WORKING FOR A HEALTHY FUTURE

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Health, socio-economic and environmental aspects of possible amendments to the EU Directive on the protection of workers from the risks related to exposure to carcinogens and mutagens at work

Refractory Ceramic Fibres

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COLLABORATING CENTRE
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SUMMARY

Based on animal toxicity data, exposure to refractory ceramic fibres (RCF) may cause lung cancer. However, there is no human epidemiological data to enable us to estimate the risks. To enable us to make a health impact assessment we have assumed that exposure to RCF is no worse than chrysotile (white) asbestos in its ability to cause lung cancer, which we consider is a "worst-case" assessment.

The International Agency for Research on Cancer (IARC) considers RCF is a possible human carcinogen (category 2b) and it is classified as a category 2 carcinogen in Europe under the classification and labelling regulations. RCF has also been identified as a Substance of Very High Concern under the REACH Regulation, although we understand that the substance definitions may be amended. This report considers the likely health, socioeconomic and environmental impacts associated with possible changes to the EU Carcinogens Directive, in particular the possible introduction of an occupational exposure limit (OEL) of either 0.1 fibres/ml or 1 fibres/ml. Note, in October 2010, SCOEL recommended a limit of 0.3 fibres/ml.

Lung cancer is the commonest cancer amongst men in Europe that is generally diagnosed on people over 40 years of age, and incidence rises steadily thereafter. Cigarette smoking most commonly causes lung cancer, although there are several occupational agents that are also known to cause this disease. Most people with lung cancer die within 5 years of diagnosis.

RCF are synthetic vitreous fibres or man-made mineral fibres used in industry for their properties of heat resistance, tensile strength and durability. European Union Directive 97/69/EC defined RCFs as "Man-made vitreous (silicate) fibres with random orientation with alkaline oxide and alkaline earth oxide content less than 18% by weight." There are about 730 workers employed in RCF production plants in Germany, France and the UK. There are about 9,270 people employed in the downstream user industry. Geometric mean exposures in the industry are less than 0.2 fibres/ml and it is estimated that about 7% of workers in manufacturing facilities and 12% of workers at downstream user facilities have been exposed above 1 fibres/ml. More than half of workers are exposed above 0.1 fibres/ml. It is assumed that exposure levels have been decreasing by about 7% per annum since the late 1990s.

The predicted number of deaths from past occupational exposure to RCF using our worst-case assumptions about potential risks is low (in 2010, no attributable deaths in manufacturing and two deaths in downstream users). The predicted number of deaths decreases in the future so that by 2050 there are no predicted deaths occurring as a result of RCF exposure at work. The number of incident lung cancers is similar to the estimated number of deaths. Introducing a OEL of either 0.1 or 1 fibres/ml has no important effect on the predicted cancer deaths or registrations from RCF. For both potential OELs the estimated DALYs decrease from 29 years in 2010 to zero years by 2060; with no intervention there are two DALYs predicted in 2060.

We have not estimated risks of mesothelioma because we do not believe the human epidemiological data substantiates such a risk. However, if this assumption is in error then a worst case assumption might be that RCF exposure could cause three times as

many cancers as we have currently estimated. While this would increase the health impact we do not believe this importantly changes our conclusions.

It is likely that an EU-wide OEL of 1.0 fibres/ml could be met through greater uptake of currently applied techniques within the industry. The associated costs are likely to be relatively low. There is calculated to be a small health benefit associated with such an OEL, valued at up to €1-2 million in total over the period 2010-2069. The value is relatively low because of the low level of assumed cancer incidence under the baseline and the existing controls in place. It is not expected that there would be any important social, macro-economic or environmental impacts with an OEL at 1.0 fibres/ml.

The other OEL investigated in detail, 0.1 fibres/ml, could have much more significant impacts upon the industry. To achieve exposure at this level would require a degree of automation and enclosure that is unlikely to be feasible, especially for certain downstream users. The compliance costs associated with an OEL of 0.1 fibres/ml are estimated at:

- Around €60 to €140 million over the period 2010 to 2069 associated with controlling exposure. This includes controls at manufacturing sites as well as downstream users, although the controls adopted at downstream users are unlikely to allow the possible OEL to be achieved in practice.

- If achieving the OEL is technically or economically infeasible, companies may decide to substitute RCF with alternatives such as AES and PCW. The associated costs could be of the order of €2.5 billion over the same period.

These costs, coupled with the technical feasibility issues, could lead to some relocation of activities to outside the EU, with associated loss of employment.

The health benefits of achieving an OEL of 0.1 fibres/ml are likely to be minimal, and have been valued at up to €1-2 million in total over the period 2010-2069. Again, the value is relatively low because of the low level of assumed cancer incidence under the baseline and the existing controls in place.

The SCOEL has recently recommended an OEL of 0.3 fibres/ml. Whilst this recommendation was issued after the OELs for analysis in the study (1.0 and 0.1 fibres/ml) were agreed, some indicative estimates have been derived for the costs of compliance, including: €6 to €20 million for an OEL at 0.2 fibres/ml and €4 to €17 million for an OEL at 0.3 fibres/ml. The latter OEL could be more technically feasible than 0.1 fibres/ml, meaning that the costs of substitution with alternatives would not be incurred.

1 PROBLEM DEFINITION

1.1 OUTLINE OF THE INVESTIGATION

Exposure to refractory ceramic fibres (RCF) in workplace air may cause respiratory cancer, although the evidence is not conclusive. RCF has been classified as a group 2b carcinogen (Possibly carcinogenic to humans) by IARC based on the results of epidemiological and toxicological studies.[1] These materials are classified as a Cat 2 carcinogens in the EU under the classification and labelling legislation.[2] It is therefore already regulated as a carcinogen throughout the EU. In this assessment we consider the impacts of introducing an OEL for RCF within the Directive.

RCF have been identified as a Substance of Very High Concern (SVHC) within the REACH Regulations, which may ultimately require RCF to be authorised for specific uses. However, we understand that the substance definitions fro SVHC) may be amended.

The key objectives of the present study are to identify the technical feasibility and the socioeconomic, health and environmental impacts of introducing a regulatory OEL for RCF.

1.2 OELS/EXPOSURE CONTROL

Existing national occupational exposure limits (OELs) in EU member states are presented in Table 1.1. These are expressed as long-term limits, averaged over an 8-hour working day. OELs from selected countries outside the EU are also presented for comparison.

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[1] Available at: http://monographs.iarc.fr/ENG/Classification/ClassificationsAlphaOrder.pdf
[2] Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labeling and packaging of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006.

Table 1.1 Occupational exposure limits in various EU member states and selected countries outside the EU

Country	OEL - long-term (fibres/ml)
Austria	0.5
Belgium	0.5
Czech Republic	1
Denmark	1
Finland	0.2
France	0.1
Germany	No limit
Italy	0.2
Netherlands	0.5
Norway	0.1
Poland	1
Slovakia	2
Spain	0.5
Sweden	0.2
United Kingdom	1
Japan	1
Switzerland	0.25
USA	0.5

Source: http://www.ecfia.eu/has_elv.htm

The long term OELs from the EU member states and other jurisdictions range from 0.1 fibres per millilitre of air (fibres/ml) to 2 fibres/ml. For the purposes of this report OELs of 1 fibres/ml and 0.1 fibres/ml are considered typical for the EU. Note, SCOEL made a recommendation for an OEL of 0.3 fibres/ml, but this was published after we had prepared this report.

1.3 DESCRIPTION OF DIFFERENT USES

Refractory ceramic fibres (RCF) are synthetic vitreous fibres (SVFs) or man-made mineral fibres (MMMFs) that are used in industry for their properties of heat resistance, tensile strength, durability and light weight (NIOSH, 2006). They are produced by melting and then blowing or spinning calcined kaolin clay or a combination of alumina (Al_2O_3) and silicon dioxide (SiO_2). Other oxides (including zirconia, ferric oxide, titanium oxide, magnesium oxide, calcium oxide and alkalies) may be added to attain the properties required for the intended application of the final product (NIOSH, 2006). RCFs are also known as Alumino-Silicate Glass Wools (ASW).[3] European Union Directive 97/69/EC defined RCFs as “Man-made vitreous (silicate) fibres with random orientation with alkaline oxide and alkaline earth oxide content less than 18% by weight.” Similar fibres that contain greater than 18% alkaline oxide and alkaline earth oxide are classified as mineral wools.

3 Alumino-Silicate Glass Wool (ASW) in ECFIA Website. Available at: http://www.ecfia.eu/products_asw.htm. Accessed 24 May, 2010.

RCFs were invented in 1942 and commercial production began in the 1950s. Production of RCFs greatly increased during the energy crises of the 1970s as RCFs were used as a cost effective and energy efficient substitute for the less energy efficient hard brick refractories (Glass *et al*, 1995). Since the 1970s demand for RCFs has continued as they have been used as a substitute in some circumstances for asbestos-containing materials.

In the EU, RCF production takes place in Germany, France and the UK. The RCF manufacturing process begins with the blending of the raw materials. The mixture is then transferred to a furnace and melted at temperatures over 1600°C. The melted mixture is fiberised by either blowing a pressurized airstream onto the molten material or by directing the molten material through a series of spinning wheels. The RCFs are then either conveyed to a bulk press and bagging station and packaged as bulk fibre, or processed to form blankets, boards, textiles, felts, cements, modules or papers. Blankets are produced with a needle felting machine, which interlocks the fibres and compressed the blanket. Once formed, the blanket is passed through an oven to burn off lubricants that were added in the fibre settling chamber and the blanket is trimmed (NIOSH, 2006; HSE, 2002). Other shapes (including boards, felts and papers) are produced by wet-end production and vacuum formation, where the fibres are mixed with water and then a mould is attached to an airline and submerged into the mixture. The air pulls the fibres onto the mould and once the fibres have been formed into the required shape the suction is stopped and the shape is dried in a curing oven (HSE, 2002).

RCFs can withstand temperatures over 1000°C. Depending on the chemistry of the specific fibre the maximum temperatures tolerated range from 1050 to 1425°C. As a result of their high melting point RCFs are used primarily in the ceramic, steel and metal treatment industries to provide insulation, reinforcement and thermal protection for furnaces and kilns. They are also used in automobile catalytic converters, in some consumer products (including toasters, ovens and woodstoves), and in NASA Space Shuttle tiles (NIOSH, 2006; HSE, 2002).

1.4 RISKS TO HUMAN HEALTH

1.4.1 Introduction

Lung cancer is the commonest malignant neoplasm among men in most countries and incidence has been steadily increasing among women. The main environmental cause is cigarette smoking, although other factors, such as genetic susceptibility, poor diet, and indoor air pollution, may act in conjunction with tobacco consumption as risks for lung cancer. Among both men and women, the incidence of lung cancer is low in individuals aged less than 40 years and increases up to age 70 or 75 (Quinn *et al*, 2001). In most European countries, the risk of lung cancer among men is two to three times higher in lower than higher socio-economic classes (Quinn *et al*, 2005).

Lung cancer is highly fatal, so the trends in incidence and mortality are closely aligned. In Europe about 10% of lung cancer patients survive for more than 5-years post diagnosis (Verdecchia *et al*, 2007). Lung cancer accounted for 15.5% of all cancers in men in Europe, and 6.9% of cancers in females (Ferlay *et al*, 2007).

There are a number of occupational agents that are known or suspected of causing lung cancer. Rushton *et al*, (2010) estimated that in Great Britain occupational exposures account for about 21% of male lung cancers and 5% of female lung cancers.

1.4.2 Summary of the available epidemiological literature on risk

There have been a number of reviews on the toxicity of RCF including a recent one by Utell and Maxim (2010). The prevailing thinking about the toxicity of RCFs is that this depends on the dose, dimension and durability of the fibres. RCFs are less durable/biopersistent than amphibole asbestos, but more durable/biopersistent than many other *synthetic vitreous fibres* (SVFs). In their production and use some RCFs are respirable, i.e. longer than 5μm, less than 3μm with an aspect ratio of 3:1. Toxicology studies with rodents using various exposure methods have shown that RCFs can cause fibrosis, lung cancer, and mesothelioma. Interpretation of these animal studies is difficult for various reasons e.g. overload in chronic inhalation bioassays (i.e. exposing experimental animals to such a high aerosol concentration of particles that the normal defence mechanisms which facilitate the removal of inhaled particles are overwhelmed, a situation which can result in the production of tumours) (Utell and Maxim, 2010, Bernstein, 2007).

Respiratory symptoms and lung function

There have been a series of studies in the US and UK evaluating the respiratory symptoms and lung function and chest x-ray results of RCF workers. Lemasters *et al* (1998) carried out a pulmonary morbidity study of employees manufacturing RCF at five US sites between 1987 and 1989. The odds ratio (OR) for working in RCF production and having one or more respiratory symptoms was 2.9 (95% confidence interval (CI) 1.4-6.2) for men and 2.4 (95 %CI 1.1-5.3) for women. For men, there was a significant decline in forced vital capacity (FVC) for current and past smokers of 165.4 ml ($p < 0.01$) and 155.5 ml ($p = 0.04$), respectively, per 10 years of work in RCF production. For forced expiratory volume in 1 second (FEV_1) the decline was significant ($p < 0.01$) only for current smokers at 134.9 ml. For women, the decline was greater and significant for FVC among non-smokers, who showed a decrease of 350.3 ml ($p = 0.05$) per 10 years of employment in RCF production.

A later longitudinal analysis of 361 male production workers who provided five or more spirometry tests over 7 years (Lockey *et al*, 1998) showed no excessive decline in lung function for workers during the 7-year follow-up period after their initial test. The authors suggested that this might be due to reductions in fibre and dust exposures since the late 1980s. In Europe, an initial study carried out in 1987 (Trethowan *et al*, 1995) found no association between RCF exposure and lung function in non-smokers. However, there was a significant association between FEV_1 and cumulative exposure in past smokers and a non-significant trend in cumulative exposure and FVC for current and past smokers. In the follow-up study (Cowie *et al* 2001), the effects were slightly smaller than those seen in 1987 but there were mild decrements in FVC and FEV_1 associated with estimated cumulative RCF exposure but only for male current smokers and not for the FEV_1/FVC ratio. In addition, there was no reduction in diffusing capacity for carbon monoxide related to exposure, another sensitive test of lung function measured by these investigators. Prevalence of respiratory symptoms was low although chronic bronchitis showed some association with recent exposure to RCF.

Radiological investigations

Pleural plaques are localised areas of pleural thickening with clearly demarcated edges usually diagnosed using radiographic methods. They are found in the lateral and lower half of the pleural cavity and are typically bilateral with well-defined borders (Utell and Maxim, 2010). A radiological investigation of workers in the US cohort exposed to RCF revealed a statistically significant increase in the prevalence of pleural plaques with pleural changes seen in 27 workers (2.7%). These changes included pleural plaques (22 of the 27 reported pleural changes) and thickening. A significant OR for pleural changes was found at the highest cumulative exposure level (>135 fiber-mo/cm3) OR=6.0 (95%CI 1.4–31.0) (Lockey *et al,* 2002). The prevalence of parenchymal abnormalities did not differ from workers exposed to other types of dust (Lockey *et al*, 1996, 2002).

The European study of Cowie *et al* (2001) found no association between category 1/0+ opacities and exposure. A weak association between category 0/1+ small opacities and cumulative exposure to RCF was suggested, but not clearly established. Pleural changes, after adjustment for age and past exposure to asbestos, showed some evidence (but not significant) of a relation between time since first exposure to RCF.

There is some controversy about the clinical significance of the presence of pleural plaques. However, general opinion appears to be that the presence of pleural plaques alone is not associated with any major decrement in lung function. In addition, the presence of plaques in an individual is not considered to indicate any specific increased risk of malignant disease of the pleura.

Mortality studies

A cohort study of workers at two RCF production plants in the USA included 942 male workers employed for one year or more between 1952 and 1997. The mortality data were reported by Lemasters *et al* (2003) and in a paper addressing risk analysis by Walker *et al* (2002). The maximum exposure ranged from 10 fibres/ml in the 1950s for carding in a textile operation; this was subsequently reduced through engineering changes to <1 fibres/ml in the 1990s. In all other areas measured at time of study initiation (1987–1988) the 8-h time-weighted average exposure estimates were in the range of 0.01–0.62 fibres/ml.

There was no excess mortality for all causes of deaths, all malignancies or diseases of respiratory system including mesothelioma. However, there was a statistically significant excess of cancers of the urinary tract (SMR=3.45, 95%CI 1.12-8.05). No statistically significant exposure response trends for any respiratory outcomes were detected by analyses with Cox's proportional hazards model to compare survival rates in relation to cumulative fibre exposure. No mesothelioma or cancers of the pleura were found following careful evaluation of death certificates, available medical records, and lung tissue samples. The authors noted limitations in the study such as the relative youth of the cohort, its small size and possible non-comparability with the general population. The average worker age at end of follow-up was 51 with a mean latency period for the cohort of over 21 years. In addition, the cohort was relatively small, with less than a thousand workers in the follow-up group.

Walker *et al* (2002) compared lung cancer and mesothelioma in the US cohort to that which would have been expected if RCF had a carcinogenic potency similar to that of various forms of asbestos. They used risk models from Hodgson and Darnton (2000) for asbestos cohorts together with the RCF exposure measurements and historical reconstructions of Rice *et al* (1997). Deaths from lung cancer in the RCF cohort were statistically significantly below that which would be expected if RCF had the potency of either crocidolite or amosite. The mortality was also lower than would be expected if RCF had the potency of chrysotile, but the difference was not statistically significant i.e. was indistinguishable from chrysotile asbestos at current cumulative levels.

Chiazze *et al* (1997) reported on a case–control study of 45 men with lung cancer (122 controls) that was nested within a cohort of 2,933 white men employed in a plant manufacturing continuous glass filament. Though reconstruction of historical conditions exposure to respirable glass fibres, asbestos, RCF (used but not manufactured at the plant for high-temperature heat insulation), and a number of other sources of exposure was assessed. The risk of lung cancer was lower in workers exposed to RCF in comparison to controls OR=0.36 (95%CI, 0.04–3.64, 1 case] at 0.01–1 fibres/ml–days; OR=0.30 (95% CI, 0.11–0.77, 7 cases) at 1–40 fibres/ml–days). The ORs were not adjusted for exposure in the workplace to other fibres or for tobacco smoking, but the trends were similar when the analysis was restricted to smokers. IARC (2002) in their discussion about this study commented that exposure to RCF may have been difficult to separate from other sources of exposure in the workplace because of the small number of cases and the large number of sources of exposure.

