of two operators; one takes the necessary measurements in a different circuit and the other notes the results [36].

A 1992 study examined a case of heat exposure in an aluminium foundry [37].

The maintenance worker's task consisted of lifting the aluminium ingots with a shovel and throwing them into basket.

The height to which the ingots were removed from their moulds and collected by the shovel was approximately 90 cm. The basket where the ingots were thrown was placed to the right of the worker. The authors concluded that this was a pure maintenance task where the thermal strain was linked to the radiating temperature of the ingots, placed first on the chain and then in the basket [37].

3.1.4. Radiation

Radiation is a method of transmitting energy, which when interacting with matter, can alter it. Health effects can occur when this interaction affects human organs, and will depend on the radiation type and its intensity [38].

According to their energy level, radiations can be classified as **not ionising** or **ionising.** Not all ionising radiations have less energy than ionising radiations; nevertheless they can also have negative effects on human health (see Table 13).

Table 13: Examples of disorders caused by exposure to non-ionising radiation [27]

Type of radiation	Symptoms
Ultraviolet (UV)	Erythema, conjunctivitis and, in the long term, skin cancer
Visible and infrared	Thermal effects: irradiated surface warming
	Ocular injuries: corneal and retina injuries
Laser	Ocular and skin effects depending on the power severity, duration and wavelength of the laser source
Microwave and radiofrequency	Thermal effects: internal organs warming. Stronger effects in organs with low vascularisation
	Non-thermal effects: interference with biological membranes and bioelectrical activities (EEG, EMG); genetic transmission disorders; interference with pacemakers.
Magnetic and static electrical fields and extremely low frequency (ELF) radiation (>30 kHz)	Photosensitivity Some studies link exposure to these types of radiation to certain types of cancer, but evidence is not conclusive

The energy of ionising radiation is high enough to wrench electrons from the orbits of atoms, causing their ionisation. Such radiation is classified as α, β, γ and X-ray. Biological cellular damage is due to the action of the ionising radiation on DNA molecules. Radiation can produce fragmentations in DNA molecules, leading to chromosomal aberrations and even cellular death. It can also transform the chemical structure of molecules, causing mutations that affect the genetic message. Damages are unspecific and can be somatic (affecting the individual) or genetic (affecting offspring). Effects can appear immediately after exposure (immediate effects) or after a period of time (deferred effects) [27, 38].

Studies indicate that some maintenance workers (e.g. welders) are particularly at risk of radiation. Arc welders are exposed to ultraviolet and visible light from the electric arc. The personal UV radiation exposure levels of a group of welders and nearby workers were estimated in a research using a photosensitive polymer film, polysulphone [39]. The polysulphone film was attached to the inner and outer surfaces of eye protection, the workers' clothing, and also placed throughout the work area. The estimated average ocular exposures (inside the helmets) for welders and boilermakers were between four and five times the maximum permissible exposure (MPE) limit and the estimated exposures at the spectacles of non-welders were around nine times MPE. Body exposures (at the clothing surface)

for welders were estimated to be around 3,000 times MPE and for non-welders around 13 times MPE. The ambient UV radiation levels in the factory were found to exceed the MPE by an average of 5.5 times, even in non-welding areas. The results suggest that [39]:

- welders require additional ocular protection to supplement conventional welding helmets;
- any exposed skin areas of workers in this environment should also be protected.

It has also been shown that the interaction of the arc and the metal being welded generates UV radiation, metallic oxides, fumes and gases [40].

Incorporation of radioactive elements to some welding sticks additionally puts workers at risk of cancer due to their exposure to ionising radiation [41]. The risks of cancer due to exposure to radiation are the subject of many epidemiological studies, especially in workers in the nuclear industry. In a cohort of 4,563 nuclear workers followed retrospectively from 1950 to 1994, one study found that the age at exposure modified the effects of external radiation dose on cancer mortality [42]. After adjustment for confounding factors, it was found that workers exposed to external radiation after the age of 50 years experienced exposure-related elevations in mortality from cancer at any site, with radiosensitive solid cancer and lung cancer substantially greater than seen in co-workers exposed at all earlier ages. In contrast, all the radiation doses contributing to mortality from cancers of the blood and lymph system were received before the age of 50 [42]. The results for cancer of any site from this study were considered consistent with the results of previous studies examining the effects of exposure age in nuclear workers. Thus, in the opinion of the authors, the effects of low-level radiation doses may depend on exposure age, and furthermore, patterns of effect modification by age may differ by type of cancer [49].

Much attention has been paid to the health effects of exposure to electromagnetic fields. One study examined exposure to magnetic fields of maintenance workers on electrified railway lines [43]. The maintenance of radiotelephony antenna may also be a source of exposure to electromagnetic fields [44,45].

3.1.5. Exposure to physical hazards among Spanish maintenance workers

An analysis of the results of the Spanish National Survey of Working Conditions [46] revealed some interesting data on the exposure to physical hazards among Spanish maintenance workers. The general sample of the survey, made up of 11,073 workers, represented all occupations and all economic activities.

For this project, two groups were created from the sample in order to exploit the data:

- maintenance workers (n = 1,280);
- other workers in the sample (n = 9,793).

The following occupations were considered as related to maintenance:

- bricklayer or bricklayer's mate (n = 626);
- painter, varnisher/lacquerer, paperhanger (n = 114);
- plumber, heating operator (n = 68);
- electrician (n = 138);
- parquetry worker, tile or floor layer, glazier, roofer, installer of insulating material, installer of air conditioning (n = 112);
- cleaners of building façades (n = 6);
- machinist, machine adjuster (n = 164);
- electrical or electronic equipment repairer (n = 52).

The results (see Figure 2) indicate higher exposure of maintenance workers to:

- loud noise (16% vs. 8%);

- very loud noise (3% vs. 2%);
- hand–arm vibrations (24% vs. 9%);
- whole-body vibrations (12% vs. 5%);
- radiation – UV light (8% vs. 4%);
- radiation – radiofrequencies (4% vs. 2%).

As shown in Figure 3, maintenance workers are also more exposed to:

- heat in summer (44% vs. 19%);
- cold in winter (44% vs.17%);
- very humid atmospheres (25% vs. 13%);
- very dry atmospheres (5% vs. 4%)

Figure 2: Exposure to noise, vibration and radiation among Spanish maintenance workers, 2007 [46]

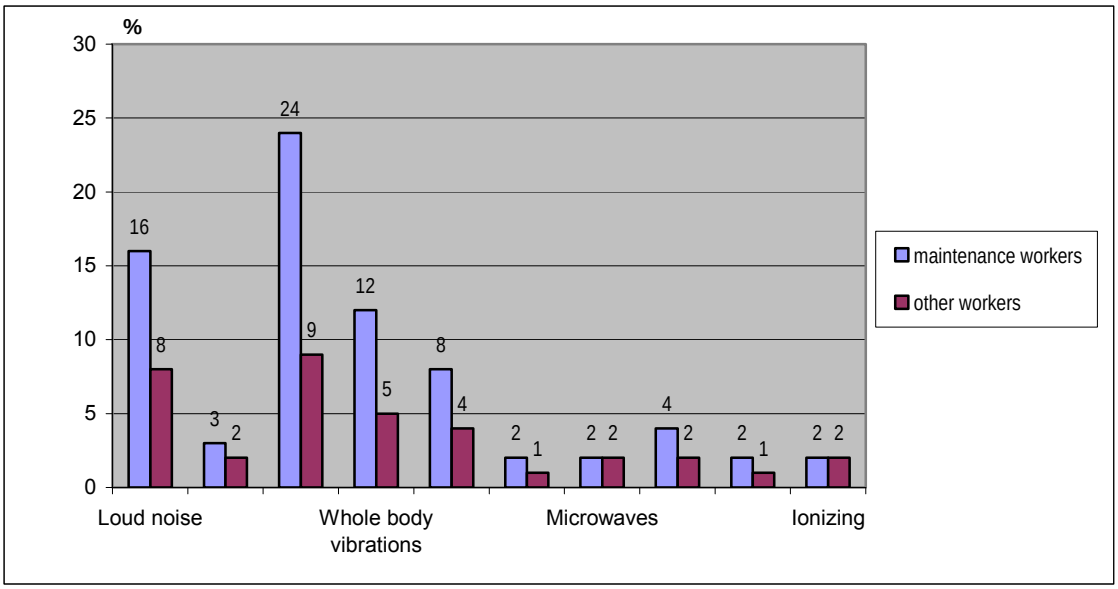
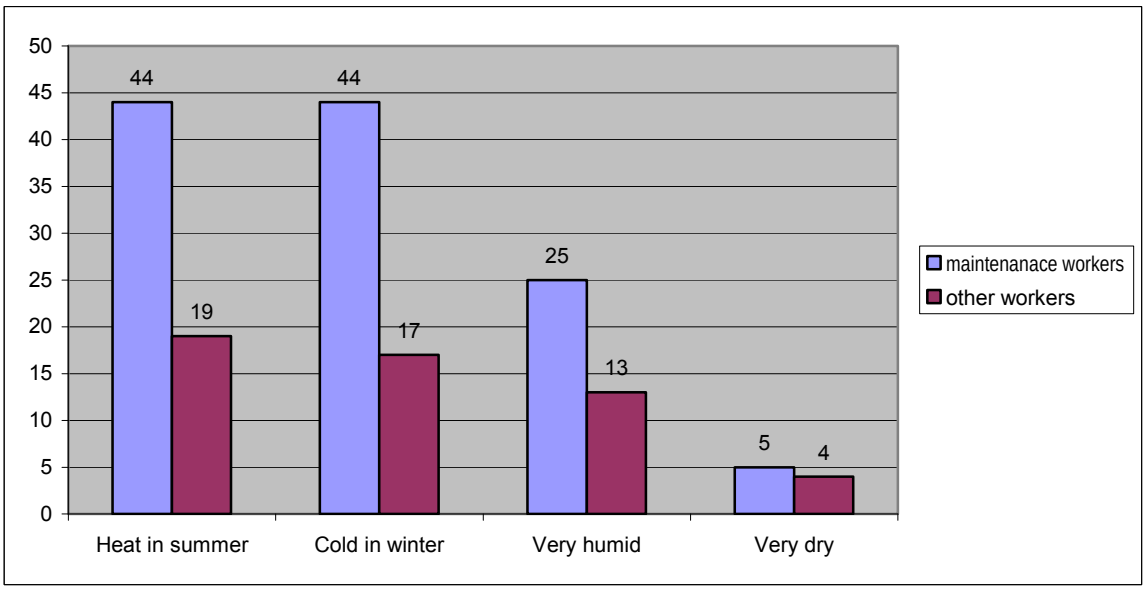


Figure 3: Exposure to cold, hot, and humid environment among Spanish maintenance workers, 2007 [46]



3.2. Physical workload

Maintenance workers often perform physically demanding work which causes high strain on the limbs and the back. Movements that cause this job to be strenuous include:

- carrying and placing heavy materials;
- bending;
- kneeling;
- reaching;
- pushing and pulling;
- working in small spaces;
- maintaining the arms in the air;
- twisting position.

Examples identified by Prevent (Belgian Institute for Prevention and Well-being at Work)[7] of activities that can lead to possible back problems or upper limb disorders include:

- lifting loads (e.g. parts of machines, tools, equipment) in awkward postures due to bad design (parts not in reach, lack of access or space to move, working under knee height or above shoulders). Maintenance tasks are often unexpected or infrequent so that no lifting devices are provided to help maintenance staff – maintenance staff often receive no help from colleagues to lift heavy loads, or to hold or manipulate parts of machines;
- carrying (heavy) loads on stairs or in narrow spaces;
- repetitive movements due to locking and unlocking screws;
- tasks where tools or parts of the installation have to be held for a certain period of time, which can lead to serious static muscular workload and local fatigue;
- unexpected physical risks due to situations where the operators are not familiar with the movements or need force to manipulate or lift parts of machines, installations, etc;
- working in narrow spaces, on slippery floors, with cables, steps, working at height;
- use of tools with a non-ergonomic design.