Risk analyses

Because of lack of human data investigators have had to base risk estimates on extrapolations from high-dose inhalation experiments with laboratory animals to relatively low-dose exposure in humans (Utell and Maxim, 2010). As mentioned earlier because the rat experiments exhibited overload, the interpretation of these studies is problematic. Utell and Maxim (2010) have reviewed the risk estimates obtained in this way and say that estimated risks for occupationally exposed cohorts vary substantially (by a factor of nearly 1,000) depending upon the models used, basis for equating rodent and human exposures, and other assumptions. Moolgavkar *et al* (2000) showed that data from experiments on synthetic vitreous fibres was consistent with the hypothesis that cancer potency is entirely dependent on fibre biopersistence; the statistical analysis concluded that two highest-dose RCF results were outliers (perhaps because of overload). After deleting these outliers, Moolgavkar *et al* (2000) concluded that the maximum likelihood estimate of the incremental risk associated with a working lifetime exposure to RCF at 1 fibres/ml was approximately 4.4×10^{-5}.

SCOEL evaluation

In their evaluation the SCOEL[4] concluded that "the genotoxic effects observed in the different studies are secondary so that RCFs are classified as SCOEL Carcinogen group D carcinogens: *non-genotoxic carcinogens and non DNA-reactive carcinogens; for these compounds a true ("perfect") threshold is associated with a clearly founded*

[4] SCOEL (2010) Recommendation from the Scientific Committee on Occupational Exposure Limits for Refractory Ceramic fibres. SCOEL/SUM/165. Available from: ec.europa.eu/social/BlobServlet?docId=3863&langId=e

NOAEL". They based their recommendation for the proposed OEL on the cumulative exposure of the highest exposed group of workers in a US study of respiratory morbidity, where there was limited evidence of a decline in lung function. Their recommend OEL was 0.3 fibres/ml.

1.4.3 Choice of risk estimates to assess health impact

The target organ of concern with exposure to RCF is the lung. Animal studies have shown increased risk from lung cancer, although the issue of dose overload potentially hinders the interpretation of results from these experiments. None of the human studies show any excess risk from lung cancer. The modeling by Walker *et al* suggests that RCF is much less potent than crocidolite or amosite asbestos but may be more similar to chrysotile asbestos. The modelling of chrysotile asbestos carried out by Hodgson and Darnton (2000) suggests that a best estimate of excess lung cancer risk from chrysotile exposure would be 0.1% i.e. 0.1% excess lung cancer per fibre/ml year, with a highest reasonable estimate of 0.5%. A recent update of a cohort of textile workers exposed to chrysotile asbestos estimate a RR of 1.102 per 100 fibre-year/ml (95%CI 1.044, 1.164) (Loomis *et al* 2009). Hodgson and Darnton in a letter following this paper point out that this gives a similar excess lung cancer risk to their estimate. This RR has thus been used for exposure to RCF although it is recognized that this is probably an overestimate.

2 BASELINE SCENARIOS

2.1 STRUCTURE OF THE SECTOR

A summary of the structure of the sector is set out below:

Demand for RCF

- Production of RCFs (also known as Alumino-Silicate Glass Wool (ASW) greatly increased during the energy crises of the 1970s as RCFs were used as a cost effective and energy efficient substitute for the less energy efficient hard brick refractories.
- Since the 1970s, demand for RCFs has continued as they have been used as a substitute in some circumstances for asbestos-containing materials.

Production

- Location: In the EU, RCF production takes place in Germany, France and the UK although exact production volumes and sites are not known.
- Products: The RCFs are either conveyed to a bulk press and bagging station and packaged as bulk fibre, or processed to form blankets, boards, textiles, felts, cements, modules or papers.
- Substitution of RCFs – This can be with Alkaline-Earth Silicate Glass Wool (AES) in many applications. AES was developed in the late 1980s and has been commercially available since the early 1990s. It is increasingly used

in applications with temperatures up to its maximum tolerable temperature of 1200°C[5]. Communication with the trade body ECFIA has indicated that, between 1994 and 2009, 60% of RCF consumption was replaced with AES.

Use of RCF

ECFIA estimate the total tonnage of RCF used in the EU is about 25,000 tonnes per year. After a significant downward trend in demand following the development of non-classified AES wools about 15-20 years ago, the demand for RCF has remained fairly stable in recent years (if corrected for the general economic downturn in 2008/2009). The main uses of RCF are set out below in Figure 2.1.

Sector	Percentage	Illustrative applications
Industrial insulation	90 %	Furnaces: Insulation in industrial heaters and furnaces in sectors such as chemicals and petrochemicals, where RCF is used in heavy fuel heaters, distillation furnaces, steam crackers, ethylene furnaces, methanol reformers, primary ammonia reformers, and boilers. Furnaces for the production and treatment of ferrous and non-ferrous metals. In the ceramic industry RCF is used in biscuit kilns and glost kilns in the porcelain sector and tunnel kilns firing bricks, sanitary, chinaware and to line tunnel kiln cars. Metal treatment: Examples include foundry consumables, casting tips, launders, etc. Other industrial high temperature insulation: Including foundry sleeves, ducting, "hot tops," mould wraps, etc.
Automotive	8 %	Catalytic converters, Diesel particulate filters
Fire protection	< 2 %	Glazing tapes, duct protectors, etc.
Others	< 1 %	Large scale heating units (boiler doors)

Figure 2.1 Uses of RCF (Source: ECFIA)

Wider man-made mineral fibres market

RCF/ASW as well as other high temperature insulation wool (HTIW) account for a relatively small proportion of the total market for man-made mineral fibres. This is shown in the diagram below (Figure 2.2):

[5] Alkaline-Earth Silicate Glass Wool (AES) on ECFIA website. Available at: http://www.ecfia.eu/products_aes.htm

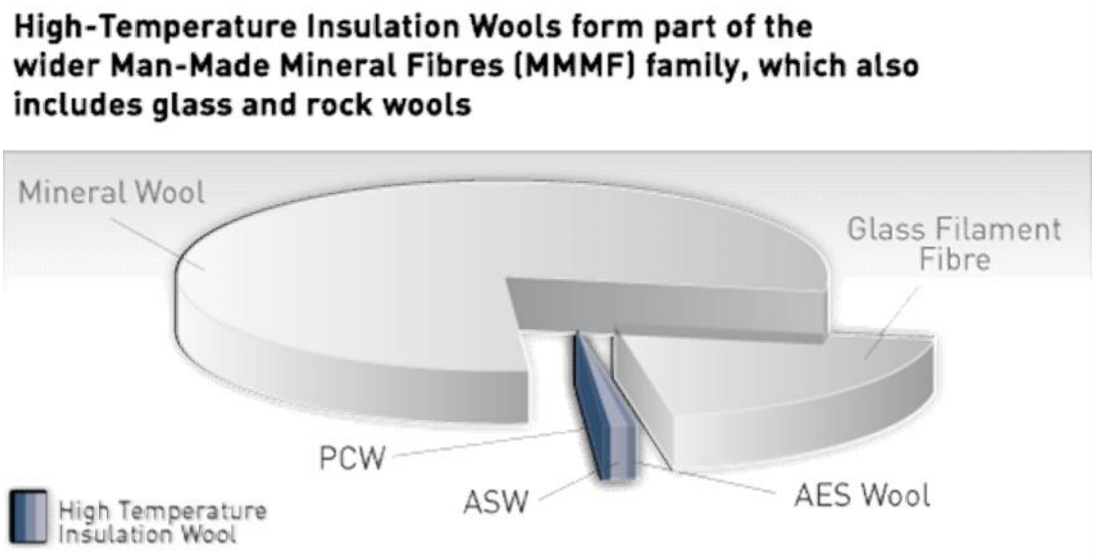


Figure 2.2 Man-made mineral fibres market (source: http://www.ecfia.eu/products.htm)

Whilst RCF/ASW use is small relative to other wider man-made mineral fibres (MMMF) there are limited alternatives to RCF/ASW in terms of temperature range and resistance to chemical attack. This is shown in the diagram below (Figure 2.3):

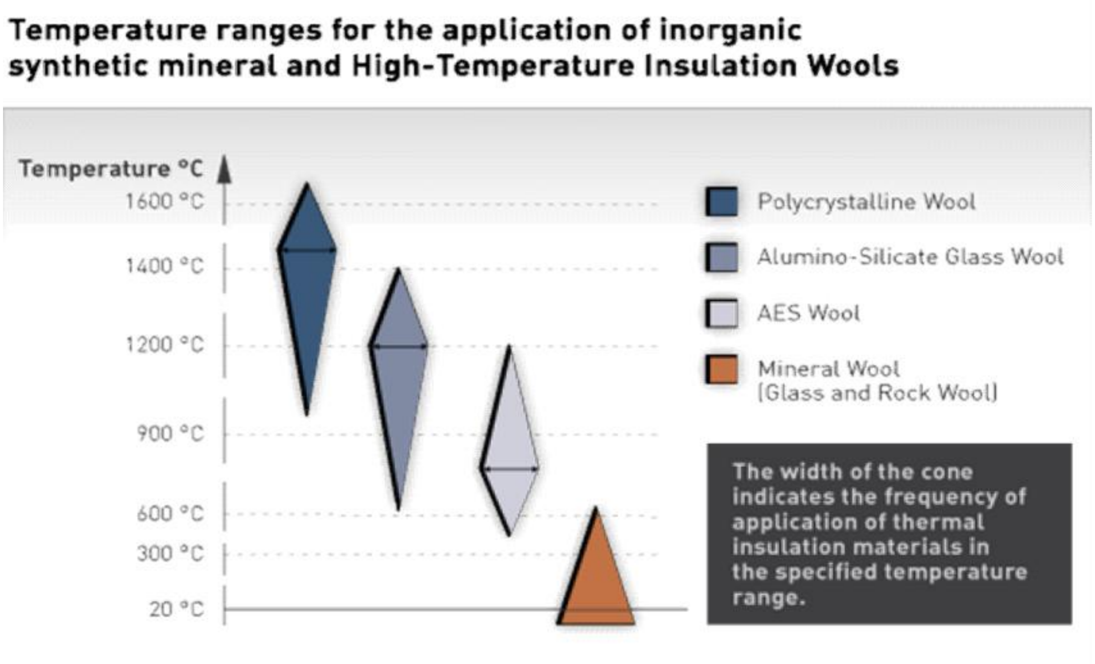


Figure 2.3 Temperature ranges for the application of inorganic synthetic mineral and high-temperature insulation wools (source: http://www.ecfia.eu/products.htm)

According to ECFIA, there are ongoing developments with alternatives: AES, which is not usable for around 10-15% of RCF/ASW uses and polycrystalline wool (PCW) which can be used of all uses but which is not made by all current RCF manufacturers and is about 20 times more expensive then AES and RCF/ASW.

2.2 PREVALENCE OF REFRACTORY CERAMIC FIBRE EXPOSURE IN THE EU

The CAREX database estimated that about 62,000 workers in the EU were exposed to RCF in the early 1990's (1990 – 1993). Although the CAREX estimates were updated for many substances in 2007, estimates were not updated for RCF therefore it is difficult to estimate current exposure prevalence based on CAREX data (Kauppinen *et al*, 2000). In 1995 a report characterizing the ceramic fibres industry in the EU estimated that approximately 30,000 EU workers were exposed to RCF. The large difference between the CAREX estimate and the 1995 estimate is likely due to methodological differences in estimation techniques rather than a halving of exposure prevalence between 1993 and 1995. Correspondence with the European Ceramic Fibre Industry Association (ECFIA), the organisation that represents the high-temperature insulation wool industry in Europe, has indicated that current exposure prevalence is lower than 1995 levels due to substitution of RCFs with Alkaline-Earth Silicate Glass Wool (AES) in many applications. AES was developed in the late 1980s and has been commercially available since the early 1990s and is increasingly used in applications with temperatures up to its maximum tolerable temperature of 1200°C.[6] Communication with the ECFIA has indicated that between 1994 and 2009 60% of RCF consumption was replaced with AES. The ECFIA has estimated that there are currently 22,000 people exposed to either RCF or AES in the EU and that the majority (about 12,000) are exposed only to AES. Therefore approximately 10,000 workers in the EU are regularly exposed to RCF.

About 730 of the 10,000 exposed workers are employed in RCF production plants. RCF production in the EU now only takes place in plants in Germany, France and the UK. All other EU RCF production plants have been closed. There are 80 potentially exposed workers in German manufacturing plants, 500 in French plants and 150 in UK RCF manufacturing plants. The remaining approximate 9,300 exposed workers are involved in downstream use of RCF at facilities spread across the EU. The number of workers in downstream use facilities is not available by EU member state.

More than 90% of workers in the manufacturing industry were men (Cowie *et al*, 1999), and for simplicity we have assumed that only men are exposed to refractory ceramic fibres.

2.3 LEVEL OF EXPOSURE TO REFRACTORY CERAMIC FIBRES

2.3.1 Estimation of exposure levels

Airborne RCF typically includes fibres in the respirable size range (< 3.5 μm in diameter, >5 μm in length with an aspect ratio >3:1). Exposures occur during manufacturing and during downstream use. RCFs are typically used only in industrial settings and exposure within the community setting is rare (NIOSH, 2006).

[6] Alkaline-Earth Silicate Glass Wool (AES) on ECFIA website. Available at: http://www.ecfia.eu/products_aes.htm

Miller *et al*, (2007) reported airborne fibre concentrations in six European manufacturing or processing plants. Respirable fibre levels showed marked differences between plants and between occupational groups. In 1995/96 the average concentrations among Primary Production, Secondary Production and Ancillary workers ranged from <0.1 fibres/ml to up to 0.376 fibres/ml. Corresponding data for Secondary Conversion and Finishing ranged from 0.316 fibres/ml to 1.25 fibres/ml. Levels in 1985 were generally higher, ranging up to 0.99 fibres/ml in Secondary production and 0.605 in Secondary Conversion and Finishing. Table 2.1 summarises their data.

Table 2.1 Airborne arithmetic mean fibre levels (fibres/ml) in six European RCF manufacturing plants

Occupational Group	Year	Number of samples	Plant 1	Plant 2	Plant 4	Plant 5	Plant 6	Plant 7	All
Primary production	1995/96	141	0.089	0.160	-	0.346	0.376		-
	1987	105	0.910	0.750	-	0.845	0.235	0.865	-
Secondary production	1995/96	78	0.227	0.145	0.275		0.247		-
	1987	101	0.990	0.638	0.722		0.262		-
Secondary conversion and finishing	1995/96	92	-	0.316	0.911	1.249	0.408	0.913	-
	1987	45	-	1.311	0.484	1.554	0.887	0.962	-
Ancillary	1995/96	137	0.030	0.075	0.320	0.167	0.177	0.139	-
	1987	65	0.252	0.414	0.325	0.426	0.174	0.605	-
Not exposed	1995/96	16	-	-	-	-	-	-	0.032
	1987	18	-	-	-	-	-	-	0.056

In 1996 the ECFIA initiated the CARE (Control And Reduce Exposure) programme with the aim of monitoring and characterizing RCF exposures at both manufacturing and downstream use facilities in order to establish recommendations for reducing exposures. The programme was based on a US project carried out by the Refractory Ceramic Fibers Coalition (RCFC). Both the European and US projects monitored RCF exposure among randomly selected workers from RCF manufacturing facilities and from downstream use facilities. Six hundred and eighty measurements were taken in the first year of the survey (1996 – 1997) and the results of this survey suggested that 84% of eight hour time-weighted average (TWA) exposures across all exposed workers were below 1 fibres/ml (Maxim *et al*, 1998). Fifty percent of exposures were below 0.25 fibres/ml, 71% were below 0.5 fibres/ml, and 94% were below 2 fibres/ml. Exposures were generally higher among downstream users than among manufacturing workers. The higher exposures at the downstream facilities occurred partly because downstream users were involved in removal and installation, which were not conducted by manufacturers, and partly because exposures at downstream facilities were higher in tasks which were conducted at both manufacturing and downstream facilities (including mixing/forming and assembling). Higher exposures at downstream facilities were also seen in the US study. The percentages of employees exposed above selected reference levels in manufacturing facilities and in downstream use facilities are shown in Table 2.2 (Maxim *et al*, 1998).

Table 2.2 Estimated percentage of RCF exposed workers with exposures below selected reference values in the EU, 1996 – 1997

Reference Value (fibres/ml)	Percentage exposed below reference value Manufacturing Facilities	Downstream use facilities
2	97.7	87.5
1	80.8	71.5
0.5	79.8	54.3
0.2	58.2	34.8

Source: Maxim *et al* (1998)

The exposed workers were classified into eight functional job categories (FJCs) which were as follows:

- **Fibre Production** – Manufacture of RCFs from raw materials. Includes needling, slitting/trimming, chopping and packaging of bulk RCF
- **Finishing** – Cutting and machining operations on RCF materials
- **Installation** – Installation of RCF materials for industrial applications, includes cutting, fitting, and pounding of RCF
- **Removal** – Removal, cleanup and disposal of RCF from industrial equipment that is no longer in use or removal from furnaces during maintenance
- **Assembly Operations** – Insertion and/or attachment of RCF materials to other materials to form an intermediate or finished product
- **Mixing/Forming** – Wet-end production of vacuum-formed shapes, board, felt and paper
- **Auxiliary operations** – Assorted applications including maintenance, handling/shipping, cleanup, supervision, and laboratory operations
- **Other** – Use of RCF in the textile and automotive industry, dry-end papermaking (HSE, 2002).

In the 1996 – 1997 survey exposures were highest in removal (geometric mean 1.52 fibres/ml), installation (geometric mean 0.74 fibres/ml) and finishing (geometric mean 0.66 fibres/ml). Geometric mean exposures in the other FJCs were all below 0.5 fibres/ml. Similar trends were also seen in the US surveys. The exposure concentrations reported by Maxim *et al* (1998) were not corrected for respirator use however in the US survey it was reported that approximately 90% of workers involved in removal, 80% of workers involved in installation and 60% of workers involved in finishing used respirators to reduce exposures. The true exposures in these FJCs were therefore likely lower than those reported above. When corrected for respirator use arithmetic mean exposures in US measurements taken between 1990 to 1996 decreased from 1.2 fibres/ml to 0.2 fibres/ml in removal, from 1 fibres/ml to 0.4 fibres/ml in finishing and from 0.4 fibres/ml to 0.1 fibres/ml in installation (Maxim *et al*, 1997).

Although the number of workers in each FJC is not available for the EU, Maxim *et al* (1997) reported the estimated fraction of all workers engaged in each FJC among manufacturers and downstream users. If it is assumed that the fractions are similar in the EU then the number of workers in each FJC can be estimated. The estimates are shown in Table 2.3.

Table 2.3 Estimated Number of Workers in each Functional Job Category (FJC) in Manufacturing and Downstream Use

Functional Job Category	Manufacturing Facilities		Downstream Use Facilities	
	Estimated fraction of total workers in FJC	**Estimated Number of Workers in FJC**	**Estimated fraction of total workers in FJC**	**Estimated number of Workers in FJC**
Fibre Production	0.39	285	0	0
Finishing	0.054	39	0.069	640
Installation	0	0	0.29	2688
Removal	0	0	0.05	464
Assembly Operations	0.066	48	0.037	343
Mixing/Forming	0.043	31	0.027	250
Auxiliary Operations	0.27	197	0.15	1391
Other	0.17	124	0.38	3523
Total	**1**	**730**	**1**	**9270**

Miller *et al*, (2007) analysed changes in exposure at six production plants in Europe. Respirable fibre concentrations were generally lower in 1995/96 than 1987. The degree of improvement, however, differed between plants and between occupational groups. Within Primary Production there were reductions in respirable fibre concentrations at four plants, with the most marked reductions at Plants 1 and 2, both in the UK (between -15% and -24% per annum for the occupational groups). The mean concentrations in Primary Production at Plant 6 almost doubled over the period (+5% per annum), but the concentrations here were much lower in 1987 than at the other plants and the final concentrations were in line with those at other plants. In plants 4 and 6 the annual percentage change in exposure level for occupational groups was between -11% and +5%. In plant 5 the exposures changed by between -3% and -10% per annum.

These data are shown in Figure 2.4.

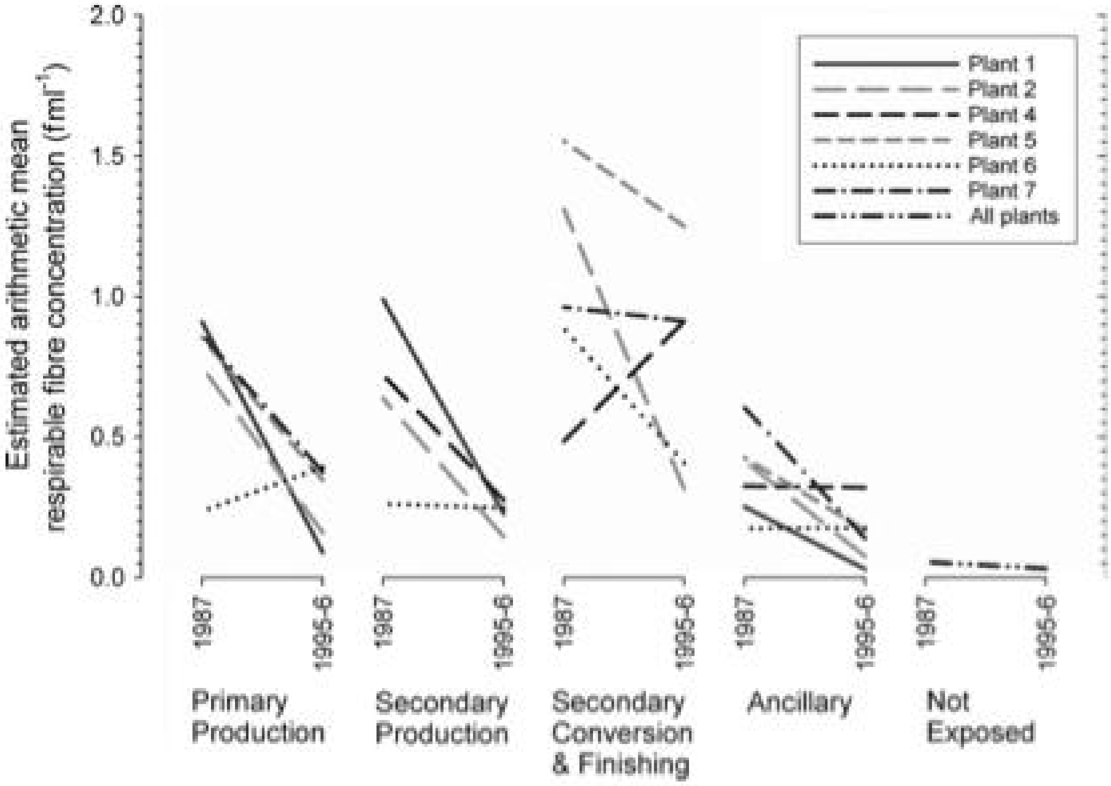


Figure 2.4 Change in estimated arithmetic average exposure level 1987 to 1995/6 - from Miller *et al* (2007)

Monitoring under the CARE program continued for at least 9 years. Data from the 9th year of monitoring (2007) is not available for comparison with 1996 data however, the ECFIA document *Recognition and Control of Exposure to Refractory Ceramic Fibres* includes geometric mean (GM) exposure concentrations for each functional job category calculated using data over all nine years of monitoring (1998 – 2007) (EFCIA, 2009). The results indicate that average exposures decreased over the monitoring period as GM concentrations in 1996 are generally higher than GM exposures pooled over all years of monitoring. The largest reduction was seen in removal. Bar charts showing GM exposure for 1996 data and for 1996 – 2007 data are shown in Figure 2.5 and Figure 2.6. Data in both charts are uncorrected for respirator usage. The bar chart for 1996 – 2007 data includes an additional FJC: Modules. This FJC includes all tasks related to creating RCF modules from pre-cut or pleated blankets including folding, trimming, and attaching hardware. These tasks were previously distributed in different FJCs including Mixing/Forming, Finishing and Installation.

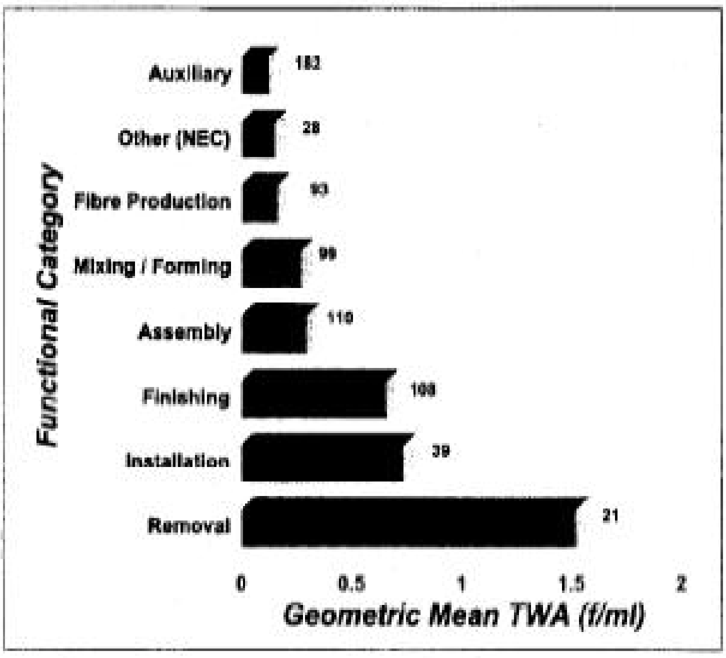


Figure 2.5 Geometric Mean TWA Exposure Levels Per Functional Job Category Measured under the CARE Program 1996 – 1997 (numbers beside bars represent the number of observations) from Maxim *et al* (1998)

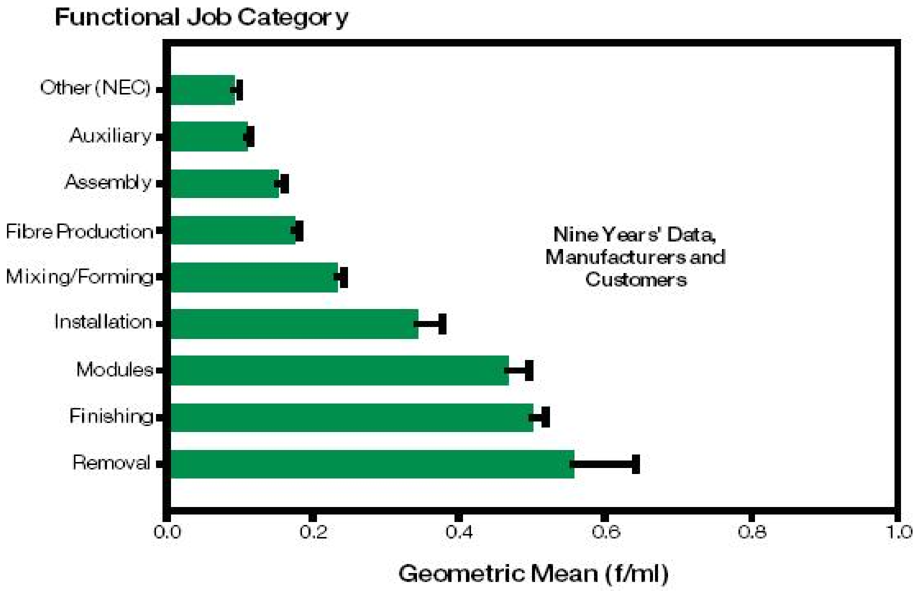


Figure 2.6 Geometric Mean TWA Exposure Levels Per Functional Job Category Measured under the CARE Program 1996 – 2007 from ECFIA (2009)

Data from the US study on which CARE was modelled showed a decline in overall average RCF concentrations from 1.15 fibres/ml in 1990 to 0.3 fibres/ml in 1998 in downstream use facilities and from 0.45 fibres/ml in 1990 to 0.25 fibres/ml in 1998 in

RCF manufacturing facilities. NIOSH has estimated that exposures have decreased by nearly two orders of magnitude in the US over the past 20 years (NIOSH, 2006). An exponential regression equation of the form $y = a.e^{-bx}$ was fitted to the 1990 and 1998 values in both downstream and manufacturing facilities to calculate the average annual change in concentration over the period from 1990 to 1998. The temporal trends were expressed as the annual change in arithmetic mean concentration using the following expression:

$$\% \text{ change per year} = 100 * (\exp[b] - 1)$$

Over the period 1990 – 1998 an annual decline in RCF concentrations of 15.5% was calculated for downstream use facilities in the US and an annual decline of 7.1% was calculated for RCF manufacturing facilities in the US. The increased rate of decline in downstream use facilities relative to manufacturing facilities has meant that average exposure concentrations in US downstream use facilities were close to those seen in US manufacturing facilities in 1998. The rate of decline in downstream use facilities has likely slowed since 1998 to a rate similar to the 7.1% annual decline seen in manufacturing facilities. Although RCF concentrations in Europe have typically been higher than those in the US, trends in exposure in Europe have resembled US trends. European and America manufacturers have been working together since the 1990's to reduce exposures so these trends are probably also representative of Europe and a reduction of approximately 7% per year since the late 1990's is a reasonable estimate of the trend in RCF exposure. Exposure prior to the late 1990s reduced more quickly in the British manufacturing plants and there were some increases in exposure in some areas at other manufacturing sites, but this was all part of a process of exposures within the industry converging.

In addition to reducing mean exposures the variation around the mean may also have been decreased. US data from 1998 (year five of their five year monitoring program) showed a geometric mean concentration of 0.18 fibres/ml (geometric standard deviation 3.12) in RCF manufacturing and a geometric mean concentration of 0.13 fibres/ml (geometric standard deviation 5.83) among downstream users . These data were uncorrected for respirator use. Current European geometric mean concentrations are likely at or below these levels, and, when corrected for respirator use, even lower (Maxim *et al*, 1998). Typical current EU exposure levels estimated by ECFIA ranged from <0.1 fibres/ml to 0.6 fibres/ml for different industry sectors indicating that that GMs of 0.18 fibres/ml and 0.13 fibres/ml for manufacturing and downstream use respectively are within the appropriate range. The results of a study of RCF exposures in the Finnish metal industry in 2004 and 2005 support this conclusion. RCF concentrations in personal samples taken during normal operations in steel plants and foundries were all below 0.50 fibres/ml. During furnace maintenance that involved removal and installation of furnace insulation, concentrations ranged from 0.1 fibres/ml to 14 fibres/ml (respiratory protection was always used during this work) (Linnainmaa et la, 2007).

The exposure distribution for both manufacturing and downstream use was estimated using a Monte Carlo simulation based on a GM of 0.18 fibres/ml and a GSD of 3.12 for manufacturing and a GM of 0.13 fibres/ml and a GSD of 5.83 for downstream use. It was estimated that with these exposure distributions 6.6% of workers in manufacturing facilities and 12.4% of workers at downstream user facilities would have been exposed above 1 fibres/ml. It was estimated that 69.7% of workers in manufacturing and 55.9% of workers in downstream use would be exposed above 0.1 fibres/ml. This estimate indicates that if US 1998 exposure levels are assumed to be representative of current EU exposure levels, exposure reductions would be required in both manufacturing and downstream use to meet an OEL of 1 fibres/ml and substantial exposure reductions would be required to meet an OEL of 0.1 fibres/ml.

2.4 HEALTH IMPACT FROM CURRENT EXPOSURES

2.4.1 Background data

It has been assumed there is only a potential risk of lung cancer associated with exposure to refractory ceramic fibres. Table 2.4 summarises the information used for the health impact assessment.

Table 2.4 Occupational cancers associated with exposure to Refractory ceramic fibres

Cancer site	**Lung Cancer**	
ICD-10 code	C33-C34	
IARC group for carcinogen	2B	
Strength of evidence for cancer site [(1)]	-	
Latency assumption	10-50 yrs	
Source of forecast numbers - deaths	Eurostat, 2006 (for C32-C34)	
Source of forecast numbers - registrations	GLOBOCAN, 2002[7]	
Exposure levels	Relative Risk (RR)	Source of RR
"High"	1.102 (1.044-1.164)	Chrysotile study (2010)
"Low"	1	default

[(1)] Based on Siemiatycki *et al*, 2004

2.4.2 Exposed numbers and exposure levels

Industry sectors, their NACE codes, classifications to High/Medium/Low/Background exposure as applicable for the mid 1970's and numbers exposed in 2006 are given in the previous section on the exposure. The estimated average exposure level (GM) and measure of variability (GSD) for functional job categories exposed to refractory ceramic fibres are a GM of 0.18 fibres/ml and a GSD of 3.12 for manufacturing and a GM of 0.13 fibres/ml and a GSD of 5.83 for downstream use for 2010.

We present data for a "baseline" scenario which for all industries assumes a 7% annual decline in exposure levels and standard change in employed numbers up to the 2021-30 estimation interval and constant levels thereafter.

Only France, Germany and the UK are represented in the results for manufacturing industry. In the absence of country specific numbers exposed for downstream use, no country specific data is presented.

[7] IARC, GLOBOCAN database, available at: http://www-dep.iarc.fr/globocan/database.htm

2.4.3 Forecast cancer numbers

Separate estimates for total numbers of deaths for lung (C32-C34) cancer by age band are available from EUROSTAT for the 27 countries of the EU, for 2006, and for registrations for lung cancer from GLOBOCAN for 2002. The forecast numbers of deaths and registrations by country used to estimate attributable numbers are in Appendix 8.1.

2.4.4 Results

The cancer deaths and registrations attributed to occupational exposure to refractory ceramic fibres for the baseline scenario are presented per year for the target years given and are based on the all working age cohort of currently (2006) exposed workers. Attributable fractions and numbers of deaths and registrations, and Years of Life Lost (YLLs), Years Lived with Disability (YLDs) and Disability Adjusted Life Years (DALYs), are estimated.

As the exposure data suggests that exposure declines over time, a dynamic baseline scenario has been used.

A summary of the results for the total EU is in Table 2.5 below. These data are shown separately for the manufacturing and downstream user sectors.

Table 2.5 Results for the baseline forecast scenario, total EU (27 countries), refractory ceramic fibres, men plus women[8]

Scenario	All scenarios		Baseline (trend) scenario (1) - Current (2005) employment and exposure levels are maintained			
EU Total	*2010*	*2020*	*2030*	*2040*	*2050*	*2060*
Manufacture						
Numbers ever exposed	3,039	2,896	2,721	2,543	2,385	2,303
Proportion of the population exposed	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lung cancer						
Attributable fraction	0.00007%	0.00005%	0.00002%	0.00001%	0.00000%	0.00000%
Attributable deaths	0	0	0	0	0	0
Attributable registrations	0	0	0	0	0	0
'Avoided' cancers						
YLLs	3	2	1	0	0	0
DALYs	3	2	1	0	0	0
Downstream Use						
Numbers ever exposed	31,704	32,354	33,134	33,106	33,072	33,072
Proportion of the population exposed	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%
Lung cancer						
Attributable fraction	0.00059%	0.00045%	0.00029%	0.00016%	0.00008%	0.00004%
Attributable deaths	2	1	1	1	0	0
Attributable registrations	2	2	1	1	0	0
'Avoided' cancers						
YLLs	25	22	15	9	4	2
DALYs	26	23	16	9	4	2

[8] Deaths and registrations are rounded to the nearest whole number. Where YLLs/YLDs/DALYs appear in association with zero deaths/registrations, this is due to rounding the deaths/registrations down to zero.

The attributable deaths from previous RCF exposures in the EU in 2010 were small for both manufacture and downstream use, with less than one attributable lung cancer death for manufacture and an estimated 2 lung cancer deaths for downstream use. The estimated deaths and cancer registrations are expected to remain constant over the next 50 years for manufacture and to decrease over the following 50 years for downstream use with less than one attributable lung cancer death predicted to occur in 2060. The corresponding estimated attributable fraction (AF) for lung cancer decreases from 0.00007% in 2010 to 0.00000% in 2060 for manufacture and from 0.00059% in 2010 to 0.00004% in 2060 for downstream use. DALYs also decrease in the baseline scenario – from 3 years in 2010 to 0 years in 2060 for manufacture and 26 years in 2010 to 2 years in 2060 for downstream use.

2.5 POSSIBLE COSTS ASSOCIATED WITH NOT MODIFYING THE DIRECTIVE

2.5.1 Health impacts – possible costs under the baseline scenario

Introduction

The health data (cancer registrations and Years of Life Lost - 'YLL') for the baseline in which there are no further modifications to the Carcinogens Directive are shown in section 2.4 of this report. These data include the number of cancer registrations and YLLs from lung cancer resulting from predicted future exposure to RCF. There is predicted to be a decline in registrations and YLLs over time as a result of predicted exposure reduction owing to implementation of existing and ongoing risk management measures across the EU.