Musculoskeletal disorders (MSDs) are frequents among ship maintenance workers performing various manual operations such as sandblasting, high-pressure water cleaning and spray painting [47]. Back pain accompanying improper biomechanics is observed also among automobile body repair shop workers [48].

Analysis of a number of reported work-related musculoskeletal disorders and risk factors among workers in Norway's offshore petroleum industry from 1992 to 2003 found that 53% of the disorders were upper limb disorders, 20% back disorders and 16% lower limb disorders [49]. Of all the cases analysed, 40% were maintenance workers. Among these workers, upper limb and back problems were the most frequently reported, mainly because of high physical workload and repetitive work [49].

Useful information about the risks faced by a range of professions encountered in the construction industry is available on the website of the Dutch organisation, Arbouw.[8]

Arbouw reports that 70% of workers who repair concrete found their job physically demanding; 27% complained about often being tired. Standing up (19%), working in the same position (34%) and bending regularly (35%) were especially mentioned as being hard; lugging material, hacking, drilling and beaming were also considered hard. Among workers who maintain machines, about 52% reported that the work is hard [50]. Lifting the tools, placing and lifting machine parts, pushing and

[7] http://www.prevent.be
[8] http://www.arbouw.nl/werknemer/beroepen-en-risicos/

pulling during screwing down, and unscrewing machine parts are all activities during which workers are exposed to high physical strain. Workers often have to work on machines with difficult access, usually in awkward body positions [50].

Workers maintaining sewers complained about bending regularly (37%), problems with their back (45%), arms (45%), legs (39%), knees (27%) and wrists, hands and fingers (22%). Almost all (97%) of these workers stated that their work was very physically demanding [51]. The motional space is very small, causing them to work in forced body positions and therefore the static strain is very high. When descending to the sewer and leaving it, workers have to climb and clamber which produces additional strain [51].

About 51% of maintenance painters believed their work is physically hard and 21% reported often being tired. Painters suffer especially from having to stand up for long periods (22%), working in the same position for a long time (28%), and bending regularly (25%). There were also a lot of complaints concerning the muscles and joints in the neck (27%), back (38%), shoulders (27%) and knees (24%) [52]. Removing old paint and polishing the surface is heavy on hands, arms, shoulders, back and neck, especially when working near the ground or above eye level. Twisting, bending and kneeling are also very frequent during maintenance painting work [52].

Work was reported as physically strenuous (especially on the back) by 50–60% of workers positioning rails on railway lines. When trains are approaching, workers need to replace materials and tools very quickly, which produces an additional strain on the body [53]. Two-thirds (66%) of carpenters performing maintenance and reparation work reported that their work is physically demanding; bending regularly was especially found to be annoying (24%) [54]. Carpenters often have to work above eye level, kneeling, bending, and twisting, and in small spaces and on slanting roofs. Supplying, placing and assembling heavy pieces are tasks also considered very strenuous [54].

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Results from the French SUMER 2003 survey [14] also indicate high exposure to physical load, particularly to postural and joint constraints (see Table 14).

The proportion of maintenance workers who reported being exposed to such constraints is higher than that observed for all the professional families (87% vs. 72%). This trend can be observed for each of the three maintenance professional families featuring in the survey, but particularly for skilled maintenance workers and automotive repair workers.

Table 14: Percentage of maintenance employees reporting being exposed to postural and joint constraints, SUMER 2003 survey [14]

Type of constraint	Skilled maintenance workers	Automotive repair workers	Maintenance and organisation technicians and supervisors	Total maintenance domain*	Total of all the professional families
Postural and joint constraints (all)	**93.8%**	**98.1%**	**76.1%**	**87.16%**	**71.80%**
Standing position or standing about	73.3%	87.8%	50.4%	66.74%	48.90%
Displacement of feet during work	75.0%	69.6%	56.5%	65.81%	43.50%
Kneeling position	55.7%	75.0%	30.4%	49.19%	14.90%
Fixed position of the head and neck	23.6%	25.4%	24.2%	24.27%	22.50%
Maintaining the arms in the air	45.7%	65.1%	2.5%	40.12%	15.20%
Other postural constraints (e.g. squatting or twisting position)	61.1%	81.2%	36.8%	55.21%	24.90%
Highly repetitive gesture	10.6%	16.9%	6.4%	10.22%	16.90%
Number	304,600	202,000	382,800	889,400	17,334,200

* Data recalculated by taking into account the numbers of each of the three maintenance professional families.

These results suggest that:

- the majority of those examined in the survey are subject to the postural and joint constraints to which maintenance staff are subjected, i.e. standing position and standing about; displacement of feet; kneeling position; fixed position of the head and neck; maintaining the arms in the air; other postural constraints (e.g. squatting or twisting position);
- the proportion of maintenance employees who stated being exposed to these constraints is, for almost all of them, much higher than that observed for all employees. Highly repetitive gestures are the only constraint for which a lower percentage for maintenance staff than all the employees is observed;
- particular constraints affecting maintenance employees that are more numerous than all the professional families are as follows:
- kneeling position (almost half of these employees vs. 15% of all the professional families);
- maintaining the arms in the air (more than 2.5 times more statements for maintenance employees);
- other postural constraints (e.g. squatting or twisting position) were reported over two times more often among maintenance employees (55% vs. 25%);
- displacement of feet while working (66% vs. 44%).

These trends are observed for each of the three maintenance professional families, and more particularly for skilled automotive workers, followed by skilled maintenance workers.

Table 15 shows the ratios of maintenance employees who reported in the SUMER 2003 survey [14] being exposed to constraints related to the manual handling of loads during their last week of work. More than half of the maintenance employees (55%) stated that they handled loads manually, whereas the corresponding percentage for all the professional families is 43%. The professional family of maintenance and organisation technicians and supervisors does not differ greatly from that observed for the professional families as a whole. On the other hand, automotive repair workers (68%), and to a lesser degree skilled maintenance workers (63%), are more often exposed to this type of constraint compared with all salaried employees surveyed (43%).

Table 15: Percentage of maintenance employees reporting being exposed to constraints related to the manual handling of loads, SUMER 2003 survey [14]

Exposure	Skilled maintenance workers	Automotive repair workers	Maintenance and organisation technicians and supervisors	Total maintenance domain *	Total of all the professional families
Manual handling of loads	63.0%	67.9%	40.8%	54.56%	42.8%
Numbers	304,600	202,000	382,800	889,400	17,334,200

* Data recalculated by taking into account the numbers of each of the three maintenance professional families.

3.3. Chemical hazards

3.3.1. Work with asbestos

Even though use of asbestos is prohibited, exposure to asbestos during maintenance work is still highly possible. Studies show that nowadays the highest level of exposure to asbestos may happen during maintenance activities. Typical activities by craftsmen include removal of floor covering with asbestos-containing backings or the removal of friction linings [55].

Asbestos has been widely used due to its physicochemical properties which make it highly resistant to fire, alkali and acid, and very suitable as a thermal and acoustic insulating material. Examples of its widespread use in the construction industry include [56]:

- as protection against fire in metal structures;
- in acoustic panels;
- in thermal insulation of pipelines;
- in the manufacture of tiles;
- in pipes made of cement-asbestos;
- in paint, asphalts and putties.

Asbestos has also been used as an insulating material in ships, train coaches, aeroplanes, thermal and nuclear plants, in domestic appliances, in boilers and pipelines, and in a multitude of other applications [56].

Some varieties of asbestos, principally chrysotile asbestos, can be woven. This feature has enabled the use of asbestos fabrics in fireproof curtains, insulating suits, fire extinction hoses and gloves. This means that, although the asbestos is not used in the production process itself, it may be found as a part of the building material, structure, devices or facilities.

Whenever it is necessary to carry out demolition, rehabilitation, maintenance, repair and other operations that imply manipulation of asbestos materials, there are hazards for workers' health. The design and application of a specific work plan to protect workers is obligatory [57, 58].

Specific operations generating a risk for maintenance workers include:

- demolition of structures where asbestos is present and their refurbishment;
- works and operations designed to remove asbestos or those involving materials, buildings, structures, devices and facilities that contain asbestos;
- disposal of ships or units in which asbestos materials are present;
- maintenance and repair work in buildings, facilities or units in which there is a risk of releasing asbestos fibres.

Maintenance operations in which asbestos fibres might be released are as follows:

- **Working on sprayed asbestos or thermal insulation materials**: maintenance work in places containing sprayed asbestos (electricity, heating, air conditioning, plumbing, placement or retreat of false roofs, etc.) where piercing and scraping operations are performed, or there is a possibility of contact with sprayed asbestos;
- Working on materials that contain asbestos:
- Asbestos board: operations involving partial placement, cutting and mechanisation of the fireproof plates of false roofs made of asbestos or which contain asbestos, etc.
- Coatings: maintenance and renovation works in places where adhesives/plasters containing asbestos are present (e.g. preparation of supports, sanding, piercing, demolition of partitions);
- Jointing and filters: disassembly or jointing (plumbing, heating) by scraping off, brushing, sanding, etc.
- Friction products: interventions on friction linings (brakes, clutches) such as dusting, removing, machining (sawing, rectifying, piercing, sanding) and assembling;

- **Working with and manipulation of woven asbestos**: intervention (placement, cutting, elimination) on asbestos ribbons, cords or plaiting asbestos, etc.
- Working on elements of asbestos:
- Cement: repair of roofs and other elements constructed of asbestos, which implies operations such as cutting, slicing, piercing and sanding;
- Diverse work including the storage and manipulation of asbestos:
- Storage, maintenance and transport of objects containing asbestos;
- Transport, storage and elimination of the waste containing asbestos.
- Cleaning activities (i.e. maintenance of equipment used to work with asbestos).

Epidemiological data prove that there has been, and may continue to be, a significant risk to maintenance workers who come in contact with asbestos-containing materials (ACM) through their work. The sampling and assessment of the exposure of maintenance workers is a particular problem because they may not know that they are working with ACM. In a study among industrial plumbers in the UK, their awareness of working with asbestos was investigated and compared with the monitored, actual level of exposure. The results showed that workers' expectations and awareness of work with asbestos were far lower than found during monitoring [59, 60].

Studies have been also carried out to evaluate the respiratory effects on maintenance workers of asbestos exposure. For example, it has been shown that asbestos exposure of custodians and maintenance employees in buildings with friable asbestos-containing materials might be associated with a frequency of pleural thickening as seen on chest X-rays [61].

A series of studies have analysed the exposure of car mechanics to asbestos:

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One such study [62] presents a historical analysis of published data regarding the exposure of brake mechanics to asbestos as a result of carrying out their work. Concerns about this possible hazard were first raised in the late 1960s. This analysis focused on 30 years of data collected during the repair of car brakes and eight-hour time-weighted average (TWA) personal samples. Nearly 200 jobs and eight-hour TWA airborne asbestos samples were analysed to assess how asbestos concentrations varied by:

- type of vehicle serviced;
- country in which the mechanics worked;
- time period;
- brake cleaning method used.

Based on the results from this analysis, it seems that mechanics repairing brakes from heavy trucks and buses experienced higher daily asbestos exposures than automobile and light truck mechanics. The increased use of brake dust control measures in some garages resulted in at least a 10-fold decrease in the TWA airborne concentrations of asbestos from the 1970s to the late 1980s [62].

3.3.2. Working in confined spaces

A ‘confined space’ means an enclosed or partially enclosed space that is at atmospheric pressure when anyone is in the space. There could have restricted entry to, or exit from, this space, and although it is not intended or designed primarily as a workplace, it is likely to be entered by someone to work. A confined space at any time contains, or is likely to contain, any of the following [63]:

- an atmosphere that has potentially harmful levels of a contaminant;
- an atmosphere that does not have a safe oxygen level;
- anything that could cause engulfment.

Examples of confined spaces include [63]:

- storage tanks, tank cars, process vessels, pressure vessels, boilers, silos and other tank-like compartments;
- pits and degreasers;
- pipes, sewers, sewer pump stations including wet and dry wells, shafts and ducts;
- shipboard spaces entered through small hatchways or access points, cargo tanks, cellular double bottom tanks, duct keels, ballast or oil tanks and void spaces.

The presence of gases and toxic vapours in confined spaces makes the atmosphere very dangerous for workers’ health. Gases such as carbon disulphide, carbon monoxide, hydrogen cyanide or hydrogen sulphide combined with lack of oxygen might be a cause of death. A study of construction poisoning fatalities from 1990 to 1999 found that majority of the cases occurred in confined spaces [64].

Accidents in confined spaces are generally characterised by the presence of two factors:

- an ignorance of the risks present in the workplace and during the accomplishment of the work by those in charge of the work;

- a lack of communication between production and maintenance departments.

Some work practices inside confined spaces may also generate risks [65].

3.3.3. Welding work

Maintenance workers involved in electrical arc welding are at risk of inhalation of the smoke and toxic gases produced by the electrical arc. The inhalation is variable depending on the type of the electrode coating or protective gas, and on the base or contribution materials. Workers can be exposed to metal fumes (oxides of iron, chrome, manganese, copper, etc.) and gases (oxides of carbon, of nitrogen, etc.). Phosgene poisoning can also occur when welding works are carried out in the proximities of degreasing tanks with chlorinated products or on humid pieces with the above mentioned products [66].

One study was unable to prove a clear relationship between exposure to welding fumes and lung cancer, but welders with the longest experience had a relative risk of 1.9 for lung cancer [67]. Another study sought to determine the prevalence of coexisting welding related systemic symptoms indicative of metal fume fever (MFF) and welding related respiratory symptoms suggestive of occupational asthma (OA) in a sample of welders, and the strength and significance of any association between these two groups of symptoms [68]. The authors concluded that there is a strong association between welding related MFF and welding related respiratory symptoms suggestive of OA. As such, MFF could be viewed as a pre-marker of welding related OA (a hypothesis which requires further investigation) [68]. Occupational exposure to welding fumes among welders disturbs the homeostasis of trace elements in systemic circulation and induces oxidative stress [69].

3.3.4. Maintenance of public swimming pools

Maintenance personnel at swimming pools are exposed during their work by inhalation or by skin contact to a series of chemical products. There are risks of inhalation of chlorine, ozone and substances released by reaction between the chemical agents added to the water of the swimming pool (principally disinfectants) and organic matter (of human origin) [70,71]. Relatively high concentrations of trihalomethanes (THMs) have been found in some indoor swimming pools in London [72]. Another study observed an excessive risk of respiratory symptoms indicative of asthma among swimming pool workers [73].

3.3.5. Working in car repair shops

The main chemical risks for workers carrying out maintenance in car repair shops are [74–76]:

- inhalation of irritating gases and welding fumes derived from the application of blowpipes to metallic surfaces with surface treatment;
- inhalation/skin contact of vapours from spray painting, e.g. organic solvents, isocyanates;
- inhalation of dust during sanding;
- inhalation of asbestos fibres (see section 3.3.1) in operations such as maintenance of brake shoes and wheel removal;
- contact with oils and greases in mechanical repairs;
- inhalation of petrol fumes during mechanical repairs;
- inhalation of exhaust gases, especially carbon monoxide and diesel particulate matter during the running of Otto (four-stroke) and diesel engines respectively.

3.3.6. Maintenance work at solid waste treatment plants

Alongside the standard operations at solid waste treatment plants, there are supporting services such as maintenance and cleaning.

A transfer station is a site where solid wastes are collected and stored until they can be transported elsewhere for assessment or destruction, with or without prior segregation. The procedure at this type of facility consists of unloading waste from trucks, compressing it and then shipping the material to the corresponding treatment unit.

Maintenance work at transfer stations consists of maintaining the compression system, control panels and air ventilation filters [77]. A study to evaluate workers' exposure to dioxin-like substances[9] confirmed that workers may be exposed to these substances during the performance of cleaning operations at municipal solid waste (MSW) incinerators [78].

Maintenance workers at solid waste treatment plants can be exposed to:

- exhaust gases from vehicle engines (trucks and power shovels), especially in the unload zone;
- steam or harmful gases generated by waste materials accepted by those plants where waste entry is uncontrolled;
- toxic gases generated in certain work zones due to the use of products such as disinfectants and cleaning agents.

There is also exposure to waste itself during the maintenance of compression equipment and transfer lines and/or equipment.

3.3.7. Exposure to hazardous substances during maintenance of industrial installations

Workers may be exposed to dangerous substances during the maintenance of industrial installations either producing or applying chemical substances. Such exposure often happens when systems are opened.

The intake of the substances can occur through skin or respiration. For example, high exposure to chemical pollutants was reported during the shutdown of a plant synthesising toluene di-isocyanate (TDI) [79].

During maintenance work investigated by BAuA (German Federal Institute for Occupational Health and Safety) [80], the efficiency of protection barriers was found to decline when normally closed systems were opened. Workplace measurements (personal air sampling and stationary sampling) were also made. In relation to personal protective equipment (PPE), the quality of the equipment provided, sizing/fitting and the use of protective devices was recorded and assessed. The enterprises included in the investigation programme produced a range of chemicals such as chlorine, organic solvents and vinyl chloride.

The occupational exposure limits (OELs) were exceeded in about a quarter of the total of around 170 workplace measurements performed as part of the investigation programme. Most cases in which OELs were exceeded occurred during cleaning, followed by changing of fittings and valves, and other work at the opened system [80].

As well the respiratory exposure, the dermal route of exposure was also studied. In contrast to the normal operation mode, the dermal route exposure occurred to a larger extent during maintenance. In addition, PPE was incorrectly used in more than 75% of all cases. A special problem was repair work for which PPE was neither correctly provided nor fitted nor used [80].

3.3.8. Maintenance of buildings

Maintenance workers carrying out their job in public buildings built in the 1960s and 1970s might be affected by polychlorinated biphenyls (PCBs). These substances were used [81]:

- as isolating fluids in transformers and condensers;
- as a softening agent in plastics and joint packings;

[9] Polychlorinated dibenzo-*p*-dioxins (PCDDs), dibenzofurans (PCDFs) and polychlorinated biphenyls (PCBs)

- in ceiling linings;
- in cleaning cables;
- as flame retardants in wall paints, finishes, adhesives and hydraulic oils.

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PCBs are now classified as carcinogenic and have not been produced since 1983.

Formaldehyde (HCHO) is another chemical sometimes found in buildings. It is a toxic, colourless, flammable gas which is used in a manifold of ways. It can be found in, for example, glued products from derived timber products, insulating material, painting material, colours, finishes and parquet floor sealers

Formaldehyde is also present in glass and mineral wool, textiles and floor coverings [82].

Exposure to formaldehyde can lead to type-IV allergies and sensitisations among the workforce [81].

This in turn may lead to asthma, allergies, irritated mucous membranes and difficulty in breathing. Formaldehyde is categorised as carcinogenic by the World Health Organization (WHO). Under EU legislation it is categorised as a Category 3 carcinogen (Dangerous Substances Directive 67/548/EEC) [103].

3.3.9. Road maintenance

As well as exhaust fumes from traffic, road construction and maintenance workers are potentially exposed to a range of hazardous substances including [83]:

- asphalt fumes containing asphaltenes and polycyclic hydrocarbons (PAHs);
- carbon monoxide;
- diesel exhaust;
- organic solvents;
- biological agents;
- dust;
- herbicides;
- benzene;
- lead;
- silica;
- asbestos.

3.3.10. Exposure to chemical hazards among Spanish maintenance workers

The numbers and percentages of maintenance employees handling dangerous substances in the workplace and those exposed to vapours and fumes by inhalation relative to the remainder of workers are shown in Tables 16 and 17 respectively. These figures come from the Spanish National Survey of Working Conditions 2007 [46] (see section 3.1.5).

Table 16: Handling dangerous substances in the workplace, 2007 [46]

Rest				Maintenance workers			Total
				Industry	Construction	Services	
Handling dangerous substances in the workplace	Yes	N	1,571	109	237	33	1,950
		%	16.1%	43.3%	25.6%	31.1%	17.6%
	No	N	8,160	142	684	73	9,059
		%	83.5%	56.3%	74.0%	68.9%	81.9%
	NS *	N	32	1	2	0	35
		%	0.3%	0.4%	0.2%	0.0%	0.3%
	NR **	N	10	0	1	0	11
		%	0.1%	0.0%	0.1%	0.0%	0.1%
Total		**N**	**9,773**	**252**	**924**	**106**	**11,055**
		%	**100%**	**100%**	**100%**	**100%**	**100%**

* Doesn't know.

** No response

Table 17: Inhalation of vapours and fumes in the workplace, 2007 [46]

Rest				Maintenance workers			Total
				Industry	Construction	Services	
Inhalation of vapours and fumes	Yes	N	1,682	145	462	33	2,322
		%	17.2%	57.5%	50.0%	31.4%	21.0%
	No	N	8,030	106	456	72	8,664
		%	82.2%	42.1%	49.4%	68.6%	78.4%
	NS *	N	34	0	5	0	39
		%	0.3%	0.0%	0.5%	0.0%	0.4%
	NR **	N	27	1	1	0	29
		%	0.3%	0.4%	0.1%	0.0%	0.3%
Total		**N**	**9,773**	**252**	**924**	**105**	**11,054**
		%	**100%**	**100%**	**100%**	**100%**	**100%**

* Doesn't know.

** No response

The data indicate higher exposure of maintenance workers to dangerous substances compared with other workers. Noteworthy figures are as follows:

- The percentage of maintenance employees stating that they handle dangerous substances in the workplace is almost twice that by the rest of workers as a whole in case of services (31% vs. 16%) and more than two times higher in case of industry (43% vs.16%).
- The percentage of maintenance employees exposed to vapours and fumes through inhalation in the workplace is almost two times higher than reported by the rest of workers as a whole in case of services (31% vs. 17 %), but three times higher and more in case of construction (50% vs. 17%) and industry (58% vs. 17%).

3.4. Biological hazards

Maintenance workers exposed to biological agents are those especially from the following sectors [84]:

- healthcare;
- waste management;
- agriculture;
- biotechnology;
- pharmacological plants;
- clinical, veterinary and diagnostic laboratories;
- swimming pools.

3.4.1. Legionella

Legionella is a gram-negative bacterium of which more than 48 species have been identified, including *Legionella pneumophila*. Ideal conditions for Legionella for reproduction are fresh or salt water, and a temperature between 25 and 50°C.

There is evidence that *Legionella pneumophila* can be spread at least 6 km from its source [85]. The uptake of Legionella via inhalation (aerosols) is harmful and causes legionellosis – either the more severe Legionnaires' disease or the milder Pontiac fever.

Water supply and building air conditioning systems are the two sources most frequently linked to epidemics caused by Legionella. Among them the following areas can be highlighted [86]:

- warm water distribution circuits;
- air conditioning and refrigeration towers;
- thermal waters in rehabilitation and play centres;
- medical equipment using aerosol-based therapeutics;
- decorative fountains.

Two cases of death due to Legionnaires' diseases on a ship were reported in 2001 [87]. The two mechanics had carried out maintenance work on the cargo ship, which had been moored up in Tunisia for two years; the origin of infection was probably a water pump that they repaired.

Cases of Pontiac fever due to maintenance of a steam turbine condenser have also been reported [87].

An outbreak of Pontiac fever occurred in 2000 among workers performing high pressure cleaning in a sugar beet plant [88].

Legionella has also been found in dental clinics. For example, 20% of the investigated technicians in a dental office in 1988 showed antibodies against *Legionella pneumophila* [89].

Legionellosis is also possible after changing filters contaminated with Legionella in cooling towers or air conditioning system. A study on a group of workers who became ill with fever and flu-like symptoms after repairing a decanter for sludge concentration at a sewage treatment plant during a hot and humid summer period concluded that the fever was caused by *L. pneumophila* emitted to the environment by the uncovered decanter [90].