Method in brief

Using the health data (cancer registrations and Years of Life Lost - 'YLL'), it is possible to monetise the costs under the baseline by estimating the:

- Life years lost – This is calculated by using the YLL and multiplying this by a valuation of the Value of Life Year Lost (VLYL). This gives a value for the time (in years) lost as a result of premature death.
- Cost of Illness (COI) –This is a monetary cost of the time spent with cancer. In this study, a unit COI estimate is multiplied by the number of cancer registrations, give a total value for COI. (COI is often the main market-based approach in relation to health impact[9]). COI includes the direct and indirect costs of cancer but not the intangible costs (see below).
- Willingness to Pay (WTP) to avoid cancer – WTP in this study is used as an alternative method (high cost scenario) based on publicly available, peer reviewed studies on what people would be willing to pay to avoid having cancer. This includes various intangible costs (such as disfigurement, functional limitations, pain and fear) and includes the costs associated with life years lost.

[9] ECHA (2008) "Applying SEA as part of restriction proposals under REACH" Available at: http://echa.europa.eu/doc/reach/sea_workshop_proceedings_20081021.pdf

The cost variables used in this study are presented in Table 2.6 in 2010 prices. For the purposes of this study, valuations are increased by 2% each year in the future in part to present costs in real terms (i.e. adjusting for inflation in prices) and to reflect the increasing value society attaches to its health (as economic growth typically increases over a long period of time)[10].

Table 2.6 Summary of cost variables used in this study (€ 2010 prices)

Cost/benefit elements	Low scenario	High scenario
VLYL - Each year lost	€ 50,393	€ 0 (note 1)
COI or WTP - Unit cost (per cancer registration)	€ 49,302 (COI)	€ 1,793,776 (WTP)
(Note 1) – By using WTP (€1.8m) in the high scenario instead of COI, the WTP can include the costs of premature death and therefore there was a risk of double counting benefits if VLYL costs were included.		

All costs and benefits over time in this study are discounted using a 4% discount rate as recommended by the European Commission's Impact Guidelines[11]. In order to assess the effect that discounting has on the results ('sensitivity analysis'), we have also presented estimates that take into consideration a declining discount rate for impacts occurring after 30 years and no discounting.

The health data shown in section 2.4 are 'snap-shots' (i.e. an estimation for the initial year of a ten year period) of the number of cancer registrations, deaths, YLLs in future years at 10 year intervals. In calculating the costs associated with these effects, each 'snap-shot' result is multiplied by 10 in order to derive an estimate for the whole assessment time period (for example, 2020 results are multiplied by 10 to give results over the period 2020-2029). This assumes that each snap-shot year is representative of the following 10 years.

The method to valuing health benefits is explained in more detail in the method paper titled *"Valuing health benefits – Method paper".*

Results

The health costs under the baseline scenario are presented in Table 2.7 and are predicted to decline over time. In Section 2.4 the number of cancer registrations and YLLs are estimated to decline over time, accounted for by risk management measures (RMMs) already imposed (as applied at production and end use) over the past 10-20 years.

The introduction of an EU-wide OEL is not expected to have a significant impact in the short term given that the main Member States already have a national OEL in place (the stringency varies by Member State). Table 2.7 sets out the ranges of health costs for each representative decade based on the above method. The ranges are based on the high and low cost scenarios (see Table 2.6). The results are also illustrated in Figure 2.7.

[10] This is consistent with some other European Commission studies and is standard practice for air quality under the Clean Air for Europe (CAFE) programme.
[11] European Commission impact Assessment Guidelines (Jan 2009) - http://ec.europa.eu/governance/impact/commission_guidelines/docs/iag_2009_en.pdf

Table 2.7 Health costs - baseline scenario – 2010 to 2070 (Present Value – 2010 €m prices)

Costs by Gender (€m)	2010-2019	2020-2029	2030-2039	2040-2049	2050-2059	2060-2069	Total
Total	14 to 34	10 to 24	5 to 14	3 to 7	1 to 3	0 to 1	33 to 83

Notes:
- All costs are presented in present value using a discount rate of 4%. The low range is based on low estimates for costs of illness and life years lost. The upper range of costs relate to WTP estimates to avoid having cancer, which include intangible costs associated with having cancer.
- Totals are based on exposures to males only so no male and female breakdown is provided.

There is insufficient data to provide a breakdown by Member State. RCF/ASW is only manufactured in three member States (France, UK and Germany, and previously in Poland and the Czech Republic, so exposure from manufacture will be limited to these Member States. However, exposure from use and disposal (e.g. from insulation in furnaces), whilst limited to certain occupational groups, may be located across Europe.

The occupational type estimated to be most affected under the baseline is during installation. There are also notable health costs resulting from the finishing and removal phase. This is shown in Figure 2.9, which shows the total health costs over the period 2010 to 2070.

Detailed tables are included in Appendix 8.2.

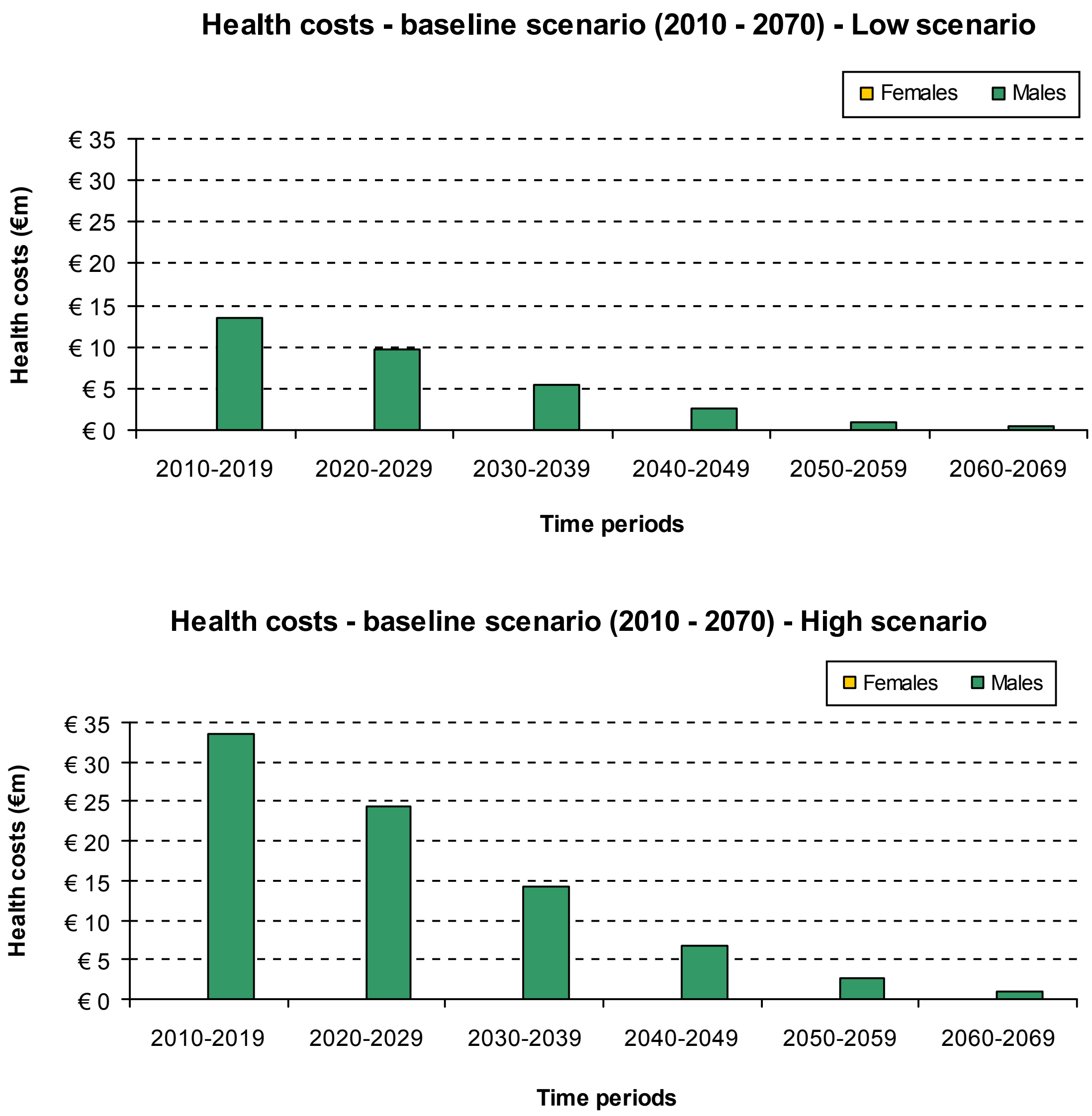


Figure 2.7 Health costs - baseline scenario – 2010 to 2070 (Present Value – 2010 €m prices)

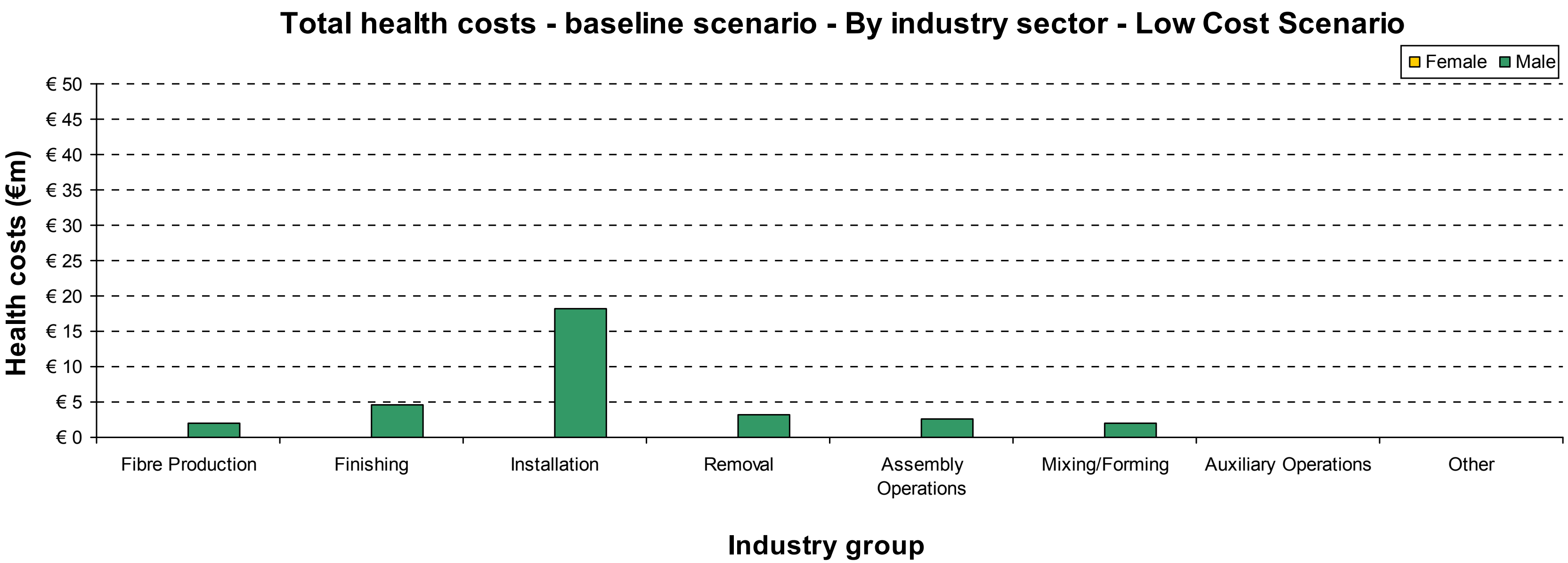


Figure 2.8a Total health costs - baseline scenario - by industry group (Present Value – 2010 €m prices)

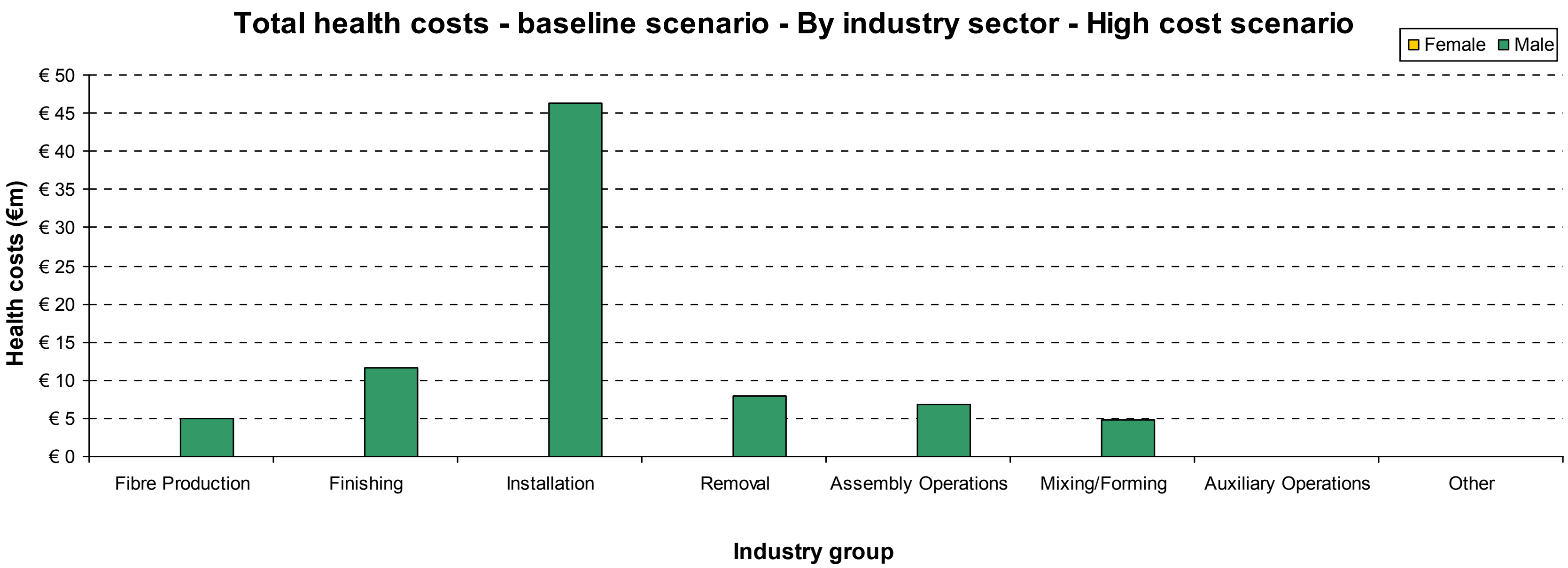
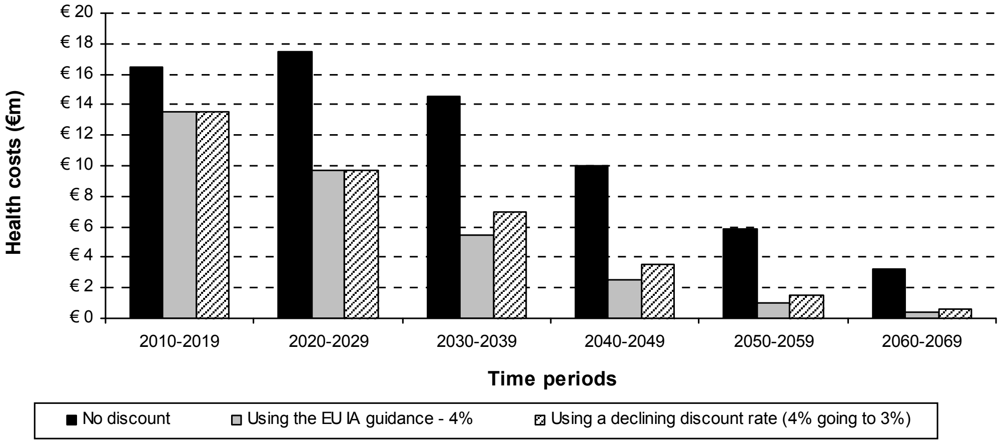


Figure 2.9b Total health costs - baseline scenario - by industry group (Present Value – 2010 €m prices)

In order to present all socio-economic costs and benefits consistently in present value terms, all future costs and benefits have been discounted. The primary approach was to apply the European Commission IA recommended 4% discount rate. Since most health impacts occur over a long period of time relative to costs, the impacts of discounting are significant.

In Figure 2.10, the effects of different discount rates on the overall results are shown, indicating that the impacts of discounting become more pronounced the further in the future that the impact occurs. As the number of registrations and YLLs decline over time, the difference between using discounting and with no discounting can become less evident. However, when there are more significant registrations and YLLs (as seen in years between 2010 and 2030) the impacts of discounting become more apparent.

Health costs - baseline scenario - Effect of using different discount rates - Low cost scenario



Health costs - baseline scenario - Effect of using different discount rates - High cost sccneario

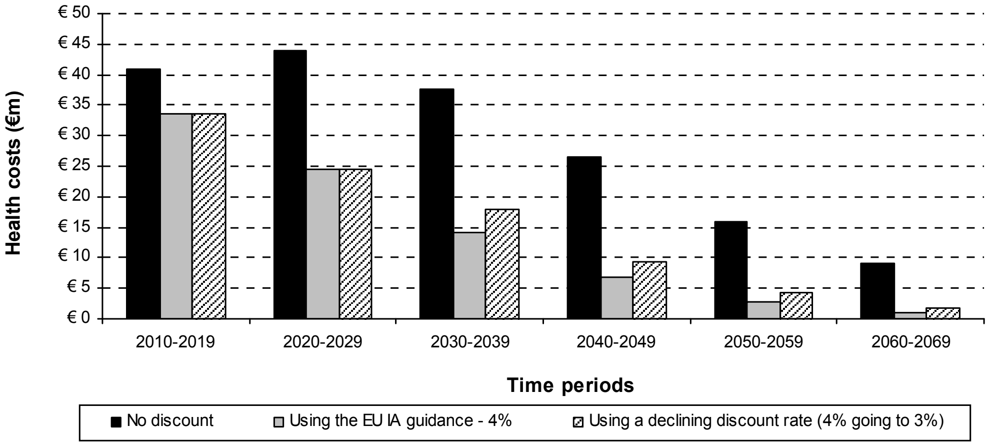


Figure 2.10 Impacts of discounting

3 POLICY OPTIONS

3.1 DESCRIPTION OF MEASURES

In addition to reductions in levels of exposure, the prevalence of exposure to RCF has been reduced substantially through substitution with the mineral wool Alkaline-Earth Silicate Glass Wool (AES), and this trend is expected to increase in coming years. Current use of AES has been restricted by the maximum tolerable temperature. RCF tolerates higher temperatures than AES, but continuing product development of AES has increased the maximum tolerable temperature and the gap between the maximum temperatures tolerated by AES and RCF is narrowing (EFCIA, 2009). As the maximum tolerable temperature of AES has been increased, further increases in the maximum tolerable temperature have become more difficult to achieve and the rate of substitution of RCF with AES may slow down.[12]

The NIOSH publication *Criteria for a Recommended Standard: Occupational Exposure to Refractory Ceramic Fibers* states that the use of appropriate engineering controls and work practices can reduce RCF exposure to below 0.5 fibres/ml in most functional job categories. It is difficult to consistently maintain exposures below 1 fibres/ml in finishing and removal of RCF products through the use of engineering controls and work practices, although with the use of respiratory protective equipment time weighted average exposures can be maintained below 1 fibres/ml (NIOSH, 2006). Controlling exposure below 0.1 fibres/ml would require complete containment and automation of all processes involving RCF. This is not practicable in many downstream user situations such as furnace demolition.