3.4.2. Hepatitis A virus and Leptospira

Controversy exists on the possible exposure to hepatitis A virus (HAV) of maintenance workers at sewage treatment works. To assess whether the scientific literature supports the hypothesis that workers exposed to sewage are at higher risk of hepatitis A, all original papers describing

epidemiological studies examining on the risk of hepatitis A infection in workers exposed to sewage were reviewed [90]. This systematic review did not confirm an increased risk of clinical hepatitis A in workers exposed to sewage. An increased risk of subclinical hepatitis A (defined only by the presence of anti-HAV antibodies) cannot be excluded, but the association between being seropositive and exposure to sewage was not strong and became weaker still if publication bias was taken into account [90].

A study of the prevalence of *Leptospira interrogans* and HAV antibodies in serum samples from sewer workers and controls concluded that leptospirosis continues to be a problem to sewer workers but that hepatitis A is apparently no longer a risk [91]. The most likely explanation is that Leptospira are still abundant in the sewage system in contrast with HAV, which is only rarely found in sewage as a result of the general decline in the incidence of hepatitis A over the past three decades [91].

3.4.3. Maintenance work in water supply installations and wastewater treatment plants

Wastewater treatment plants employ physical, chemical and/or biological processes to remove contaminants. Workers can be exposed to a range of hazardous substances and biological agents from these processes. The composition of the microflora in wastewater treatment plants varies with respect to spectrum of species and wastewater concentration (factors such as microorganism input, chemical substances in the wastewater, climatic conditions and procedures influence these parameters) [93].

Factor analysis as part of a study to investigate work-related symptoms in workers at wastewater treatment plants yielded three clusters of correlated symptoms [94]:

- ‘lower respiratory and skin symptoms’;
- ‘flu-like and systemic symptoms’;
- ‘upper respiratory symptoms’.

Symptoms appeared to be more prevalent in workers exposed to endotoxin levels higher than 50 endotoxin units per m^3 (EU/m^3). A significant dose–response relationship was found for ‘lower respiratory and skin symptoms’ and ‘flu-like and systemic symptoms’. It was concluded that [94]:

- wastewater treatment workers reported a wide range of symptoms that may be work-related;
- microbial exposures including those to endotoxins seem to play a causal role.

3.4.4. Maintenance work in solid waste treatment plants

Workers in solid waste treatment plants can be exposed to a wide range of biological risks. Bacteria, fungi, spores, viruses, parasites as well as degradation products such as endotoxins occur as aerosols or biological agents that adhere to biodegradable waste. These agents may cause diverse respiratory diseases (allergies, bronchitis, severe diseases of the mucosa like organic dust toxic syndrome) but also hemorrhagic fevers, brucellosis, diphtheria, Q fever, tuberculosis, viral hepatitis, leprosy, bacterial dysentery, meningitis, and cholera [95,96].

3.4.5. Maintenance of public swimming pools

Workers can be exposed to different types of biological agents when maintaining swimming pools. The biological agents present in these humid environments include:

- Protozoa – these can be saprophyte (i.e. obtain nourishment from decomposing vegetables and animals) such as the paramecium, or parasites such as amoebae;
- Fungi (including moulds) – these proliferate in humid zones such as changing rooms, walls and floors, and can cause cutaneous or deep injuries;

- Bacteria – these multiply rapidly in cases of incorrect maintenance of the swimming pool and they may cause infectious diseases such as legionellosis;
- Viruses – in this case, there are major risks from poliomyelitis and those viruses causing plantar warts.

3.4.6. Maintenance of public buildings – exposure to pigeon droppings and moulds

Pigeons are present everywhere in urban surroundings. An analysis in 1997 of the number of pigeons in several German cities gave the estimated pigeon population in, for example, Berlin or Munich as around 40,000. Each pigeon produces about 2.5 kg of dry droppings per year, making a total of 100 tons each year in a city like Berlin or Munich. The droppings damage stone and steel constructions (buildings, bridges) [97]. Furthermore, they may contain microorganisms such as bacteria (e.g. *Campylobacter jejuni*, *Salmonella enteritidis*, *Clamydophila psittaci*), yeasts (e.g. *Crytococcus neoformans*), fungi (e.g. *Histoplasma capsulatum*) and viruses, which are to some extent pathogenic for human beings. Infections might occur via oral (insufficient hygiene), airways or skin/mucosa path of infection [98].

For maintenance activities cleaning of contaminated parts is necessary. In doing so, dust and liquid aerosols are produced, which might be taken up via different paths [98]. However, the contamination of dropping with microorganisms is, in the majority of cases, unknown [99]. Appropriate measures are therefore necessary to minimise exposure to these biological agents.

Moulds and their spores can generally be regarded as natural components of the environment. However, moulds producing toxic substances such as carcinogenic mycotoxins can be released indoors and reach the air via the respiratory system, mouth, skin and mucous membranes. This is especially true for areas such as bathrooms, kitchens and basements [100]. Moulds grow by degrading nutrients from organic substrates such as wood and wood products, fabrics, foodstuffs, plants and plant debris, and soil [101].

Workers may be exposed to moulds in any indoor workplace (offices, schools, hospitals, other public buildings). High exposure to moulds is especially observed among construction workers, in solid waste or wastewater treatment plants, in cotton mills, and in agriculture. Health effects include [101]:

- asthma, or exacerbation of asthma in a mould-sensitive asthmatic;
- allergic diseases;
- increased rates for upper respiratory disease;
- infection (people with suppressed immune system are especially susceptible to fungal infections);
- nose, throat or eye irritation;
- runny nose, cough, congestion, headache and flu-like symptoms;
- skin irritation.

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3.5. Psychosocial hazards

According to Prevent (Belgian Institute for Prevention and Well-being at Work), the following psychosocial issues may impose a problem for maintenance workers [102]:

- Complex problems have to be solved under time pressure. During maintenance work, the productivity of an organisation is cut back. There is an urgency to restart activities as soon as possible because production has to go on and people are waiting to resume their work. This can put a lot of pressure on maintenance workers, causing stress and increasing the probability of making mistakes and accidents [104]. In additionally, unfavourable working conditions such as, for example, excessive heat may increase the level of stress [105];
- Shift work, weekend work, night work, on-call work and irregular working hours can lead to stress, or mental health problems sleeping problems, fatigue, lack of work-life balance, obesity, etc. [106];
- Workers have to deal with complex problems in non-routine situations. Nowadays technologies are very complex and require specific knowledge by the workers who manipulate and repair them. Maintenance workers also often work on dangerous machines that do not have an adapted human-machine interface (e.g. information from displays is not clear, unreadable scales, controls not known or not in reach);
- Working with workers from contractors can lead to communication difficulties;
- Lone work/isolated work can lead to uncertainty and fear, lack of coaching and social support. When an accident happens, maintenance workers have to rely on their ability to help themselves. In case of serious accidents, it may take time until a colleague discovers the worker. When working alone, no-one knows where the worker is located exactly in the machine or installation. So if the nature, planning and location of the work are not well communicated to the operators, the chance of an accident is high;
- Exposure to unexpected/unknown safety and health risks;
- Maintenance activities can often be found at the bottom of the hierarchy in terms of respect, influence and authority (e.g. at nuclear power plants) [107–109]. Furthermore, maintenance work is often considered as mostly manual labour, which requires little or no mental work. This may give maintenance workers the impression that their work is not acknowledged enough, affecting job satisfaction and work-related stress.

3.5.1. Working time characteristics

With respect to working time characteristics (work duration, night work, flexibility of working hours, weekend work, etc.), the SUMER 2003 survey [14] in France did not highlight higher constraints for maintenance employees in comparison with professional families as a whole. However, examination of the survey's findings by this study (see Table 18) has revealed that:

- maintenance employees stated more frequently than the professional families as a whole that they had to stay available in case of emergency10 (24% vs. 11%). This is more particularly the case for skilled maintenance workers and for maintenance and organisation technicians and supervisors;
- the proportion of skilled maintenance workers (22%) and maintenance and organisation technicians and supervisors (15%) who work at night between midnight and 5 am is higher than that observed for the professional families as a whole (9%).

[10] Period of time (usually outside normal working hours) during which somebody has to remain fully available in case an event occurs; for example, a technician who is free to stay at home during the weekend (i.e. not working) but must nevertheless remain easily contactable and available in case an event requiring their attention occurs.

Table 18: Some characteristics of the working time of maintenance employees, SUMER 2003 survey [14]

Working time characteristic	Skilled maintenance workers	Automotive repair workers	Maintenance and organisation technicians and supervisors	Total maintenance domain *	Total of all the professional families
Availability in case of emergency	27.3%	12.2%	28.5%	24.39%	10.5%
Occasional night work (between midnight and 5am)	22.3%	_ **	15.2	_	9.3%
Numbers	304,600	202,000	382,800	889,400	17,334,200

* Data recalculated by taking into account the numbers of each of the three maintenance professional families.

** Insufficient numbers for significant statistical results.

3.5.2. Constraints related to pace of work

As shown in Table 21 with respect to constraints related to pace of work, the SUMER 2003 survey [14] in France highlights that:

- the proportion of maintenance employees who stated they had to abandon a task in order to undertake another unscheduled one was higher than that for the professional families as a whole (67% vs. 58%). This trend is particularly high for automotive repair workers (73%);
- the constraints related to pace of work were slightly higher for maintenance employees compared with all the salaried employees surveyed. The constraints also had the following elements:
- production standards or deadlines of one hour or more (27% vs. 20%);
- the need to answer outside requests that did not require an immediate answer (60% vs. 59%);
- the need to rotate around different workstations in order to overcome absences (31% vs. 27%).

Frequent work interruptions have also been shown to mainly concern operators whose function is related to maintenance [110] and are considered as a potential source of stress. The considerabletemporal constraints related to maintenance interventions and the time pressure generated by clients (e.g. in the case of subcontracted maintenance) may also increase stress levels [111].

Table 19: Constraints related to the pace of work of maintenance employees, SUMER 2003 survey [14]

Constraints related to pace of work	Skilled maintenance workers	Automotive repair workers	Maintenance and organisation technicians and supervisors	Total maintenance domain *	Total of all the professional families
Abandon a task to undertake another unscheduled one	66.1%	73.1%	65.2%	67.3%	58.10%

Constraints related to pace of work	Skilled maintenance workers	Automotive repair workers	Maintenance and organisation technicians and supervisors	Total maintenance domain *	Total of all the professional families
Outside request that does not require an immediate answer	53.9%	65%	62.5%	60.12%	58.9%
Production requirements or deadlines to achieve in one hour or more	27.2%	28.7%	25.1%	26.64%	19.9%
Rotate around different workstations in order to overcome absences	29.5%	29.9%	31.8%	30.58%	27.10%
Numbers	304,600	202,000	382,800	889,400	17,334,200

* Data recalculated by taking into account the numbers of each of the three maintenance professional families.

3.5.3. Job control and autonomy

With respect to work autonomy and job control (see Table 20), the results of the SUMER 2003 survey [14] in France show that:

- almost one third (32%) of maintenance employees stated that their work was subject to control or a computerised follow-up, whereas this percentage was 27% for the professional families as a whole;
- half of maintenance employees (51%) had to give a written account of their activities at least once a week, whereas the percentage required to do this for the salaried employees surveyed as a whole was 31%;
- a lower proportion of maintenance employees (7.5%) compared to the professional families as a whole (15%) stated that they were not in a position to modify the order of tasks to be accomplished.

Table 20: Some characteristics related to the autonomy and job control of maintenance employees, SUMER 2003 survey [14]

Characteristic of job control and autonomy	Skilled maintenance workers	Automotive repair workers	Maintenance and organisation technicians and supervisors	Total maintenance domain *	Total of all the professional families
Control or computerised follow-up of work	33.3%	20.6%	37.4%	32.18%	27.2%
Give a written account of activity at least once a week	59.3%	41.6%	49.2%	50.93%	30.8%

Characteristic of job control and autonomy	Skilled maintenance workers	Automotive repair workers	Maintenance and organisation technicians and supervisors	Total maintenance domain *	Total of all the professional families
Not being in a position to modify the order of tasks to be accomplished	6.5%	14.3%	4.8%	7.54%	14.8%
Numbers	304,600	202,000	382,800	889,400	17,334,200

* Data recalculated by taking into account the numbers of each of the three maintenance professional families.

The maintenance employees interviewed during the survey raised the question of difficulties related to inadequacies slightly more frequently than professional families as a whole:

- insufficient work information (22% vs. 19%);
- inadequate number of colleagues (27% vs. 26%);
- insufficient or inadequate materials (24% vs. 20%);
- insufficient training (24% vs. 20%).

3.5.4. Difficulties related to subcontracting maintenance

Subcontracting maintenance is often considered an aggravating factor in terms of safety and health [112–114].

Working away from one's usual place of work (e.g. at a customer's premises) or frequent changes of working environment may cause additional occupational hazards as 'employees have to adapt to different working environments, which has an impact on their exposure to occupational hazards, and they frequently travel from place to another, thereby subjecting themselves to road-related risks' [23].

The workplace diversity may increase health risks: 'subcontracting employees who intervene in facilities only from time to time are unable to manage their work environment like the permanent employees' [23].

The subcontracting of maintenance can also lead many subcontracting companies to operate simultaneously on sites where the conditions in terms of work organisation and time pressure are determined by the user company [23].

4. Outcomes related to occupational safety and health

4.1. Occupational accidents

Analyses of EUROSTAT data based on the 'European statistics on accidents and work' (ESAW) methodology [1] can help to identify accidents related to maintenance operations in a number of European countries.

Within the variable 'working process' used by ESAW to classify the causes and circumstances of accidents, it is possible to select four subcategories that are related to maintenance operations:

- setting up, preparation, installation, mounting, disassembling, dismantling;
- maintenance, repair, tuning, adjustment;
- cleaning working areas, machines (industrial or manual);

- monitoring, inspection of manufacturing procedures, working areas, means of transport, equipment (with or without monitoring equipment).

In this study, the number of accidents related to these subcategories was compared to the total number of accidents related to any other subcategory within 'working process'.

As shown in Table 21, the data show that the proportion of occupational accidents related to maintenance operations compared with total accidents was:

- 19–21% in Belgium (2005–2006);
- 18–19% in Finland (2003–2006);
- 14–17% in Spain (2003–2006);
- 10–14% in Italy (2003–2006).

In Austria (2003–2006), significantly fewer (3%) accidents related to maintenance.

Table 21: Number of occupational accidents related to maintenance activities in selected European countries (data from EUROSTAT)

		2003	2004	2005	2006
Spain	**Total**	792,565	766,460	780,433	769,657
	Maintenance operations	136,608 **17%**	107,068 **14%**	107,014 **14%**	105,886 **14%**
Belgium	**Total**	No data	No data	72,541	74,868
	Maintenance operations			15,292 **21%**	14,567 **19%**
Austria	**Total**	88,790	88,397	85,500	86,326
	Maintenance operations	3,002 **3%**	3,027 **3%**	2,808 **3%**	2,722 **3%**
Finland	**Total**	58,498	58,123	62,959	63,462
	Maintenance operations	11,103 **19%**	10,688 **18%**	11,810 **19%**	11,993 **19%**
Italy	**Total**	599,711	588,151	564,167	551,659
	Maintenance operations	60,856 **10%**	80,621 **14%**	72,458 **13%**	71,977 **13%**

4.1.1. Occupational accidents by seriousness

Data from a number of European countries indicate that around 10–15% of all fatal occupational accidents in 2006 were related to maintenance operations (see Figure 4).

The numbers of fatal accidents related to maintenance in selected European countries for period 2003–2006 are shown in Figure 5.

Figure 4: Fatal accidents related to maintenance operations in selected European countries, 2006 (data from EUROSTAT)

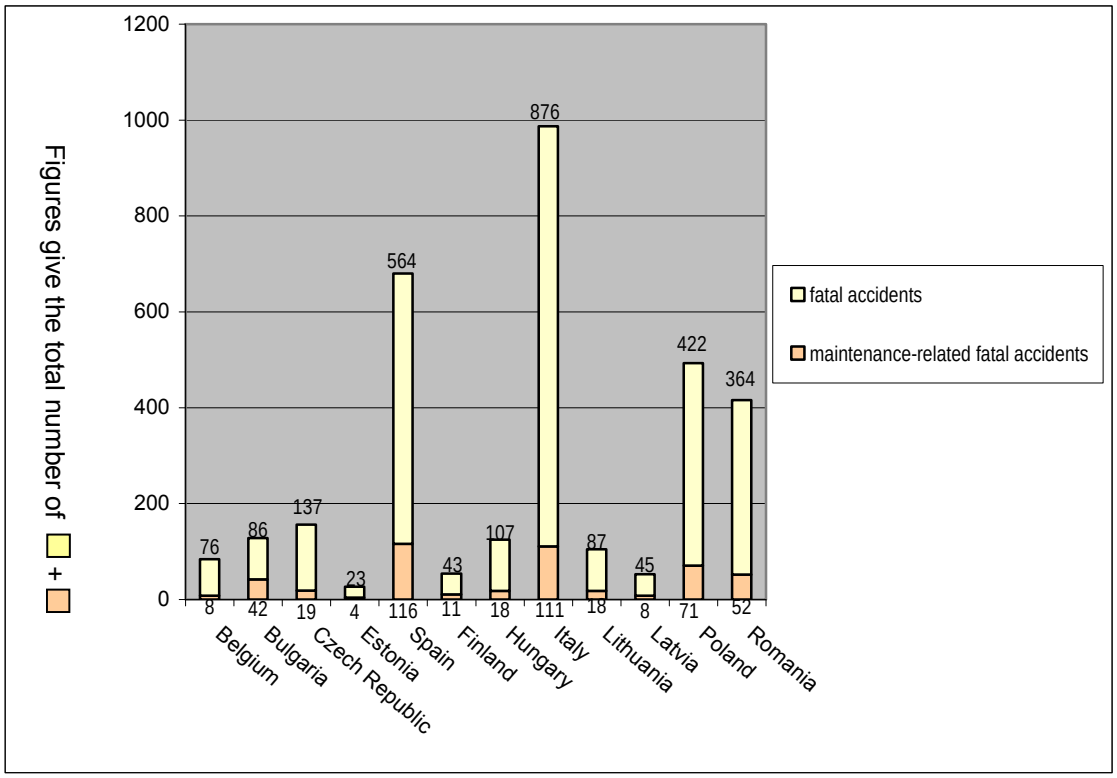
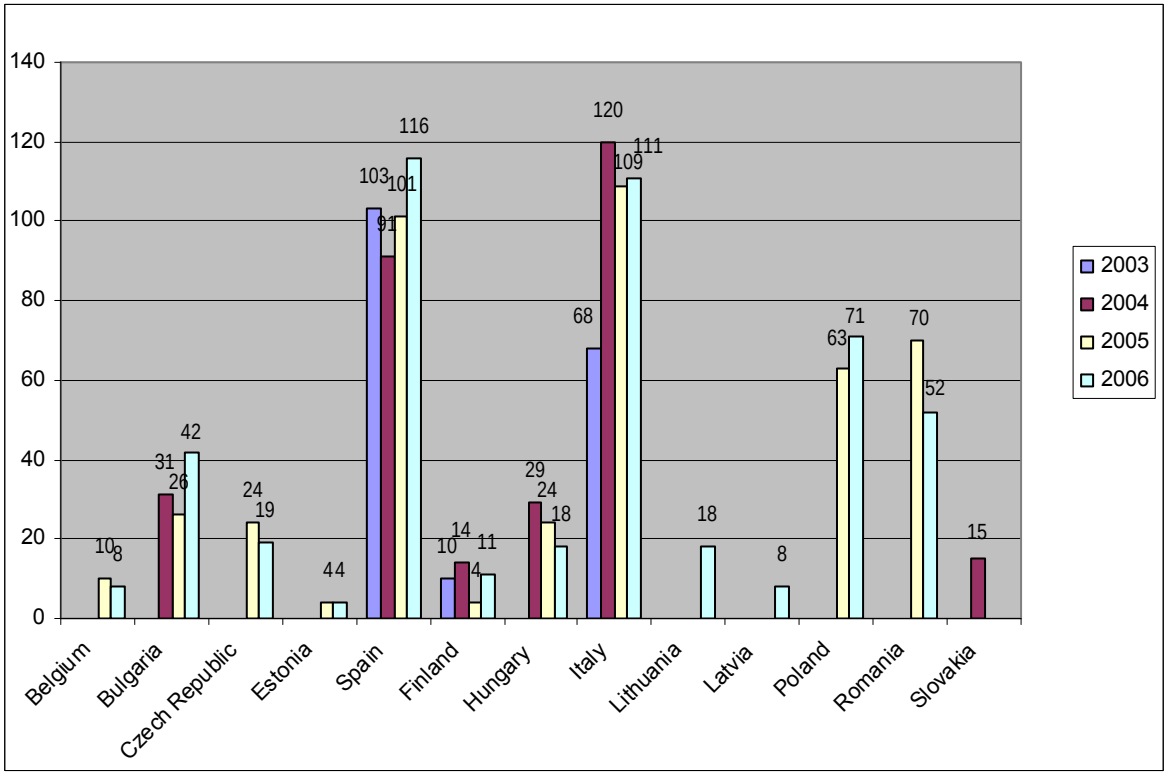
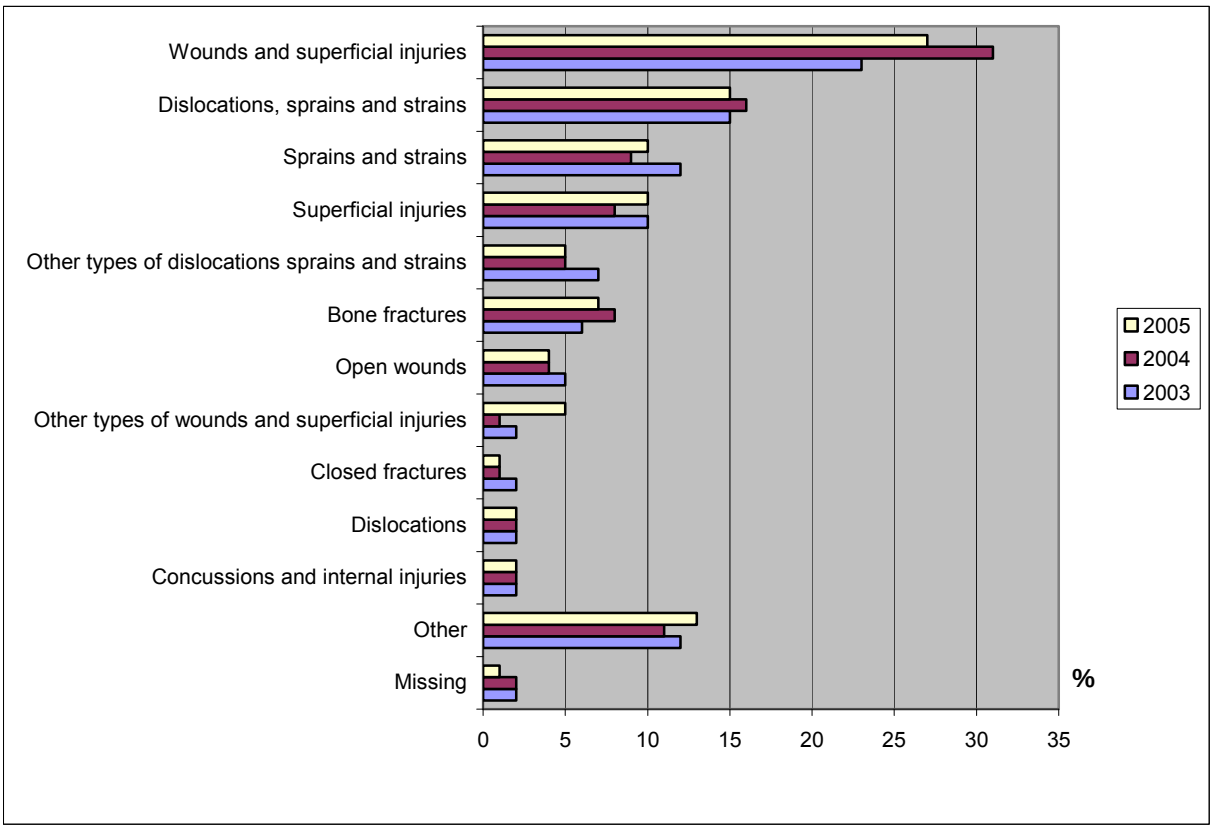


Figure 5: Fatal accidents related to maintenance operations in selected European countries, 2003–2006 (data from EUROSTAT)



According to the EUROSTAT data published in 2007, the most prevalent types of injuries stemming from maintenance-related accidents are wound and superficial injuries, dislocations, sprains and strains (see Figure 6)

Figure 6: Accidents related to maintenance operations and type of injury, 2003–2005 (data from EUROSTAT)



4.1.2. Reports of occupational accidents related to maintenance activities

An examination by HSE (Health and Safety Executive) of the 1,531 fatal occupational accidents in the United Kingdom between 1980 and 1982 from all sectors of activity taken together showed that 21% were related to maintenance [115]. A later HSE study of the 2,146 critical events in the chemical industry between 1982 and 1985 underscored the fact that about 30% (i.e. almost 700 critical events) were related to maintenance [116]; it was estimated that 125 people per year were injured fatally or otherwise in the chemical industry as a result of maintenance work [115,116].