ECFIA has also recommended control strategies for work with RCF in their document *Recognition and Control of Exposure to Refractory Ceramic Fibres*. These controls include the following:

- use of dust suppressants;
- wetting products with water prior to and during handling;
- enclosure of sources of exposure using physical or airflow barriers;
- limiting the workers involved in work with RCF or present in a room during work with RCF;
- automation of dust generating processes;
- the use of local exhaust ventilation designed to capture dust at the source;
- cleaning work areas HEPA filtered vacuums, wet vacuums and/or wet sweeping; and
- the use of respiratory protection during short-term, high exposure tasks;

The document also includes specific control procedures for downstream uses of RCF including processing of RCF products and use in furnaces (EFCIA, 2009).

The American organisation Refractory Ceramic Fibers Coalition (RCFC) has also reported that the use of hand tools during drilling, sawing and sanding of RCF instead of power tools can reduce exposure by up to 90% during these tasks. However, they

[12] AFSSET (2007) Les fibres minérals artificielles siliceuses.

may increase the risk of musculoskeletal disorders so ergonomic design should be considered carefully when changing from power tools to hand tools (NIOSH, 2006).

In their Regulatory Impact Assessment for the Maximum Exposure Limit for Refractory Ceramic Fibres, the UK Health and Safety Executive (HSE) estimated the costs associated with implementing a maximum exposure limit of 1 fibres/ml in the UK (HSE, 2002). The estimates were derived by determining the controls that would be required to reduce exposures (based on the exposure levels reported by CARE from 1996 – 2000) below 1 fibres/ml in all functional job categories. The level of increased control predicted by HSE to reduce exposures below 1 fibres/ml is summarised in Table 3.1.

Table 3.1 Predicted level of control required to reduce UK RCF exposures to below 1 fibres/ml by Functional Job Category (based on 1996 – 2000 exposure levels)

Functional Job Category	Measures required to reduce exposure to 1 fibres/ml
Production	Estimated that there would be no additional cost associated with reducing exposure
Mixing-forming	Increased engineering control at 12% of sites
Modules	Estimated that there would be no additional cost associated with reducing exposure
Finishing	Increased monitoring at 49% of sites Increased engineering controls at 49% of sites
Assembly	Increased monitoring at 7% of sites Increased engineering controls at 75% of sites
Installation	Estimated that there would be no additional cost associated with reducing exposure
Removal	Additional respiratory protection at 20% of sites Increased fibre wetting and local exhaust ventilation at many sites (not quantified)
Other	Estimated that there would be no additional cost associated with reducing exposure

Source: HSE (2002) Maximum Exposure Limit for Refractory Ceramic Fibres (RCFs): Regulatory Impact Assessment

4 ANALYSIS OF IMPACTS

4.1 HEALTH IMPACTS FROM CHANGES TO THE EU DIRECTIVE

4.1.1 Health information

For refractory ceramic fibres, OELs of 0.1 and 1 fibres/ml are to be tested. Lung cancer numbers will therefore be estimated assuming full compliance[13] with these OELs. The baseline for all industries assumes an annual decline of 7% in exposure levels as described above and standard change in employed numbers up to the 2021-30 estimation interval and constant levels thereafter.

We present data for two "intervention" scenarios as described in Table 4.1 below, compared to the baseline scenario described in section 2.4.1.

Table 4.1 Baseline and intervention scenarios

Intervention scenarios[(1)]	
Baseline scenario (1)	Current (2005) employment and exposure levels are maintained.
Intervention scenario (2)	Full compliance for OEL = 1 fibres/ml
Intervention scenario (2)	Full compliance for OEL = 0.1 fibres/ml

(1) All intervention scenarios are estimated as change to (1) the baseline scenario

Results for the baseline scenario (1) and intervention scenarios compared to the baseline scenario are in Figure 4.1 (attributable registrations), Figure 4.2 (attributable fraction) and Figure 4.3 (DALYs) for men for the total EU (27 countries) for bladder cancer estimated for refractory ceramic fibres exposure. A summary of the results for bladder cancer for the total EU is in Table 4.2 below. Due to cancer latency, no effect is seen from interventions in 2010 until 2030.

Introducing a 0.1 fibres/ml OEL in 2010 for refractory ceramic fibres exposure will reduce total cancer numbers but only by 1 case in 2060, whereas the OEL of 1 fibres/ml has no impact compared to the predicted baseline results.

[13] Full compliance is assumed in the intervention scenarios; however, due to modelling restrictions full compliance is modelled as 99% compliance.

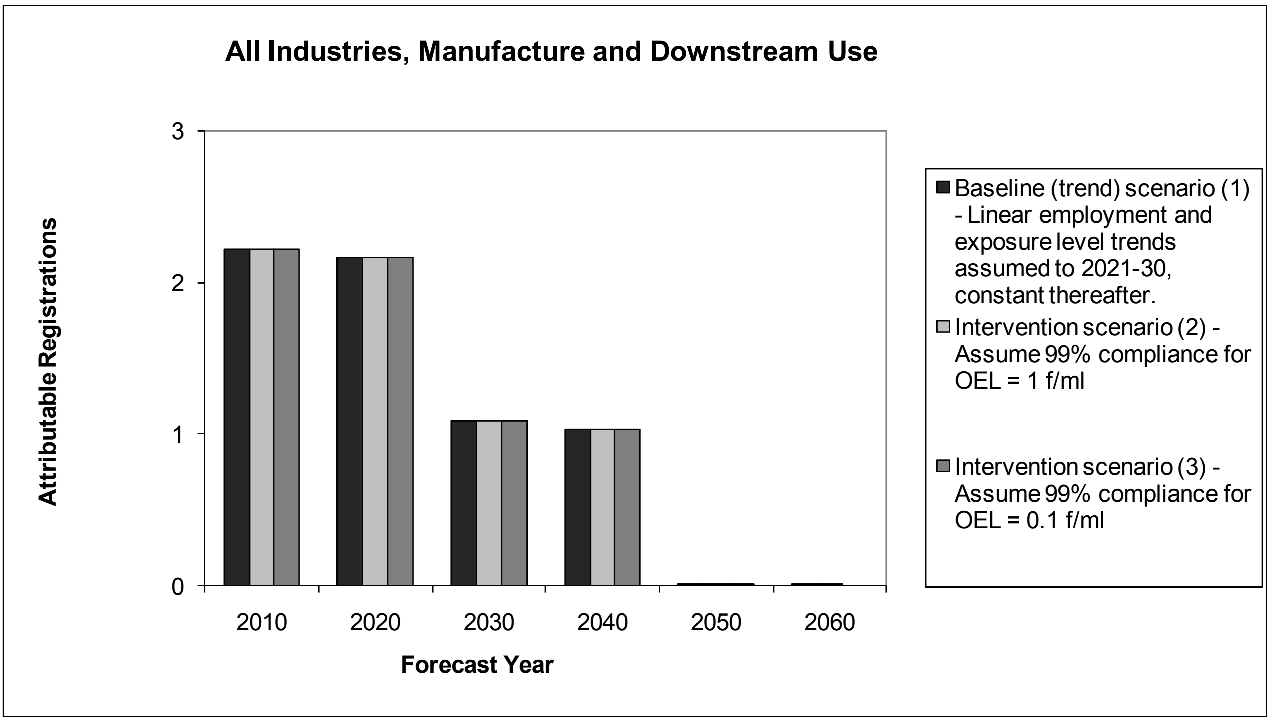


Figure 4.1 Results for intervention scenarios compared to the baseline scenario (1) – Occupation Attributable cancer registrations, Lung cancer from exposure to refractory ceramic fibres

Figure 4.1 shows the number of registrations for lung cancer attributable to RCF exposure steadily decreasing for the baseline and two intervention scenarios over the next 50 years.

Figure 4.2 shows that the attributable fraction (AF) decreases over the period up to 2060. For both the baseline and two intervention scenarios, the attributable fraction decreases from just under 0.0007% in 2010 to below 0.0001% in 2060.

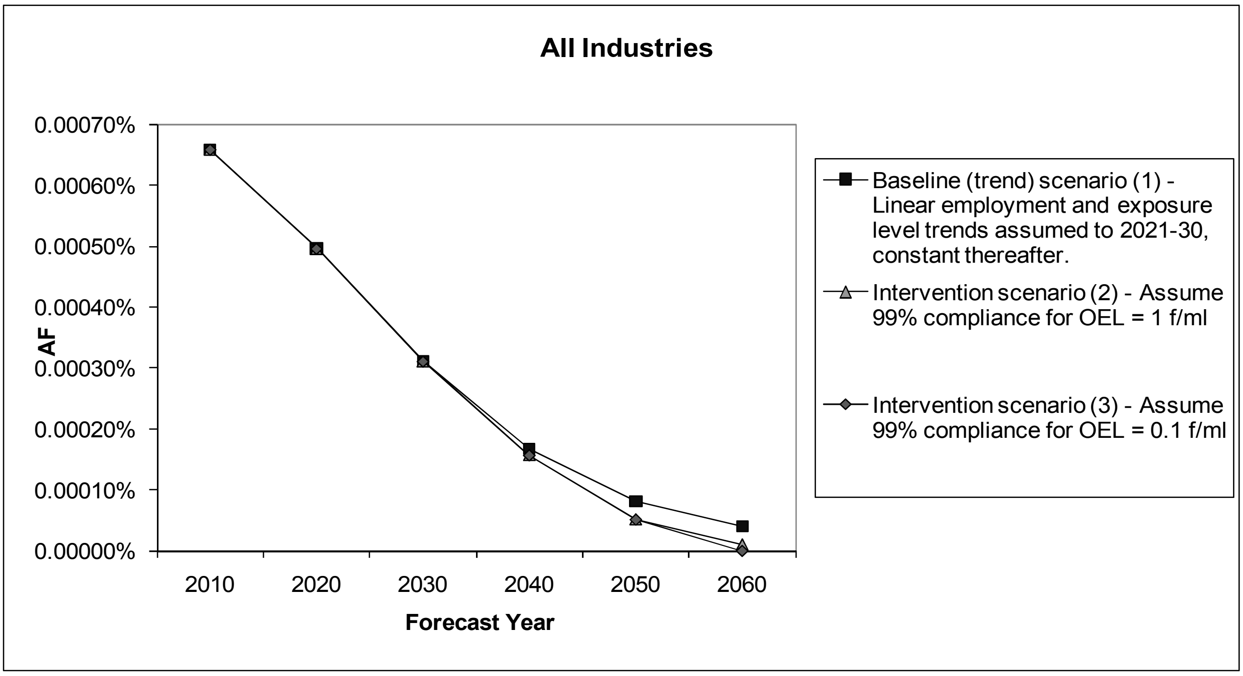


Figure 4.2 Occupation Attributable Fractions, Lung cancer from exposure to refractory ceramic fibres

The estimated DALYs decreases from about just under 30 years in 2010 to less than 5 years in 2060 for the baseline and two intervention scenarios (Figure 4.3).

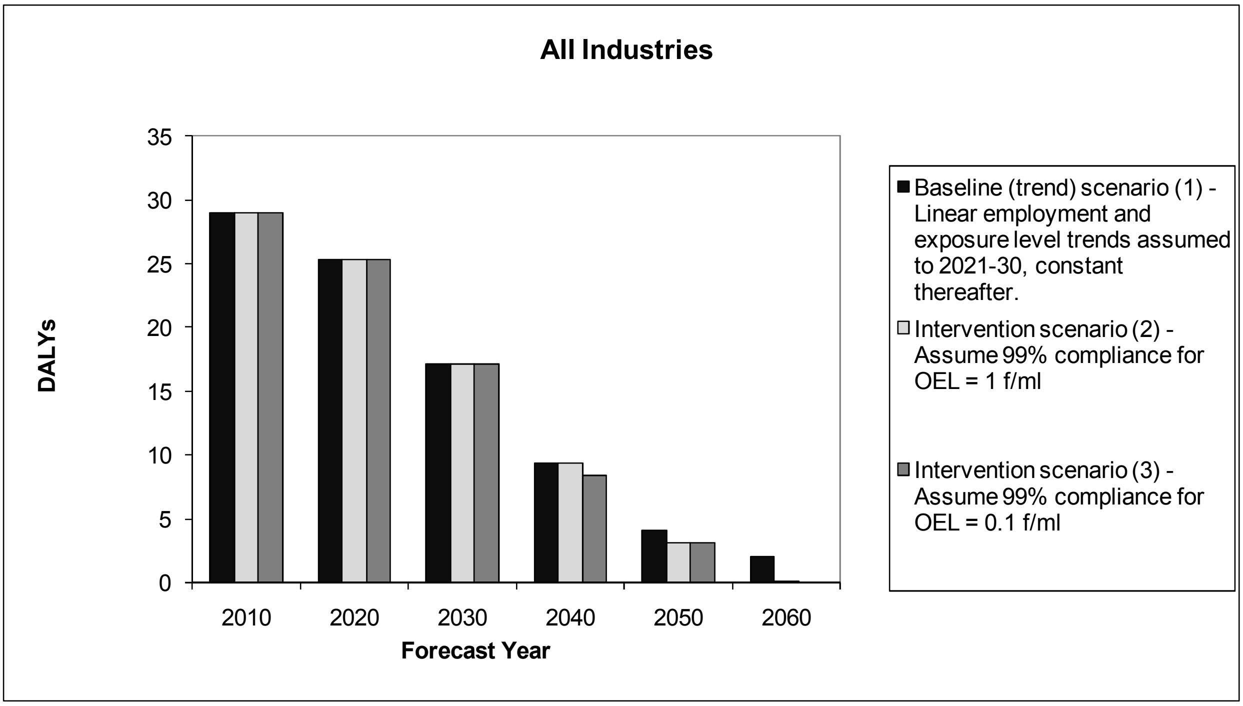


Figure 4.3 Occupation Attributable DALYs, Lung cancer from exposure to refractory ceramic fibres

Table 4.2 summarises the data shown in the previous figures. The data for the first two time periods (2010, 2020) are identical for all scenarios, and then the data for the two intervention scenarios are shown in the two groups of four columns (2030-2060). For manufacturing, attributable lung cancer deaths remain constant with less than one death in 2010 and less than one death predicted in 2060 for both intervention scenarios (2) and (3) (full compliance with 1 fibres/ml and full compliance of 0.1 fibres/ml). For downstream use, the number of attributable lung cancer deaths decreases from two in 2010 to less than one in 2060 for the both of the intervention scenarios (2) and (3) (full compliance with 1 fibres/ml and full compliance with 0.1 fibres/ml).

In Table 8.3.1 in the Appendix 8.3 are the estimated proportions exposed above the OELs to be tested, currently and as estimated under the baseline scenario (1). Under the alternative change scenarios they behave as determined by the scenarios.

Full results are given in Appendix 8.3 for men by country for manufacturing in Tables 8.3.2 and 8.3.3. A breakdown of attributable numbers for the manufacturing industry is in Tables 8.3.4 and 8.3.5 and a breakdown of attributable numbers for downstream users is in Tables 8.3.6 and 8.3.7. Estimates of numbers of cancer registrations 'avoided' in each of the forecast target years from 2030 onwards relative to the baseline scenario can be obtained by subtraction.

Table 4.2 Results for the intervention scenarios, total EU (27 countries), men plus women[14]

Scenario	All scenarios		Intervention scenario (2) - Assume 99% compliance for OEL = 1 fibres/ml				Intervention scenario (3) - Assume 99% compliance for OEL = 0.1 fibres/ml			
EU Total	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**2030**	**2040**	**2050**	**2060**
Manufacture										
Numbers ever exposed	3,039	2,896	2,721	2,543	2,385	2,303	2,721	2,543	2,385	2,303
Proportion of the population exposed (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lung cancer										
Attributable Fraction (%)	0.00007	0.00005	0.00002	0.00001	0.00000	0.00000	0.00002	0.00001	0.00000	0.00000
Attributable deaths	0	0	0	0	0	0	0	0	0	0
Attributable registrations	0	0	0	0	0	0	0	0	0	0
'Avoided' cancers[15]			0	0	0	0	0	0	0	0
YLLs	3	2	1	0	0	0	1	0	0	0
DALYs	3	2	1	0	0	0	1	0	0	0
Downstream Use										
Numbers ever exposed	31,704	32,354	33,134	33,106	33,072	33,072	33,134	33,106	33,072	33,072
Proportion of the population exposed (%)	0.01%	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Lung cancer										
Attributable Fraction (%)	0.00059	0.00045	0.00029	0.00015	0.00005	0.00001	0.00029	0.00015	0.00005	0.00000
Attributable deaths	2	1	1	1	0	0	1	1	0	0
Attributable registrations	2	2	1	1	0	0	1	1	0	0
'Avoided' cancers			0	0	0	0	0	0	0	0
YLLs	25	22	15	8	3	0	15	8	3	0
DALYs	26	23	16	9	3	0	16	8	3	0

4.1.2 Monetised health benefits

The possible health benefits (i.e. avoided healthcare costs and effects of having cancer) for the introduction of an EU wide OEL at 1fibres/ml and 0.1fibres/ml are shown in Table 4.3.

[14] Deaths and registrations are rounded to the nearest whole number. Where YLLs/YLDs/DALYs appear in association with zero deaths/registrations, this is due to rounding the deaths/registrations down to zero.

[15] A negative value for 'avoided' cancers can occur where the assumption of 99% compliance is lower than the compliance actually achieved due to the forecast (baseline) fall in exposure levels (see table of proportions exposed above the OELs under the baseline scenario used). In these cases zero 'avoided' cancers substituted for the negative value is correct, if 'at least 99% compliance' is used in the scenario description.

The benefits of introducing an OEL in 2010 are limited and only apparent from 2040 onwards. There is estimated to be little additional benefit to introducing a more stringent OEL at 0.1 fibres/ml compared to an OEL at 1 fibres/ml. The impacts of introducing an OEL are estimated to have limited benefits as there is already estimated to be a reduction on average below 1 fibres/ml and below under the baseline scenario and because there is limited evidence to link exposure to RCF to cancer. The results are also illustrated in Figure 4.4.