A HSE study of 1,971 incidents occurring on drilling installations over a three-year period from 1989 to 1991 showed that 14.7% occurred during maintenance activities [117]. These kinds of accidents involved over 100 people per year (i.e. 326 fatal accidents in total or two fatal accidents per week) [117].

According to a Dutch study [118], about 38% of chemical accidents are caused by dangerous materials released from on-site plant taking place during maintenance. Similar percentages could be found with regard to accidents involving pipework failure in chemical plants originating in the maintenance phase of plant operations [119]. Moreover, examination of a French work accidents database (EPICEA) showed that 14% of all fatal accidents which occurred in 2000 and were recorded in the database were related to work equipment and machine maintenance [8].

A US study showed that maintenance employees figure highly in occupational accident statistics. An analysis carried out in a company manufacturing automotive components in Alabama revealed that the proportion of accidents of maintenance employees was, in absolute terms, much lower than that

of employees of two operational departments (14% vs. 27% and 18% respectively), but that this trend was reversed when numbers of accidents were related to the number of employees [120].

A study of 1,604 occupational injuries with sick leave occurring between January 1998 and December 1999 among approximately 20,000 male workers from the French railway, SNCF, showed that railway maintenance operators and mechanical maintenance operators received the most injuries of the sample [121].

Analyses of work accident records (accident claims and reports) in a company producing mechanical transport refrigeration units and another performing the after-sales service for these systems indicate that the maintenance workers are probably more frequently involved in accidents than all other types of employees [8].

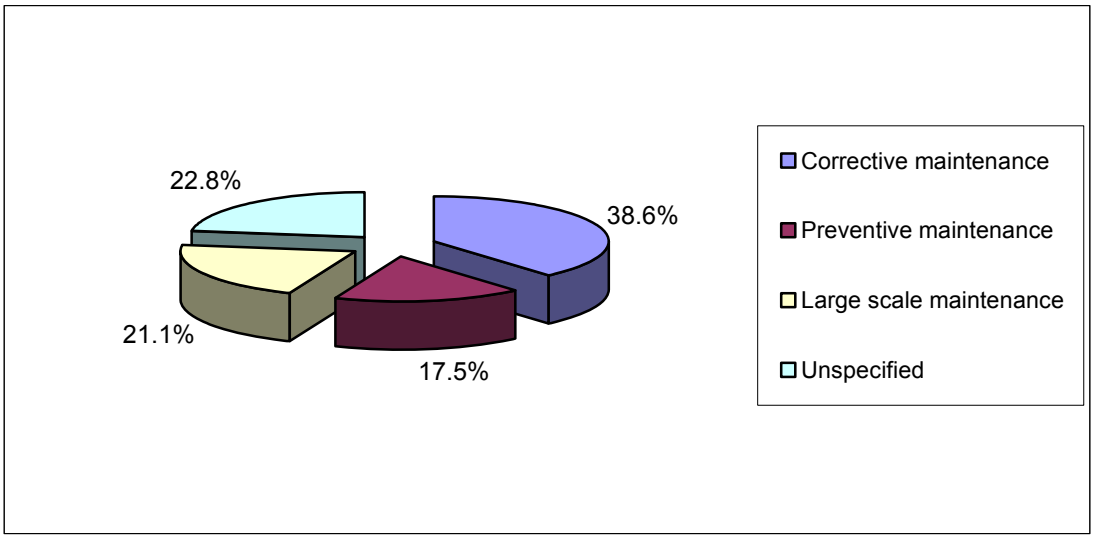
4.1.3. Occupational accidents by type of maintenance activity

The HSE analysis of 502 critical events related to maintenance in the chemical industry indicated that most of the critical events occurred during corrective maintenance activities [116]. This result underlined the findings of the earlier HSE review of the 106 work accidents related to the maintenance of work equipment and installations [115]:

- 66% of the occupational accidents occurred when a fault arose or a planned repair was carried out, i.e. during corrective maintenance activities;
- 25% of the occupational accidents occurred during cleaning activities;
- 9% of the occupational accidents occurred during examination or lubrication activities.

The French analysis of 57 accidents related to work equipment and machine maintenance [8] also found the highest proportion of the critical events (39%) occurred during corrective maintenance activities vs. 17.5% during preventive maintenance and 21% during large-scale maintenance (see Figure 7).

Figure 7: Distribution of 57 maintenance related accidents in France as a function of maintenance type [8]



According to the HSE study published in 1985 [115], accidents related to the maintenance of work equipment and installations as well as to the maintenance of roofs were the most numerous; the maintenance of work equipment and installations represented one third of all the fatal accidents and 19% of these accidents were related to the maintenance of roofs. A much more recent study indicated that numerous railway accidents and incidents were related to maintenance of equipment and to subcontracting maintenance [122].

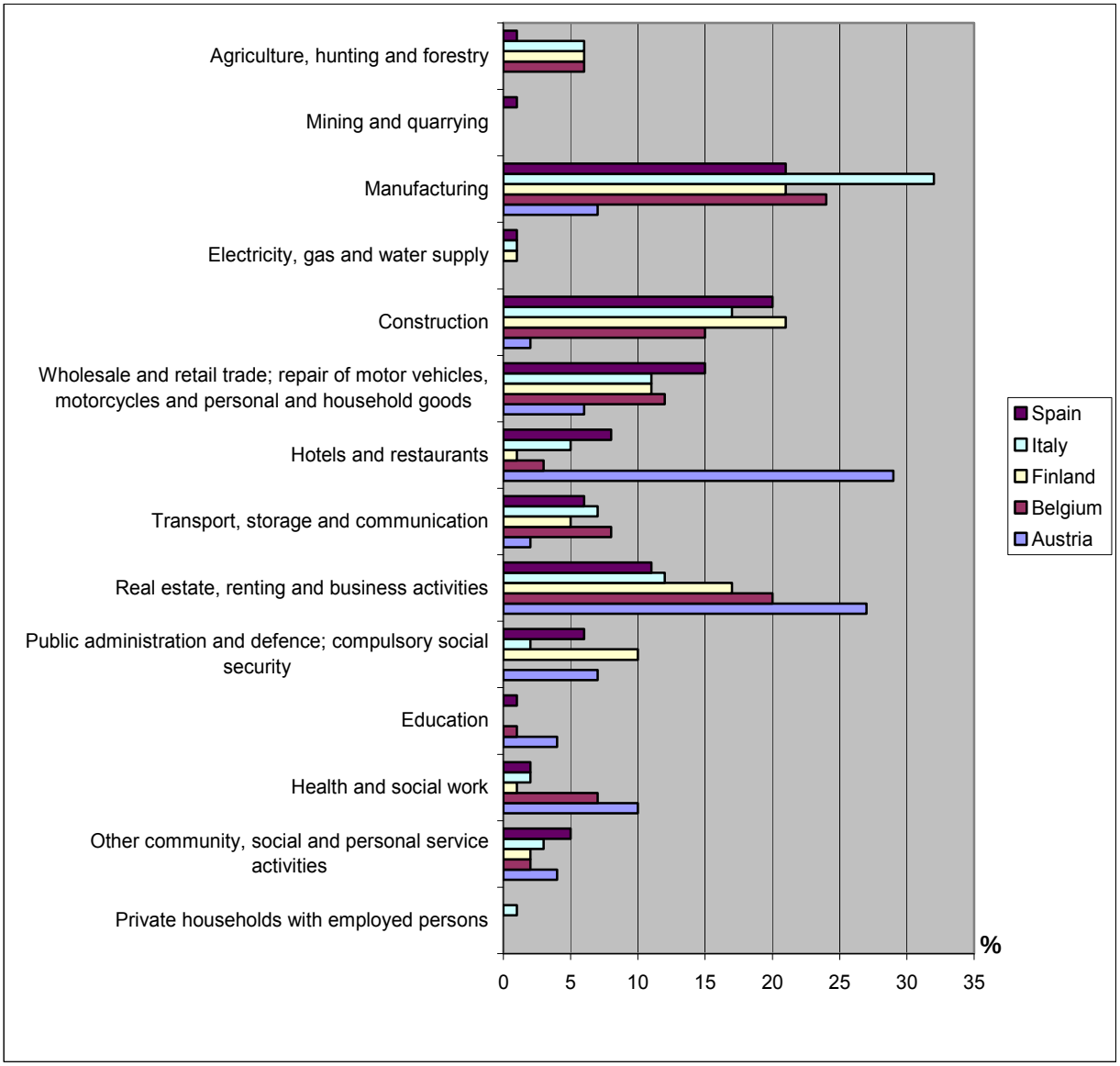
4.1.4. Occupational accidents by sector

As shown in Figure 8, EUROSTAT data for 2006 from five European countries indicate that most maintenance-related accidents occur in:

- manufacturing sector;
- construction sector;
- real estate, renting and business activities;[11]

However, in Austria 29% of all maintenance related accidents occurred also in hotels and restaurants.