Table 4.3 Health benefits of intervention over time (Present Value – 2010 €m prices)

Costs by Gender (€m)	**2010-2019**	**2020-2029**	**2030-2039**	**2040-2049**	**2050-2059**	**2060-2069**	**Totals**
Intervention option 1 - Introduce OEL at 1 fibres/ml							
Female	-	-	-	-	-	-	-
Male	0 to 0	0 to 0	0 to 0	0.2 to 0.4	0.3 to 0.9	0.3 to 0.9	0.8 to 2.3
Total	0 to 0	0 to 0	0 to 0	0.2 to 0.4	0.3 to 0.9	0.3 to 0.9	0.8 to 2.3
Intervention option 2 - Introduce OEL = 0.1 fibres/ml							
Female	-	-	-	-	-	-	-
Male	0 to 0	0 to 0	0 to 0	0.2 to 0.5	0.4 to 1	0.4 to 1	1 to 2.6
Total	0 to 0	0 to 0	0 to 0	0.2 to 0.5	0.4 to 1	0.4 to 1	1 to 2.6

Notes:
- All costs are presented in present value using a discount rate of 4%

Given that there is not a significant difference over time in terms of the health benefits from an OEL at 1 fibres/ml and 0.1 fibres/ml, it reasonable to estimate that the SCOEL recommendation of 0.3 fibres/ml would have health benefits in the region of €0.8m-€2.5m over the period 2010-69.

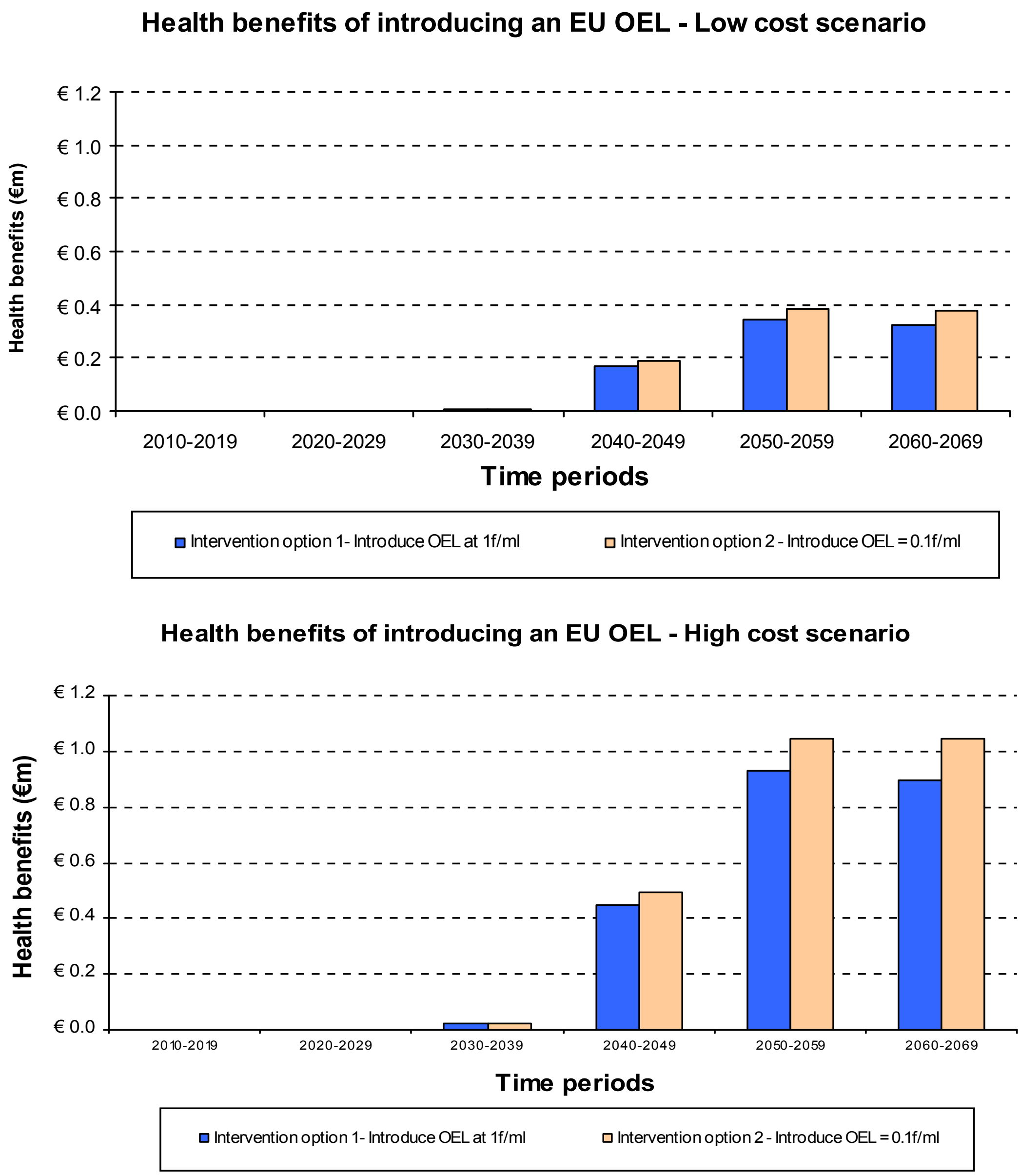


Figure 4.4 Health benefits over time of introducing an EU wide OEL (Present Value – 2010 €m prices)

Similarly to the baseline scenario, there is insufficient data to provide a breakdown by Member State. The monetised benefits of a revised OEL for RCF are likely to affect men more than women given the industrial sectors most exposed to RCF. The occupational group estimated to benefit most from a revised OEL (and full compliance[16]) is installation of RCF/ASW. This is shown in Figure 4.5 (low scenario) and Figure 4.6 (high scenario).

[16] The assumption of full compliance is a standard assumption used in EU Impact Assessments.

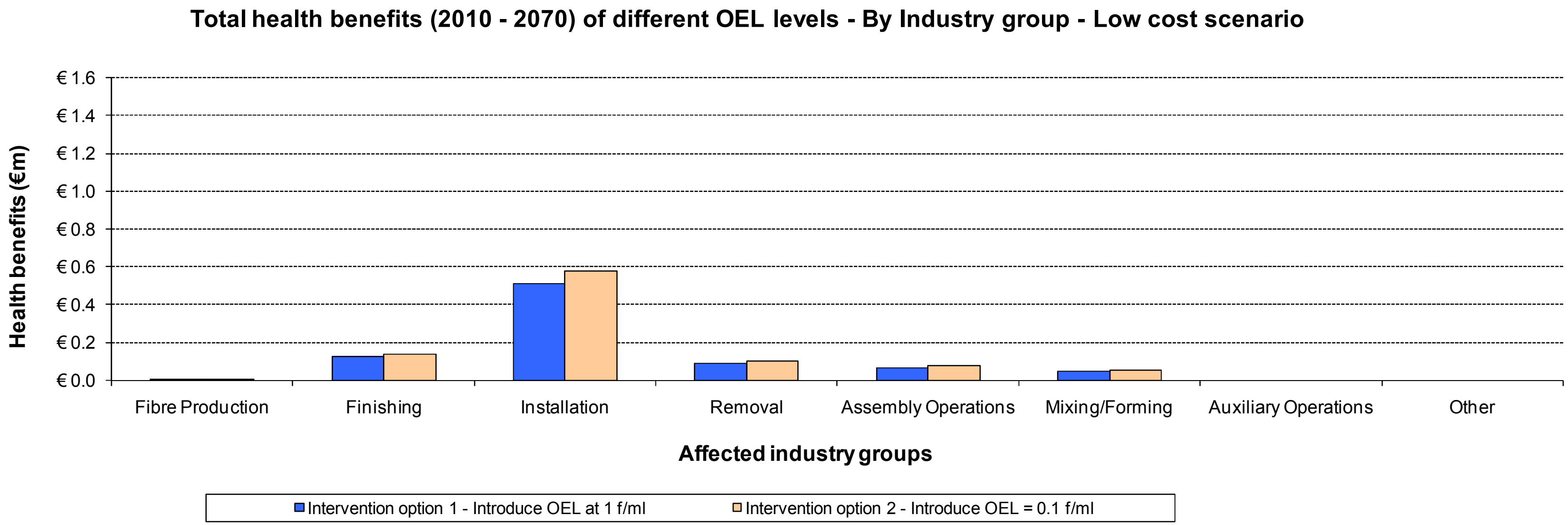


Figure 4.5 Total health benefits of introducing an EU wide OEL – By Industry Group – Low Scenario (Present Value – 2010 €m prices)

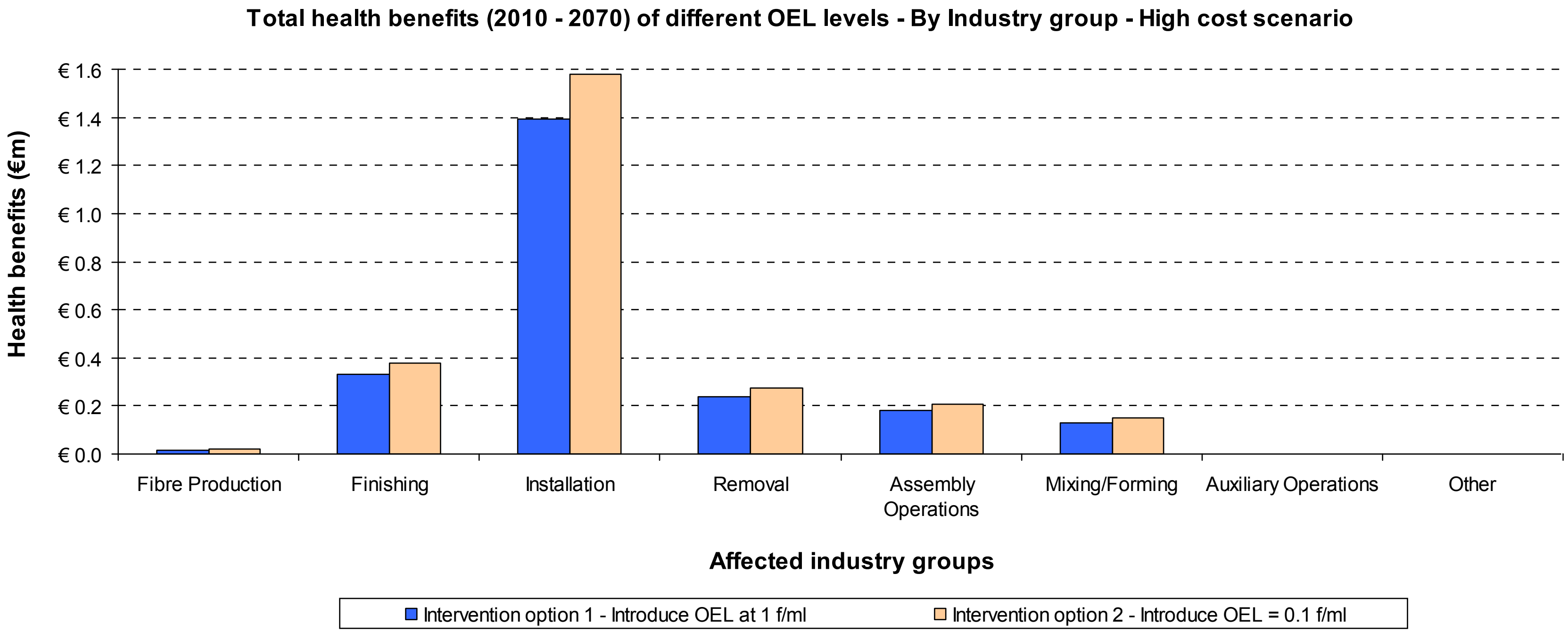
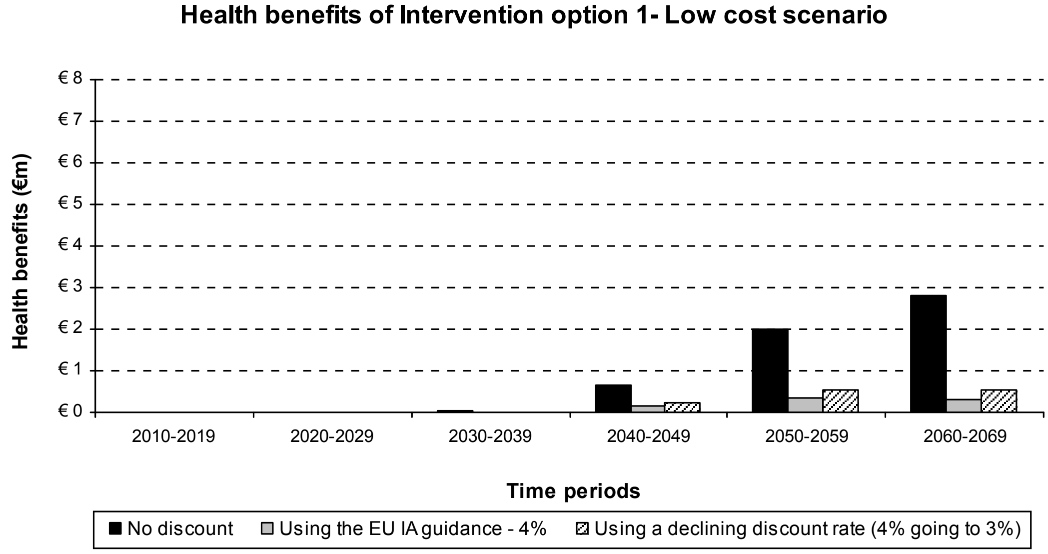


Figure 4.6 Total health benefits of introducing an EU wide OEL – By Industry Group – High Scenario (Present Value – 2010 €m prices)

As with the baseline scenario, in order to present all costs and benefits consistently in present value, it is necessary to discount all future costs and benefits. This was done using the IA guidelines recommended 4% discount rate. Since most health impacts occur over a long period of time relative to costs, the impacts of discounting are significant. As a means of sensitivity testing, different discount rates are also used. The overall impact of discounting can be seen in:

- Figure 4.7 for introducing an OEL of 1fibres/ml
- Figure 4.8 for introducing an OEL of 0.1fibres/ml

Detailed tables are included in Appendix 8.4 with results presented using different discount rates.



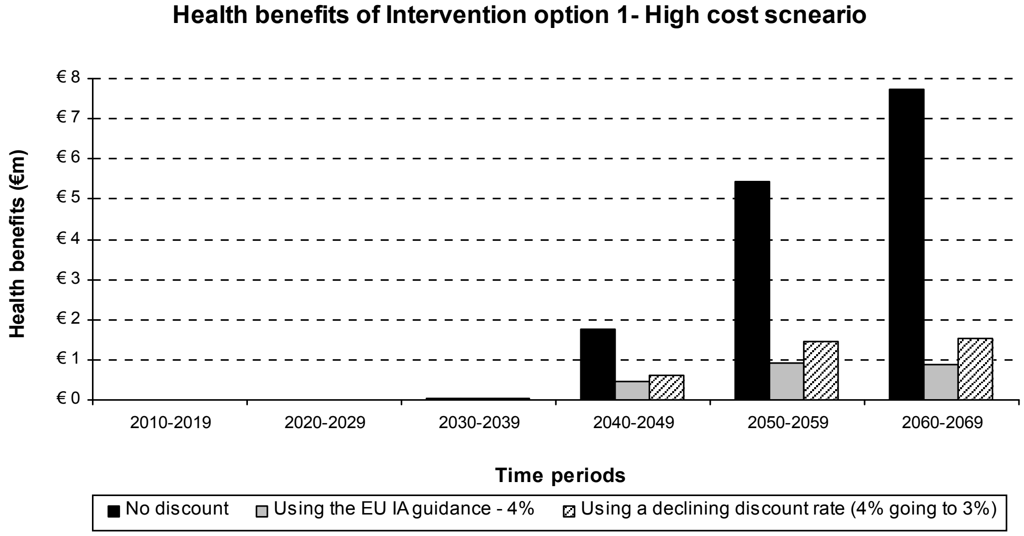


Figure 4.7 Impacts of discounting – Introducing an OEL of 1fibres/ml

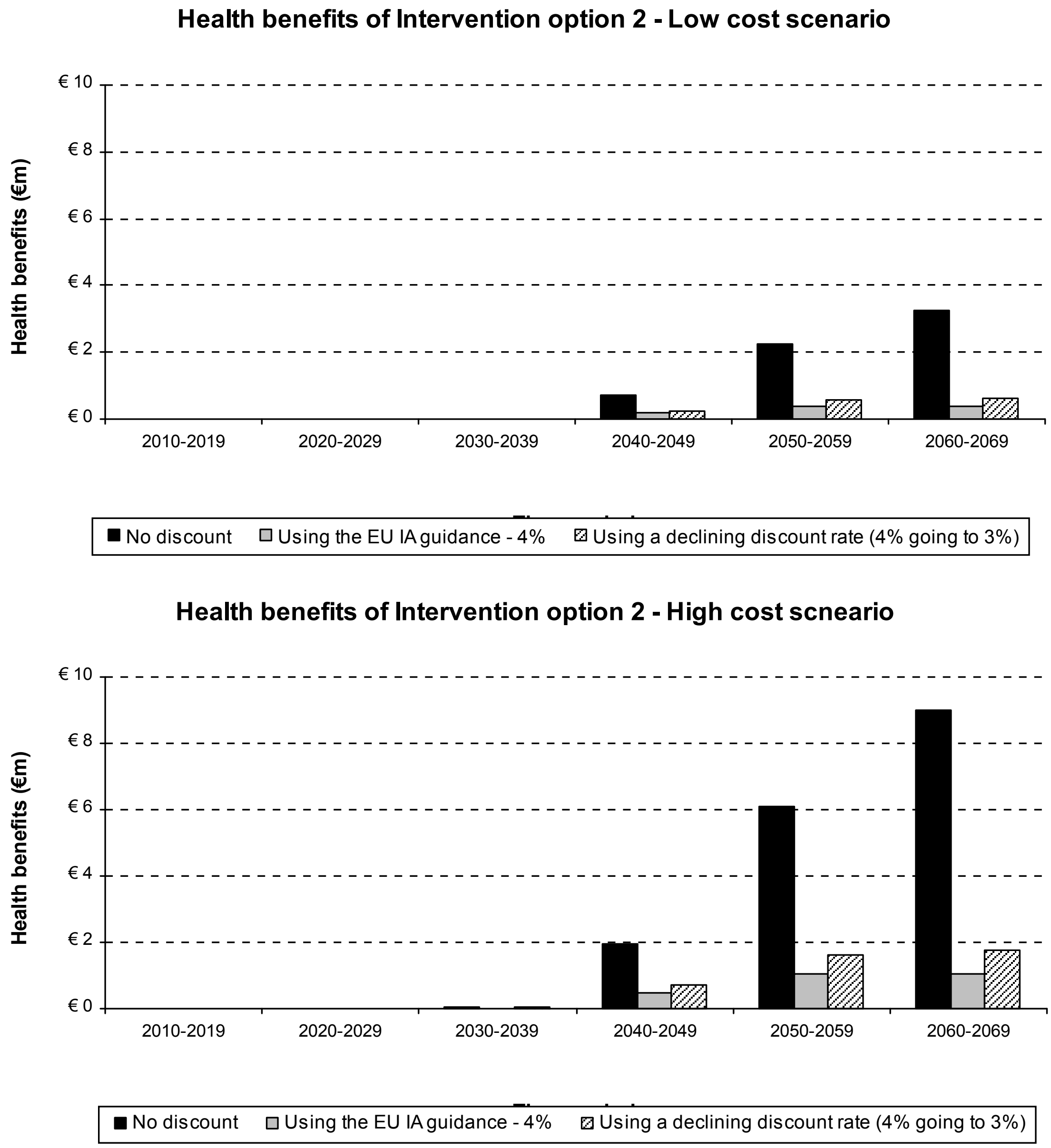


Figure 4.8 Impacts of discounting – Introducing an OEL of 0.1fibres/ml

Since the benefits of introducing an OEL are mostly realised from 2040, the level of discounting has a significant impact on the overall size of health benefits. A limitation is that the benefits of any RMMs undertaken post 2040 will not be included in this study, since the benefits of these measures to reduce occupational exposure in 2040-2070 are unlikely to be realised until after 2070 (due to the lag period) which is not estimated in this study.