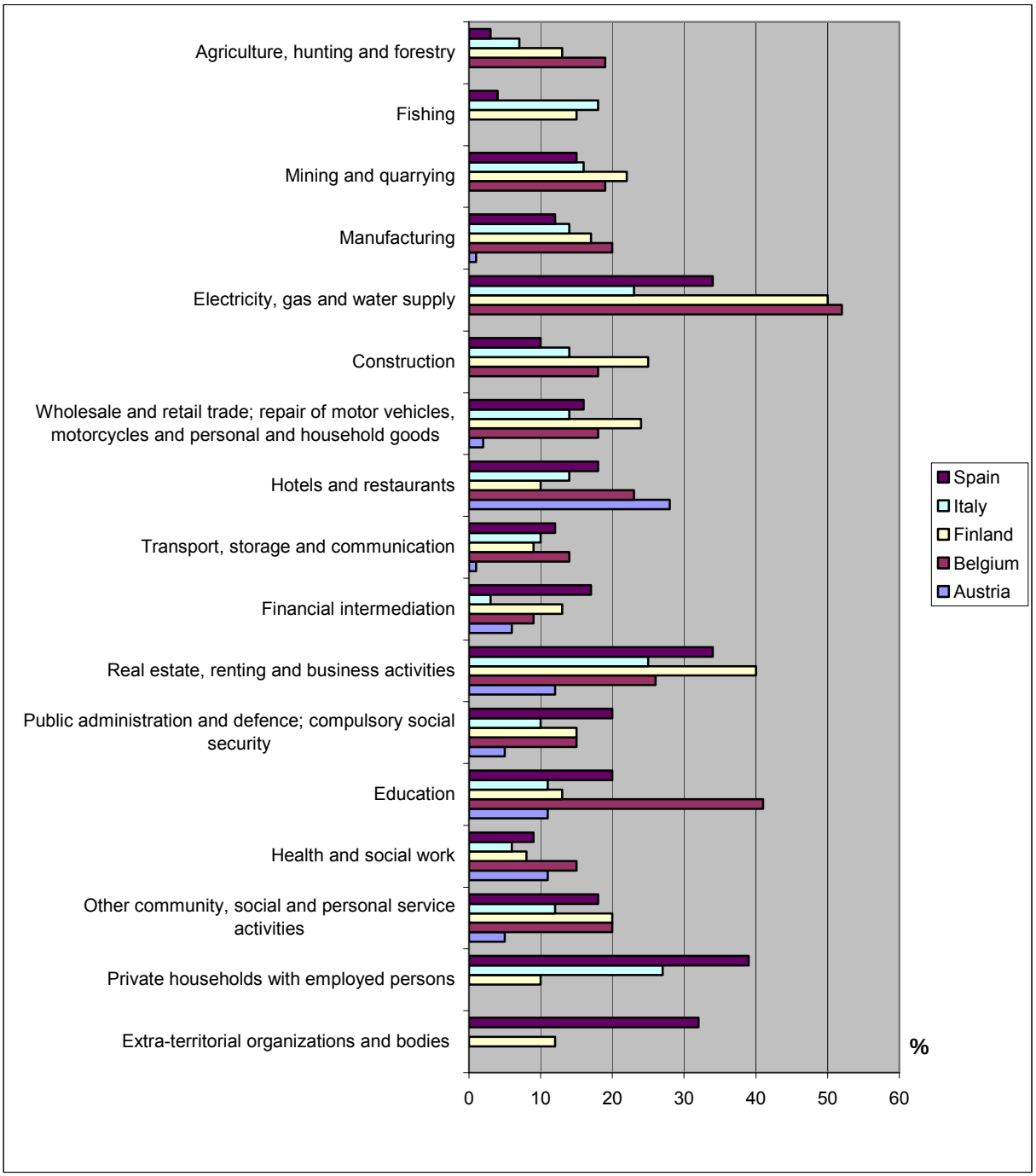
Figure 8: Percentage distribution of accidents related to maintenance operations by sector in selected European countries, 2006 (data from EUROSTAT)



[11] 'Real estate, renting and business activity' consists of subcategories such as 'maintenance and repair of office, accounting and computing machinery' as well as 'industrial cleaning'.

Figure 9 highlights some further high instances of accidents relating to maintenance operations in 2006. In the electricity, gas and water supply sector, 50% of accidents in Finland and Belgium, 34% in Spain and 23% in Italy were related to maintenance operations. In the real estate, renting and business activities sector, 40% of accidents in Finland, 34% in Spain, and 26% in Belgium related to maintenance. In Belgium, 41% of accidents in the education sector were maintenance-related. In other sectors, depending on the country, 10–20% of accidents related to maintenance operations (see Figure 9).

Figure 9: Accidents (%) related to maintenance operations within sector in selected European countries, 2006 (data from EUROSTAT)



The industrial and building sectors represented 30% and 36% respectively of the 326 fatal occupational accidents between 1980 and 1982 analysed by HSE [115]. In the construction sector, the major causes of fatal accidents among maintenance workers are due to workers being struck by heavy equipment or trucks and being struck by equipment loads or parts. In most of the cases, the

accidents were due to failing to set brakes, leaving vehicles in gear, or other failures to lock out vehicles when either getting off or working around them [123].

In Germany, the highest numbers of fatal accidents reported in the BAuA (German Federal Institute for Occupational Health and Safety) database occurred during 'transport' and 'assembly' tasks. For this report, the specific tasks of 'service/inspection', 'fault clearance' and 'repair/maintenance' were combined and called 'fatal maintenance accidents'.[12] From 2000 to 2006, more or less the same number of fatal accidents happened during these activities. While the total number of fatal occupational accidents declined, the number of fatal maintenance accidents in Germany increased between 2000 and 2003 (92 fatal accidents in 2003) and then decreased until 2006 (56 fatal accidents in 2006) (see Table 22) [124].

Between 2000 and 2006, the highest total number of fatal maintenance accidents occurred in micro-sized enterprises (1–9 employees, in total 125 fatal accidents), followed by 71 fatal maintenance accidents related to maintenance in enterprises with 10–19 employees. In general, the highest number of fatal accidents was found in small and medium-sized enterprises (1–200 employees) [124].

Table 22: Number of fatal accidents in relation to accident-related tasks in Germany, 2000–2006 [124]

	2000	2001	2002	2003	2004	2005	2006	Total
Transport	123	122	118	121	102	109	110	805
Setup/rigging	8	12	12	5	13	5	9	64
Assembly	75	63	55	43	47	54	51	388
Service/inspection	21	26	30	34	23	21	20	175
Fault clearance	24	20	22	25	20	18	17	146
Maintenance	25	23	27	33	26	25	19	178
Disassembly	31	24	23	13	29	11	11	142
Surveillance/inspection/control	12	14	15	14	19	12	11	97
Administrative work	2	2	0	2	1	0	1	8
Travel accident	27	25	25	16	17	16	6	132
Task-unspecific	2	6	2	2	0	0	4	16
Other	3	4	3	4	2	1	5	22

4.1.5. Occupational accidents by age

EUROSTAT data show that accidents related to maintenance operations are the most prevalent among middle-aged workers (25–34 and 35–44 years) (see Table 23).

Table 23: Accidents related to maintenance operations by age in selected European countries (data from EUROSTAT)

Age range	2002 *		2003 **		2004 ***		2005 ****	
	N	%	N	%	N.	%	N.	%
0–17	661	1	1,519	1	1,624	1	1,849	1

[12] The German database distinguishes between different tasks: 'Wartung/Inspektion' (translated into 'service/inspection'), 'Störungsbeseitigung' (translated into fault clearance') and 'Instandsetzen' (translated into 'repair/maintenance'). All three refer to 'maintenance.

Age range	2002 *		2003 **		2004 ***		2005 ****	
	N	%	N	%	N.	%	N.	%
18–24	6,000	12	29,579	14	26,972	13	32,471	13
25–34	14,297	29	61,951	29	59,409	28	69,890	28
35–44	13,717	28	56,420	27	57,371	27	68,050	27
45–54	10,703	22	43,021	20	43,152	21	54,015	22
55–64	3,616	7	18,004	8	18,732	9	22,331	9
65+	434	1	1,076	1	1,226	<1	1,246	<1
Total	49,428		211,570		208,486		249,852	

* Austria, Finland, Italy

** Austria, Spain, Finland, Italy

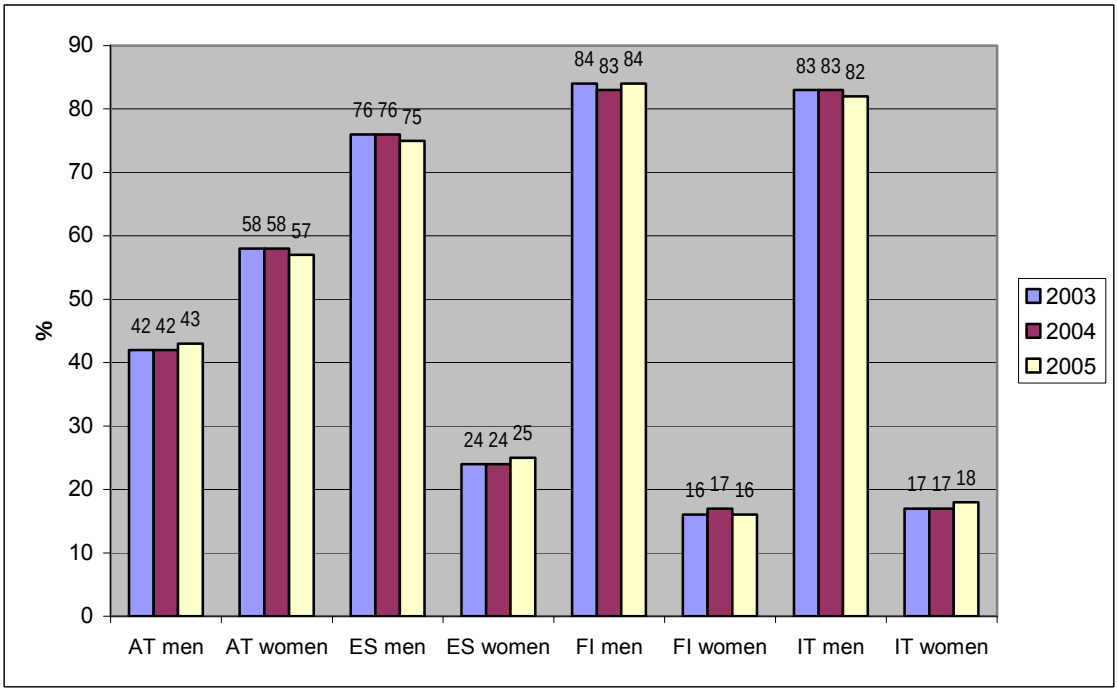
*** Austria, Bulgaria, Spain, Finland, Hungary, Italy, Lithuania, Slovakia

**** Austria, Belgium, Bulgaria, Czech Republic, Estonia, Spain, Finland, Hungary, Italy, Lithuania, Poland, Romania

4.1.6. Occupational accidents by gender

According to EUROSTAT data, accidents related to maintenance are significantly more prevalent among men than women in Finland and Italy (around 80% vs. 20%) as well as in Spain (around 70% vs. 30%), whereas in Austria they are more common among women (around 60% vs. 40%) (see Figure 10). This may be explained by the fact, compared with other countries, maintenance-related accidents in Austria are more common in private households with employees and in the hotels and restaurants sector where a relatively high percentage of staff are women. Moreover, only around 2% of accidents are related to maintenance in electricity, gas and water supply (see section 4.1.4), where majority of workers are men.

Figure 10: Accidents related to maintenance operations by gender in selected European countries, 2003–2005 (data from EUROSTAT)



In Germany, most of the fatal accidents happened among men (e.g. 54 fatal accidents among men and two among women in 2006) (see Table 24) [124].

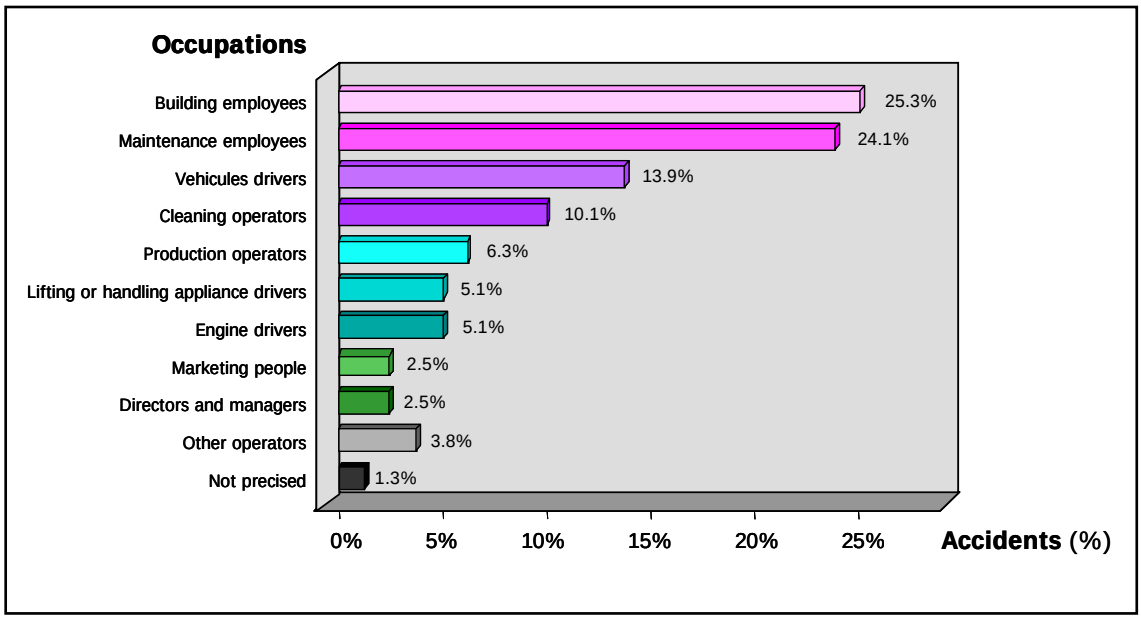
Table 24: Number of fatal maintenance accidents in relation to sex in Germany, 2000–2006 [124]

	2000	2001	2002	2003	2004	2005	2006
Men	69	66	79	92	69	62	54
Women	1	3	0	0	0	2	2

4.1.7. Occupational accidents related to subcontracting maintenance

Examination of a French work accidents database (EPICEA) identified 79 accidents related to subcontracting in 2002 and showed that maintenance staff was the second most common group of victims of these accidents, just behind construction employees [125]. Indeed, maintenance staff were the victims of almost one in four of the accidents relating to subcontracting (24%; see Figure 11) [125].

Figure 11: Distribution of 79 subcontracting related accidents in France as a function of the occupation of the victim [125]



4.2. Occupational diseases and health problems

Studies indicate that industry maintenance workers might be especially at risk of contracting occupational diseases [12]. According to a study by AFIM (Association of Maintenance Engineers and Technicians) carried out in the Provence Alpes Côte d'Azur region of France with maintenance subcontracting companies, industrial maintenance employees have an occurrence of occupational diseases 8–10 times greater than the average population [126,127]. This represents 1,100 victims per year of occupational disease in industrial maintenance.

The seven main occupational diseases that concern industrial maintenance employees are [12]:

- diseases related to the inhalation of asbestos dust;
- respiratory diseases;
- hearing impairment;

- musculoskeletal disorders (MSDs);
- diseases of the peripheral nervous system;
- diseases of the circulatory system;
- skin diseases.

In France, almost 1% of maintenance technicians are victims of a permanent disability each year [127].

Increased morbidity and/or mortality rates related to asbestos exposure can be found for marine maintenance engineers [128] and building maintenance workers [129]. Plumbers, gas fitters, carpenters, electricians, ventilation engineers, cleaners and other work groups maintaining buildings and disturbing asbestos-containing materials are also at risk [130,131].

Maintenance workers exposed to asbestos may suffer from cancers such as lung cancer and mesothelioma; 24% of the deaths from mesothelioma were found in maintenance worker occupations [132]. Aircraft maintenance workers have also been found to have an increased risk of cancer [133], indicating that they are exposed to a variety of chemicals of which some were known or possible carcinogens. Minor symptoms include headaches, dizziness, irritated eyes, abdominal cramps, body odour, contact dermatitis, diarrhoea and vomiting [133]. In addition, neuropsychiatric and neurological symptoms (e.g. memory loss, irritability and poor sleep) may be observed [133].

An HSE study [134] found that musculoskeletal disorders, representing 40% of all the occupational diseases in the air transport industry, mainly concerned baggage handlers and ground maintenance staff.

Likewise, a study of work-related musculoskeletal disorders reported over a 12-year period (1992–2003) in Norway's offshore petroleum industry showed that there were 3,131 new cases of musculoskeletal disorders during this period [49]. About 40% of all the cases reported (i.e. disorders of the upper limbs, back pain, and less often neck disorders and disorders of the lower limbs) were maintenance workers, and more particularly mechanics, electricians and scaffolders. The activities reported as the cause of work-related musculoskeletal disorders were high physical workload, repetitive work, but also fixed position, walking, climbing stairs or kneeling. According to the authors, 'workers in maintenance represented the largest group of cases, upper limb and back were the most frequently reported anatomical regions and high physical workload and repetitive work dominated as the reported causes' (p. 114) [49].

Moreover, musculoskeletal disorders are important diagnostic causes of sick leave among maintainers in the offshore petroleum industry [135] as well as onshore in Norway [135,136].

4.3. Poor maintenance

Lack of maintenance or inadequate maintenance can also lead to dangerous situations, accidents and health problems. This may be related to lack of, or poor maintenance of:

- vehicles;
- industrial or agriculture machines;
- electric facilities;
- fire-extinguishers;
- buildings;
- water facilities.

Maintenance failures may contribute to large-scale disasters with serious damaging consequences for humans and the environment. The first two examples below from the UK illustrate the possible scenarios of such accidents. A further example from the German labour inspectorates highlights the importance of maintenance procedures in relation to (fatal) occupational accidents. However, many accident communications remain unpublished.

4.3.1. Example: Park Environmental Services Ltd, Newport, UK

On 16 July 2001, an estimated 186 m^3 of hydrogen sulphide gas were released from a 500 m^3 treatment tank at Park Environmental Services Ltd, which operated a treatment plant for processing chemical waste at Newport in South Wales [137].

Approximately 20 tonnes of waste alkali solution were transferred from a road tanker to a treatment tank. Mixed waste acids were added to the treatment tank with a view to controlling the pH level. During processing, the acid reacted with the polysulphide contaminants in the waste alkali solution. Hydrogen sulphide gas was produced, which escaped from the treatment tank. The gas then settled at ground level.

Due to inadequate maintenance, the lid collapsed into the treatment tank. Furthermore, the analysis of the waste chemicals to determine the nature and volume of toxic gas was insufficient. In addition, the extraction system was neither adequate for use with, nor designed for, an open vessel. It could therefore not prevent the loss of containment of the toxic gas formed.

The incident had the following impacts [137]:

- one fatality from asphyxiation;
- three injuries to on-site personnel from exposure to hydrogen sulphide gas;
- serious danger to human health involving the release of one dangerous substance;
- fines imposed by the courts totalling £250,000;
- a nationwide enforcement initiative to look more closely at the chemical waste industry and its safety/environmental standards.

4.3.2. Example: Fehrer (GB) Ltd, Smethwick, West Midlands, UK

Fehrer Ltd manufactured polyurethane resins for moulding into car seat cushions. On 24 July 2002, a fire in an area around a curing oven spread to the process and manufacturing areas, and destroyed the factory [138].

The incident occurred during a factory shutdown while various maintenance works were being undertaken including cutting out redundant pipework with an oxy-propane torch. A spark from the cutting operation ignited combustible material.

The incident had the following impacts [138]:

- no injuries sustained;
- property damage of over EUR 2 million;
- 110 people had to be evacuated from their homes;
- destruction of the factory.

4.3.3. Example: compost storage facility, Germany

An industrial fitter working at a compost storage facility in Germany in 2003 was killed during the maintenance of a machine used to mix different compost fractions. The machine had paddles fixed on two shafts. Some days previously the fitter had repaired one broken paddle. However, the repair was inappropriate and the fitter had to repeat the maintenance work. In the morning, the fitter entered the mixing machine via a ladder. The ignition key was plugged in the ignition lock and the main control switch was not locked. Another employee did not know about the maintenance procedure and started the mixing machine. The industrial fitter was pulled in by the shafts. Although the employee immediately pushed the emergency stop switch, the fitter could not be saved [124].

5. Prevention measures

Given the wide range of hazards and risks associated with maintenance, it is necessary to include it in a company's comprehensive management system.

- **Structured approach.** Maintenance may mean stopping a production process and requiring workers to operate in hazardous locations (e.g. inside machinery and plant). As outlined in this report, there are many associated hazards and risks. Therefore, a system has to be in place to ensure that:
- maintenance can be carried out safely;
- the workers involved in an ongoing production process remain safe during the process;
- equipment can be started up safely afterwards.

A risk assessment record should be included in typical task documentation.

- **Organising work.** Maintenance is often performed under pressure – to restart a stalled production process or to complete scheduled work before a deadline. Workers who are under this kind of pressure – and possibly putting in long hours to complete the task – may not work as safely as they should. Taking shortcuts can end up actually prolonging the task, as well as risking injuries and damage to equipment.

- **Training.** The competence of the people carrying out maintenance, including inspection and testing, is vital to safety. Most workers carry out some maintenance tasks. Even though workers are frequently multi-skilled and routine maintenance may be part of their job description, activities that are not performed regularly must to be included in their training. Accidents may occur if workers try to do tasks they are not trained for or experienced in.

Employers must ensure that workers:

- have the skills to carry out the necessary tasks;
- are informed about safe work procedures;
- know what to do when a situation exceeds the scope of their skills.

- **Procurement of equipment.** Maintenance activities can require workers to operate in dangerous locations. This may involve the use of equipment that is not routinely used in the workplace, including personal protective equipment (PPE). Procurement procedures must be in place to ensure that the necessary tools and PPE (along with the necessary training and care of this equipment) are available for safe maintenance. For example, temporary lighting may need to be explosion protected, and appropriate PPE provided (e.g. respiratory protection for use when cleaning filters). During the procurement of new machinery and buildings, ease of access for performing maintenance should be considered: risks during maintenance can be minimised or even eliminated through good design of work equipment and the provision of relevant information by the supplier or manufacturer.

Artists: Magda Szymeczko, Andrzej Leraczyk. Courtesy of the Occupational Safety Poster Competition organised by the Central Institute for Labour Protection – National Research Institute, Poland

- **Subcontracting.** Companies are increasingly outsourcing their maintenance activities, resulting in a major impact by procurement and management of contracts between companies on occupational safety and health. Maintenance carried out by a contractor must be well integrated into the ongoing activities of the company to safeguard the safety and health of all workers involved. Good practice examples where the needs of both the contractor and host company are taken into consideration include 'good neighbour schemes', 'safety passports' and induction procedures. During the procurement process, issues of cultural and language differences should be considered, as well as issues resulting from the sometimes uncertain employment of some subcontractors.

5.1. Maintenance as a process

It is essential to take a structured approach to maintenance, seeing it as a process rather than a task.

The process starts with the **planning** phase, when risk assessment is carried out. The scope of work is decided upon and the required resources are identified (e.g. range of skills of workers and their roles, tools needed), as well as the hazards and precautions to be taken. It is advisable to involve the maintenance workers in the planning process.

Only then can the location of the task be **made safe** – power locked off, moving parts of machinery secured, temporary ventilation installed, access and egress routes established, etc.

Appropriate tools (including PPE) must be made available.

Procedures decided on in the planning stage must be followed, but provision must also be made for managing unexpected problems.

Once the actual maintenance has taken place, the **work is checked** to make sure:

- the item worked on is safe to use again;
- all isolations are removed;
- all tools are retrieved;
- any waste is removed.

The process should be documented and **records** of tasks performed, as well as the sign-off condition, should be verified and approved.

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Council Directive 96/82/EC of 9 December 1996 on the control of major-accident hazards involving dangerous substances (Seveso II Directive) aims to prevent major accidents which involve dangerous substances. Furthermore, the Directive promotes the exchange of information among the Member States on accidents and near misses that occur within sites that fall under the Directive in order to prevent similar occurrences in the future [139]. The Major Accidents Hazards Bureau[13] at the European Commission's Joint Research Centre operates a system for the distribution of information concerning these major accidents as well as the lessons learned from them:

- Major Accident Reporting System (MARS);
- Seveso Plants Information Retrieval System (SPIRS).

This information can be used in order to make procedures – also in relation to maintenance – safer.

[13] http://mahbsrv.jrc.it/

6. Conclusions

Literature studies indicate that significant numbers of maintenance workers may be exposed to a variety of risks when doing their job. In addition, a significant number of accidents are related to maintenance activities and especially to corrective maintenance. Thus it is vital for maintenance workers to be well informed about occupational risks. They should be provided with the appropriate work equipment, protection equipment, and work procedures.

The process of maintenance should start at the design and planning stage and before maintenance workers enter the workplace.

Implementing appropriate risk assessment procedures related to maintenance operations, as well as employing adequate preventive measures to ensure the safety and health of workers involved in maintenance activities are essential.

After maintenance operations are completed, special checks (inspections and tests) should be carried out to ensure that:

- maintenance has been carried out properly;
- new risks have not been created.

During the whole process, good maintenance management should ensure that:

- maintenance is co-ordinated, scheduled and performed correctly as planned;
- the equipment or workplace is left in a safe condition for continued operation.

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