4.2 ECONOMIC IMPACTS

4.2.1 Operating costs and conduct of business

Compliance costs

- 1 fibres/ml OEL

In section 2.3.1, it was estimated that 6.6% of workers in manufacturing facilities and 12.4% of workers at downstream user facilities would have been exposed above 1 fibres/ml. This is about 50 workers in manufacturing facilities and 1,150 workers at downstream user facilities[17].

Consultation with ECFIA suggested that there would be limited costs of meeting an OEL of 1 fibres/ml as average exposure is already below 1 fibres/ml but there may be some job occupations across EU that may require action to meet an OEL at this level. Therefore it is assumed that there will not be significant costs of compliance associated with meeting an OEL of 1 fibres/ml.

- 0.1 fibres/ml OEL

In section 2.3.1, it was estimated that around 70% of workers in manufacturing facilities and around 56% of workers at downstream user facilities would have been exposed above 0.1 fibres/ml. This is about 500 workers in manufacturing facilities and 5,200 workers at downstream user facilities[18].

ECFIA provided details of ongoing work towards reaching the French OEL limit of 0.1 fibres/ml. In order to reduce exposure in area where dust levels had remained high to 0.3 fibres/ml or below, dust extraction systems were required at a cost estimated at €11k per stationary workstation (with 160 stationary workstations for production facilities alone). They estimate if a solution exists the investment required it would cost around €20k per stationary workstation to achieve 0.2 fibres/ml.

However, ECFIA estimate that, to achieve 0.1 fibres/ml would require using automated systems able to handle various types of shapes on each machine. This would need to include feeding the machine, taking shapes out of the carton, machining the shapes and placing them in the finished product packaging. The whole installation would need to be enclosed in a confined space, with an estimated cost of €200k per workstation. This would mean an initial cost of broadly €32m for the 160 workstations in production. Communications with ECFIA suggest that there are between 5 and 10 workstations per company meaning the initial costs per enterprise will be around €1-2m for around 20-30 firms[19].

In addition to the costs of automated dust extraction equipment, there would be annual costs to maintain these systems. ECFIA estimate this would be around 10% of the cost of capital (i.e. €20k per workstation) although this will not include the costs of bagging the dust. This estimate is used as an upper estimate in addition to a lower conservative estimate of €10k per workstation.

[17] Specific calculations were 48 and 1,149 workers.
[18] Specific calculations were 509 and 5,182 workers.
[19] Specific calculations were 16 and 32 firms

Downstream facilities will also incur costs of compliance (e.g. furnace insulation fixers, repairs and replacement). In these instances, ECFIA suggests that controlling exposure to below 0.1 fibres/ml is not practicable as it would require complete containment and automation of all processes and therefore no cost estimates have been derived.

General costs of additional RPE and training with the requirements of carcinogens Directive is assumed to cost between €1,500 and €3,000 per firm. These costs are likely to already be occurring to control levels at average GM exposure levels of 0.3-0.6 fibres/ml (see Figure 2.6) through the CARE (Control And Reduce Exposure) programme. It is assumed that a small proportion of firms may not be achieving such levels and so would incur costs to reduce exposure in line with good practice (although this would not necessarily enable them to meet 0.1 fibres/ml). It is assumed that around 100-260 firms[20] may incur these additional costs.

The total costs of compliance are estimated to be between €60m and €140m over the period 2010-69. This is set out set out below in Table 4.4. Whilst costs are included for downstream users, it should be noted that the measures would not actually allow an OEL at this level to be met.

Table 4.4 Estimated costs of compliance with OEL of 0.1fibres/ml (Present Value – 2010 €m prices)

Number of enterprises affected		**Action required**	**Annualised average cost per enterprise (2010)**		**Total annual cost in millions (2010)**		**Total cost 2010-2069 in millions**	
Low	**High**		**Low**	**High**	**High**	**High**	**Low**	**High**
10	30	Dust extraction equipment	€ 73,582	€ 147,164	€ 1.5	€ 2.2	€ 33	€ 50
10	30	Annual maintenance of extraction equipment	€ 50,000	€ 100,000	€ 1.0	€ 3.0	€ 24	€ 71
100	260	Downstream facilities - Use of RPE and good practice (would not allow OEL to be met in all cases)	€ 1,500	€ 3,000	€ 0.15	€ 0.8	€ 4	€ 18
-	-	TOTAL	-	-	€ 2.6	€ 6.0	€ 60	€ 139

As mentioned in section 2.1, there has been significant substitution of RCF/ASW with the two main alternatives, Alkaline-Earth Silicate Glass Wool (AES) and Polycrystalline Wool (PCW).

Discussions with ECFIA indicate that currently around 10-15% of RCF/ASW cannot be substituted with AES due to its lower applicable temperature range and susceptibility to chemical attack. AES comes at a price premium (10% more expensive with RCF approximately €1.50/kg) and is also less durable (a factor of 0.8 is assumed for its lifetime). The extra cost if all RCF/ASW (~20kt per year) was replaced with AES could

[20] These were based on an assumption that there are between 20-50 affected workers per firm assuming a slightly higher number of workers per firm relative to other materials considered in this study.

be around £566 million over the period 2010-69[21] with costs mainly as result of reduced durability. As it is not technically feasible to substitute all ASW/RCF these costs are likely to be an underestimate of the true cost of substitution with AES. The costs also do not factor in the higher labour costs from reduced durability (i.e. additional distribution, installation, repair, replacement, disposal).

Given that it is currently not possible to completely substitute with AES, the cost premium of substituting with PCW is also estimated. Switching completely to PCW is considered a high scenario (and likely to be an overestimate) given that PCW is 20 times more expensive than RCF/ASW but is as durable as RCF/ASW. The premium if all RCF/ASW (~20kt per year) was replaced with PCW could be around €13,411-20,395 million over the period 2010-69; with the upper estimate assuming a 2% increase in annual prices over time for inflation.

In practice, there is likely to be a mixture of switching to AES and PCW. Assuming 85% of the RCF/ASW is substituted with AES and the 15% of uses of RCF which can't be substituted with AES is substituted with PCW, the price premium is estimated at around €95million over the period 2010-69.

Incurring the premium of substitution would seem to be a less likely option if an OEL was introduced at 0.1 fibres/ml given the more significant costs compared to using dust extraction equipment. However, given that it would be technical infeasible for many downstream users to meet such a limit, they could be forced to substitute despite the significantly higher costs.

Table 4.5 below summarises the main estimated costs of meeting various OELs (including 0.2 and 0.3 fibres/ml) and the costs of substitution away from the use of RCF/ASW.

[21] Costs discounted over time using a 4% discount rate. The cost is €602m if it is assumed prices rise by 2% per year due to inflation.

Table 4.5 Summary of compliance costs with various OELs at substitution (Present Value – 2010 €m prices)

Compliance route	Annualised cost	Costs 2010 to 2069	Notes
Continued use of ASW - Achieve OEL of 0.3 fibres/ml	€ 0.2 - 0.6m	€ 4 - 17m	This is the level recommended by the SCOEL. This was not available at the time of deciding the OELs to be assessed. A similar Monte Carlo simulation was undertaken to assess the percentage of workers exposed above the OEL which was estimated to be 33% of manufacturing sites (241 workers) and 32% of downstream facilitates (2,958 workers).
Continued use of ASW - Achieve OEL of 0.2 fibres/ml	€ 0.2 - 0.9m	€ 6 - 20m	A similar Monte Carlo simulation was undertaken to assess the percentage of workers exposed above the OEL which was estimated to be 46% of manufacturing sites (338 workers) and 41% of downstream facilitates (3,765 workers).
Continued use of ASW - Achieve OEL of 0.1 fibres/ml	€ 2.6 - 6m	€ 60 - 139m	Includes downstream users costs but downstream users may not be able to meet OEL
Substitute completely with AES	€ 11m	€ 566m	The majority of the costs can be attributed to the reduced lifetime of AES and additional costs of replacement. However the costs for AES do not include additional maintenance costs due to reduced lifetime.
Substitute completely with PCW	€ 570m	€ 13,411m	-
Substitute 85% AES and 15% PCW	€ 95m	€ 2,492m	Costs for AES do not include additional maintenance costs due to reduced lifetime

Conduct of employers

The introduction of an EU-wide OEL could require enterprises to reorganise their workplace to ensure that exposure to RCF is minimised. Additional training and supervision of personnel handling the substance is likely to be required to ensure that employees minimise their exposure by adhering to good practice in order to reduce exposure (e.g. using the measures set out in section 3).

Potential for closure of companies

Communications with one of the RCF/ASW manufacturers indicated that an OEL at 0.1 fibres/ml is borderline in terms of the capability of currently available sampling techniques. It would be very difficult, if not impossible, to provide valid evidence to show compliance.

Achieving an OEL of 0.1 fibres/ml is reportedly only achievable for continuous processes with as much automation as possible, and using more sophisticated LEVs. As end product/customer requirements are often different in terms of sizes, shapes and products, the industry reports that it is not technically or economically feasible to achieve 0.1 fibres/ml. Anecdotal information suggests that, in France where the OEL is 0.1 fibres/ml, manufacturers are relocating production of complicated operations to elsewhere in Europe.

Therefore it is possible that an OEL set at 0.1 fibres/ml could lead to firms relocating production processes outside of the EU. It could also lead to downstream jobs such as fitting and removal of furnace insulation becoming untenable, if the OEL cannot technically be met in those industries. Based on industry consultation, it is unlikely that the additional cost to end-users will be in itself significant enough to warrant relocating furnaces outside of the EU. These impacts should be mitigated at an OEL set at the 1 fibres/ml or at the SCOEL recommendation of 0.3 fibres/ml (note: the SCOEL recommendation was not available at the time of agreeing upon which OELs should be assessed as part of the current study).

Potential impacts for specific types of companies

There are already national OELs in place for RCF, but companies that do not currently implement 'best practice' procedures or which are not part of the CARE programme may be affected more by the implementation of an EU-wide OEL than those which already adhere to such procedures.

Manufacturers of RCF/ASW should also be able to make AES whilst retaining existing production equipment. However not all EU firms will make PCW within their portfolio and therefore would be more significantly affected than those manufacturers that can offer PCW as an alternative. These impacts may be mitigated at an OEL set at the 1 fibres/ml or at the SCOEL recommendation of 0.3 fibres/ml (note: the SCOEL recommendation was not available at the time of deciding the OELs to assess) which are both seemingly technically achievable.

Administrative costs to employers and public authorities

The following table (Table 4.6) describes the administrative burden to employers already subject to the Carcinogens Directive but will now incur costs of introducing an EU wide OEL on to Annex III.

Table 4.6 Administrative burdens to employers

Type of administrative cost	Relevant article(s)	Type of cost	Significance
1. Change in practice to use closed systems when using the substance.	5 – Prevention and reduction of exposure	These costs are already estimated in the cost of compliance section - This will only affect those firms that do not have or use closed systems	Estimated elsewhere
2. Develop/update health and safety and best practice guidance for: ○ Minimising use and exposure to workers to the substance ○ Redesign work processes and engineering controls to avoid/minimise release of carcinogens or mutagens ○ Hygiene measures, in particular regular cleaning of floors, walls and other surfaces ○ Information for workers ○ Warnings and safety signs ○ Drawing up plans to deal with emergencies likely to result in abnormally high exposure	5 – Prevention and reduction of exposure 7 – Unforeseen exposure 8 – Foreseeable exposure 9 – Access to risk areas 10 – Hygiene and individual protection	Firms will already have been required to develop/update health and safety and best practice guidance. The guidance and procedures may be required to be updated as control measures may change in light of a more stringent OEL. Some firms may need to redesign work practices to minimise exposure to workers and the number of workers exposed. The costs of implementing controls on exposure (such as LEV or PPE) are already estimated in the costs of compliance section.	Low
3. Additional costs of training new and existing staff in line with requirements of the Directive 4. Additional costs of making information available to employees 5. Consultation with employees on compliance with the Directive	11 – Information and training of workers 12 – Information for workers 13 – Consultation and participation with workers	Firms will already have been required to ensure training and adequate aware of risks and control measures to reduce/minimise exposure. Largely one-off cost if the revised OEL requires a change in control measures/working practice.	Low

Note: Readers should consult the Directive for the official wording around specific requirements. This table provides only a summary of what are perceived to be the most significant administrative requirements of the Directive. Grading of the significance of impacts is subjective and is based on professional judgement.

The following table (Table 4.7) describes the administrative burden to competent authorities already enforcing the Carcinogens Directive but will now incur costs of introducing an EU wide OEL on to Annex III.

Table 4.7 Administrative burdens to Competent Authorities

Type of administrative cost	Relevant article(s)	Type of cost	Significance
1. Communication with the Commission on provisions in national law to enforce the revised OEL. 2. Time and costs of implementing revised OEL into national law (consultation process)	19 – Notifying the commission 20 – Repeal	Largely one-off cost of transposing the revised OEL into national law	Low - Medium (one-off cost)

Note: Readers should consult the Directive for the official wording around specific requirements. This table provides only a summary of what are perceived to be the most significant administrative requirements of the Directive. Grading of the significance of impacts is subjective and is based on professional judgement.

Third countries

The price premium from using PCW in particular will mean that EU firms may be more susceptible to imports of PCW into the EU, as shipping costs will account for a smaller proportion of the total cost to end consumers relative to RCF. Therefore an OEL set at 0.1 fibres/ml could lead to greater demand from non-EU countries. These impacts may be mitigated at an OEL set at the 1 fibres/ml or at the SCOEL recommendation of 0.3 fibres/ml because it is expected that the compliance route to achieve these would be to reduce exposure, rather than to replace RCF with an alternative.

4.2.2 Impact on innovation and research

The industry already invests in R&D to reduce current exposure with RCF/ASW (for example through the CARE programme) as well as in developments to AES to improve its temperature range, its susceptibility to chemical attack and its durability. The introduction of a more stringent OEL may encourage or force further R&D into AES or force some firms to produce PCW (where this is not currently possible).

4.2.3 Macroeconomic impact

Whilst there may be expected to be a significant investment in protective equipment, training and general best practice in reducing exposure; or cost premium from using substitutes (the wider range being €4m-€13,411m over 60 years), this is not expected to have a macroeconomic impact since costs will be spread all over the EU and are small compared to for example the total value of goods and services in the manufacturing sector of €5 trillion in 2006.

4.3 SOCIAL IMPACTS

4.3.1 Employment and labour markets

There are not expected to be any noticeable changes to the numbers of workers required as a result of introducing an EU-wide at 1 fibres/ml. However, job patterns may be altered as it is recognised that, in order to meet best practice, behavioural change amongst employees and updating health and safety training will be required.

In terms of working conditions, the use of mechanical local ventilation may be better for workers than natural ventilation as air change rates and flow can be controlled, and thermal environmental conditions maintained at more acceptable levels. One of the disadvantages of using mechanical ventilation is heat loss, especially in colder regions. If the mechanical ventilation includes a heat exchanger with high efficiency, this might typically reduce the ventilation heat loss by 80-90% and the total heat loss by 30-60%, depending on the insulation level[22].

There is however a risk that production of RCF/ASW (and possibly AES and PCW) may be relocated outside of the EU at an OEL of 0.1 fibres/ml as costs of abatement are likely to be prohibitive, although some of the costs may be passed on e.g. to furnace operators.

4.3.2 Changes in end products

There are not expected to be any noticeable changes to the end products if exposure control measures are implemented as they do not change the characteristics of the product (e.g. furnace insulation). However, if RCF/ASW is substituted with AES, then this could result in lifetimes of products (e.g. furnace insulation) being reduced and being subject to a higher cost premium. The use of PCW would be much more expensive, but should not affect end use in terms of durability.

4.4 ENVIRONMENTAL IMPACTS

The use of RCF/ASW as a furnace insulation has environmental benefits including improved energy efficiency of furnaces through reducing heat loss for optimum furnace temperatures and also through reduced CO_2 emissions from reduced energy consumption. It is thought to be unlikely that furnace operators would move to older brick insulation or go without insulation given these environmental (and cost) benefits. The use of exposure controls therefore should not affect these environmental benefits or lead to significant increased environmental impacts.

A potentially negative aspect of using AES as an alternative is that, as it is currently not as durable as RCF/ASW, this is likely to lead to an overall increase in resource consumption and lifecycle emissions (e.g. increased production, distribution, repairs and disposal). These impacts are not expected to occur with PCW although it is a much more expensive alternative (20 times) relative to RCF/ASW.

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22 "Mechanical ventilation with heat recovery in cold climates" - http://web.byv.kth.se/bphys/reykjavik/pdf/art_157.pdf. (Note that this is in relation to housing rather than industrial buildings.)

Both the production of AES and PCW are more energy intensive than RCF/ASW and therefore there will be a small increase in emissions from production and use of electricity.

5 COMPARISON OF OPTIONS

The main impacts discussed in more detail in section 4 are summarised in the tables below, which are broken down by the main types of impacts (health, economic, social, macroeconomic and environmental).

Table 5.1 Comparison of health impacts by scenario (Present Value – 2010 €m prices)

Baseline Scenario		Intervention scenario (2) – Assumes full compliance for OEL = 1 fibres/ml		Intervention scenario (3) – Assumes full compliance for OEL = 0.1 fibres/ml	
Health Costs	**Health Benefits**	**Health Costs**	**Health Benefits**	**Health Costs**	**Health Benefits**
As set out in section 2.5, the health costs of cancer (lung) over the period 2010-70 are estimated to be €33m to €83m. This range takes into consideration tangible costs (e.g. lost income, lost output from reduced productivity, medical costs, life years lost) and intangible costs (e.g. emotional and physical suffering from having cancer). These costs are themselves be an upper bound given the difficulties in attributing lung cancer to exposure of RCF/ASW.	It is assumed that exposures will fall by 7% per year in the future. Therefore there is expected to be some reduction in health costs going forward in the absence of further regulatory intervention	There is expected to be a small cost saving from avoided health care and reduced cost of illness due to reductions in cancer registrations. This has been estimated as a benefit.	Health benefits of the possible OEL have been analysed at the Member State and industrial occupational level. The benefits of introducing an OEL in 2010 are likely to be most apparent during the installation of RCF/ASW. It was also found that the monetised benefits are likely to predominantly affect men. The monetised benefits over 2010-2070 were estimated at €1-2m.	There is expected to be a small cost saving from avoided health care and reduced cost of illness due to reductions in cancer registrations. This has been estimated as a benefit.	Health benefits of the possible OEL have been analysed at the Member State and industrial occupational level. The benefits of introducing an OEL in 2010 are likely to be most apparent during the installation of RCF/ASW. It was also found that the monetised benefits are likely to predominantly affect men. The monetised benefits over 2010-2070 were estimated at €1-3m.

Table 1.2 Comparison of economic impacts by scenario (Present Value – 2010 €m prices)

Baseline Scenario		Intervention scenario (2) – Assumes full compliance for OEL = 1 fibres/ml		Intervention scenario (3) – Assumes full compliance for OEL = 0.1 fibres/ml	
Economic Costs	**Economic Benefits**	**Economic Costs**	**Economic Benefits**	**Economic Costs**	**Economic Benefits**
There are expected to be costs to RCF/ASW related firms to put into place improved training and cleaning measures (e.g. the CARE programme) to reduce exposure that would occur regardless of further intervention over the period 2010-2070.	-	Consultation with ECFIA suggested that there would be limited costs of meeting an OEL of 1 fibres/ml as average exposure is already below 1fibres/ml but there may be some job occupations across the EU that may require action to meet a 1 fibres/ml. Therefore it is assumed that there would not be significant costs of compliance with an OEL of 1 fibres/ml.	Having an EU-wide OEL should remove competitive distortions between EU Member States with different limits.	The total costs of compliance through exposure control measures are estimated to be between €60m and €139m over the period 2010-69. The extra cost if all RCF/ASW (~20kt per year) was replaced with AES could be around £566million over the period 2010-69 with costs mainly as result of reduced durability. The premium if all RCF/ASW (~20kt per year) was replaced with PCW could be around €13-20billion over the period 2010-69; with the upper estimate assuming a 2% increase in annual prices over time for inflation. As it is not technically feasible to substitute all ASW/RCF with AES, perhaps a more realistic scenario would be substitution of around 15% with PCW and 85% with AES, at an estimated cost of €95m over the period 2010-69.	Having an EU-wide OEL should remove competitive distortions between EU Member States with different limits.

Table 1.3 Comparison of social impacts by scenario

Baseline Scenario		Intervention scenario (2) – Assumes full compliance for OEL = 1 fibres/ml		Intervention scenario (3) – Assumes full compliance for OEL = 0.1 fibres/ml	
Social Costs	**Social Benefits**	**Social Costs**	**Social Benefits**	**Social Costs**	**Social Benefits**
There are not expected to be any noticeable social impacts under the baseline scenario at an EU level.		**No change** - There are not expected to be any noticeable changes to the numbers of workers required as a result of introducing an EU-wide at 1 fibres/ml. However, job patterns may be altered as it is recognised that in order to meet best practice, behavioural change amongst employees and updating health and safety training will be required.		There is a risk that production of RCF/ASW (and possibly AES and PCW) may be relocated outside of the EU at an OEL of 0.1 fibres/ml as costs of abatement and/or substitution are likely to be prohibitive in some cases, although some of the costs may be passed on e.g. to furnace operators. The price premium from using PCW in particular will mean that EU firms may be more susceptible to imports of PCW into the EU, as shipping costs will account for a smaller proportion of the total cost to end consumers relative to RCF. Therefore an OEL set at 0.1 fibres/ml could lead to greater demand from non-EU countries.	

Table 1.4 Comparison of macro-economic impacts by scenario

Baseline Scenario		Intervention scenario (2) – Assumes full compliance for OEL = 1 fibres/ml		Intervention scenario (3) – Assumes full compliance for OEL = 0.1 fibres/ml	
Macro-economic Costs	**Macro-economic Benefits**	**Macro-economic Costs**	**Macro-economic Benefits**	**Macro-economic Costs**	**Macro-economic Benefits**
There are not expected to be any noticeable macroeconomic impacts under the baseline scenario.		There are not expected to be any significant macroeconomic impacts relative to the baseline scenario from introducing an EU-wide OEL.			

Table 1.5 Comparison of environmental impacts by scenario

Baseline Scenario		Intervention scenario (2) – Assumes full compliance for OEL = 1 fibres/ml		Intervention scenario (3) – Assumes full compliance for OEL = 0.1 fibres/ml	
Environmental Costs	**Environmental Benefits**	**Environmental Costs**	**Environmental Benefits**	**Environmental Costs**	**Environmental Benefits**
The use of RCF/ASW as a furnace insulation material has environmental benefits, including improved energy efficiency of furnaces through reducing heat loss for optimum furnace temperatures and through reduced CO_2 emissions from reduced energy consumption.		**No change -** It is thought to be unlikely that furnace operators would move to older-type brick insulation or go without insulation given the environmental (and cost) benefits. The use of general exposure controls therefore should not affect these environmental benefits or lead to significant increased environmental impacts.		A potentially negative aspect of using AES as an alternative is that as it is currently not as durable as RCF/ASW, this is likely to lead to an overall increase in resource consumption and lifecycle emissions (e.g. increased production, distribution, repairs and disposable). These impacts are not expected to occur with PCW, although it is a much more expensive alternative (20 times) relative to RCF/ASW. Both the production of AES and PCW are more energy intensive than RCF/ASW and therefore there will be a small increase in emissions from production and use of electricity.	

Note: Costs and benefits under the intervention options are relative to the baseline scenario (i.e. are not absolute impacts but differences)

6 CONCLUSIONS

Exposure to RCF may cause lung cancer. The International Agency for Research on Cancer considers RCF is a possible human carcinogen (category 2b) and it is classified as a category 2 carcinogen in Europe under the classification and labelling regulations. RCF has also been identified as a Substance of Very High Concern under the REACH Regulations. This report considers the likely health, socioeconomic and environmental impacts associated with possible changes to the EU Carcinogens Directive, in particular the possible introduction of an occupational exposure limit (OEL) of either 0.1 fibres/ml or 1 fibres/ml. We note that in October 2010, the EU SCOEL recommended a limit of 0.3 fibres/ml, but this recommendation was made after we have completed the work for this report.

Lung cancer is the commonest cancer amongst men in Europe that is generally diagnosed on people over 40 years of age, and incidence rises steadily thereafter. Cigarette smoking most commonly causes lung cancer, although there are several occupational agents that are also known to cause this disease. Most people with lung cancer die within 5 years of diagnosis.

RCF are synthetic vitreous fibres or man-made mineral fibres used in industry for their properties of heat resistance, tensile strength, durability and lightweight. European Union Directive 97/69/EC defined RCFs as “Man-made vitreous (silicate) fibres with random orientation with alkaline oxide and alkaline earth oxide content less than 18% by weight.” There are about 730 workers employed in RCF production plants in Germany, France and the UK. There are about 9,300 people employed in the downstream user industry. Geometric mean exposures in the industry are less than 0.2 fibres/ml and it is estimated that about 7% of workers in manufacturing facilities and 12% of workers at downstream user facilities would have been exposed above 1 fibres/ml. More than half of workers are exposed about 0.1 fibres/ml. It is assumed that exposure levels have been decreasing by about 7% per annum since the late 1990s.

The predicted number of deaths from past occupational exposure to RCF is low (in 2010, no attributable deaths in manufacturing and two deaths in downstream users) and that this will decrease in the future so that by 2050 there are no predicted deaths occurring. Introducing a OEL of either 0.1 or 1 fibres/ml has no important effect on the predicted cancer deaths or registrations from RCF exposure at work. For both potential OELs the estimated DALYs decrease from 29 years to zero years by 2060; with no intervention there are two DALYs predicted in 2060. These are considered to be a “worst-case” estimate of the possible health impact.

We have not estimated risks of mesothelioma because we do not believe the human epidemiological data substantiates such a risk. However, if this assumption is in error then a worst case assumption might be that RCF exposure could cause three times as many cancers as we have currently estimated.[23] While this would increase the health impact we do not believe this importantly changes our conclusions.

[23] Using the model of asbestos health risks developed by Hodgson and Darnton (2000) an exposure at 0.1 fibres/ml for forty years starting at age 18 would result in a lung cancer risk of about 8 per 100,000 person-years exposure and a risk of 16 per 100,000 years for mesothelioma. The relative mesothelioma risk is lower at higher levels of exposure, i.e. this is a worst case assumption.

It is likely that an EU-wide OEL of 1.0 fibres/ml could be met through greater uptake of currently applied techniques within the industry. The associated costs are likely to be relatively low. There is calculated to be a small health benefit associated with such an OEL, valued at up to €1-2 million in total over the period 2010-2069. The value is relatively low because of the low level of assumed cancer incidence under the baseline and the existing controls in place. It is not expected that there would be any important social, macro-economic or environmental impacts with an OEL at 1.0 fibres/ml.

The other OEL investigated in detail, 0.1 fibres/ml, could have much more significant impacts upon the industry. To achieve exposure at this level would require a degree of automation and enclosure that is unlikely to be feasible, especially for certain downstream users. The compliance costs associated with an OEL of 0.1 fibres/ml are estimated at:

- Around €60 to €140 million over the period 2010 to 2069 associated with controlling exposure. This includes controls at manufacturing sites as well as downstream users, although the controls adopted at downstream users are unlikely to allow the possible OEL to be achieved in practice.

- If achieving the OEL is technically or economically infeasible, companies may decide to substitute RCF with alternatives such as AES and PCW. The associated costs could be of the order of €2.5 billion over the same period.

These costs, coupled with the technical feasibility issues, could lead to some relocation of activities to outside the EU, with associated loss of employment.

The health benefits of achieving an OEL of 0.1 fibres/ml are likely to be minimal, and have been valued at up to €1-2 million in total over the period 2010-2069. Again, the value is relatively low because of the low level of assumed cancer incidence under the baseline and the existing controls in place.

The SCOEL has recently recommended an OEL of 0.3 fibres/ml. Whilst this recommendation was issued after the OELs for analysis in the study (1.0 and 0.1 fibres/ml) were agreed, some indicative estimates have been derived for the costs of compliance, including: €6 to €20 million for an OEL at 0.2 fibres/ml and €4 to €17 million for an OEL at 0.3 fibres/ml. The latter OEL could be more technically feasible than 0.1 fibres/ml, meaning that the costs of substitution with alternatives would not be incurred.

7 REFERENCES

Bernstein DM. (2007). Synthetic vitreous fibers. A review toxicology, epidemiology and regulations. *Critical Reviews in Toxicology;* **37**: 839-886.

Chiazze L, Watkins DK, Fryar C. (1997). Historical cohort mortality study of a continuous filament fiberglass manufacturing plant. I. White men. *J Occup Environ Med;* **39**: 432–441.

Cowie HA, Beck J, Wild P, Auburtin G, Piekarski C, Hutchinson PA, Russell M, Tomain JP, Cherrie JW, Groat S, Miller BG, Hurley JF, Soutar CA. (1999). Epidemiological research in the European ceramic fibre industry 1994-1998 Vol 2. A study of the respiratory health of workers in the RCF industry. Institute of Occupational Medicine. Research Report TM/99/01.

Cowie H, Wild P, Beck J, Auburtin G, Piekarski C, Massin N, Cherrie J, Hurley J, Miller B, Groat S, Soutar C. (2001). An epidemiological study of the respiratory health of workers in the European refractory ceramic fiber industry. *Occup Environ Med;* **58**: 800-810.

EFCIA (2009) Recognition and Control of Exposure to Refractory Ceramic Fibres.

Ferlay J, Autier P, Boniol M, Heanue M, Colombet M, Boyle P. (2007). Estimates of the cancer incidence and mortality in Europe in 2006. *Annals of Oncology*; **18(3)**: 581-592.

Glass LR, Brown RC, and Hoskins JA. (1995). Health effects of refractory ceramic fibres: scientific issues and policy considerations. *Occup Environ Med*; **52**: 433-440.

Hodgson JT, Darnton A. (2000). The quantitative risks of mesothelioma and lung cancer in relation to asbestos exposure. *Ann Occup Hyg;* **44**: 565–601.

Hodgson JT, Darnton A. (2009). Mesothelioma risk from chrysotile. (Letter to the editor) *Occup Environ Med;* published online November 10 2009.

HSE. (2002). Maximum Exposure Limit for Refractory Ceramic Fibres (RCFs): Regulatory Impact Assessment

IARC. (2002). IARC Monographs on the Evaluation of Carcinogenic Risks to Humans: Man-Made Vitreous Fibres. Lyon: IARC Press.

Kauppinen T, Toikkanen J, Pedersen D *et al* (2000) Occupational exposure to carcinogens in the European Union. *Occup Environ Med*; **57**: 433-440.

Lemasters,GK, Lockey JE, Levin LS, McKay RT, Rice CH, Horvath EP, Papes DM, Lu JW, Feldman DJ. (1998). An industry-wide pulmonary study of men and women manufacturing refractory ceramic fibers. *Am J Epidemiol;* **148**: 910–919.

Lemasters GK, Lockey JE, Yiin JH, Hilbert TJ, Levin LS, Rice CH. (2003). Mortality of workers occupationally exposed to refractory ceramic fibers. *J Occup Environ Med;* **45**: 440-450.

Linnainmaa M, Kangas J, Mäkinen F, *et al* (2007). Exposure to Refractory Ceramic Fibres in the Metal Industry. *Annals of Occupational Hygiene*; **51(6)**:509-516.

Lockey JE, LeMasters GK, Levin L, Rice C, Yiin J, Reutman S, Papes D. (2002). A longitudinal study of chest radiographic changes of workers in the refractory ceramic fiber industry. *CHEST;* **121**: 2044–2051.

Lockey J, LeMasters G, Rice C, Hansen K, Levin L, Shipley R, Spitz H, Wiot J. (1996). Refractory ceramic fiber exposure and pleural plaques. *Am J Respir Crit Care Med;* **154**: 1405–1410.

Lockey J, Levin L, LeMasters GK, *et al* (1998). Longitudinal estimates of pulmonary function in refractory ceramic fiber manufacturing workers. *Am J Respir Crit Care Med;* **167**: 1226-1233.

Loomis D, Dement JM, Wolf SH, Richardson DB. (2009). Lung cancer mortality and fibre exposures among North Carolina asbestos textile workers. *Occup Environ Med;* **66**: 535-542.

Maxim LD, Allshouse JN, Deadman JE, Kleck C, Kostka M, Webster D, Class P, Sebastien P. (1998). CARE – A European Programme for Monitoring and Reducing Refractory Ceramic Fibre Dust at the Workplace: Initial Results. *Gefahrstoffe – Reinhaltung der Luft*; **58**: 97-103.

Maxim LD, Allshouse JH, Kelly WP, *et al* (1997). A Multiyear Workplace-Monitoring Program for Refractory Ceramic Fibers: Findings and Conclusions. *Regulatory Toxicology and Pharmacology*; **26**: 156-171.

Miller BG, Cherrie JW, Groat S, Kauffer E. (2007). Changes in Workplace Concentrations of Airborne Respirable Fibres in the European Ceramic Fibre Industry 1987-1996. *Annals of Occupational Hygiene*; **51(6)**: 501-507.

Moolgavkar SH, Luebeck EG, Turim J, Brown RC. (2000). Lung cancer risk associated with exposure to man-made fibers. *Drug Chem Toxicol;* 23: 223–242.

NIOSH. (2006). Criteria for a Recommended Standard Occupational Exposure to Refractory Ceramic Fibers. Atlanta, GA: Department of Health and Human Services, Centers for Disease Control Prevention, National Institute for Occupational Safety and Health.

Quinn M, Babb P, Brock A, Kirby L, Jones J. (2001). Cancer Trends in England and Wales 1950-1999. In: *Series on Medical and Population Subjects No. 68.* Office of National Statistics: London.

Quinn M, Wood H, Cooper N, Rowan S. (2005). Cancer Atlas of the United Kingdom and Ireland 1991-2000. In: *Series on Medical and Population Subjects No. 68.* Office of National Statistics: London.

Rice CH, Lockey JE, Lemasters GK, Levin LL, Staley P, Hansen KR. (1997). Estimation of historical and current employee exposure to refractory ceramic fibers during manufacturing and related operations. *Appl Occup Environ Hyg;* **12**: 54–61.

Rushton L, Bagga S, Bevan R, Brown TP, Cherrie JW, Fortunato L, Holmes P, Slack R, Van Tongeren M, Young C, Hutchings SJ. (2010). Occupation and cancer in Britain. *British Journal of Cancer*; **102**: 1428-37.

Siemiatycki J, Richardson L, Straif K, Latreille B, Lakhani R, Campbell S, Rousseau M-C, and Boffetta P. (2004). Listing Occupational Carcinogens. *Environmental Health Perspectives*; **112**: 1447 – 1460.

Trethowan WN, Burge PS, Rossiter CE, Harrington JM, Calvert IA. (1995). Study of the respiratory health of employees in seven European plants that manufacture ceramic fibers. *Occup Environ Med;* **52**: 97–104.

Utell MJ, Maxim D. (2010). Refractory ceramic fiber (RCF) toxicity and epidemiology: a review. *Inhalation Toxicology;* **22(6)**: 500-521.

Verdecchia A, Francisci S, Brenner H, Gatta G, Micheli A, Mangone L, Kunkler I. (2007). Recent cancer survival in Europe: a 2000-02 period analysis of EUROCARE-4 data. *Lancet Oncology;* **8(9)**: 784-796.

Walker AM, Maxim LD, and Utell M. (2002). Risk analysis for mortality from respiratory tumors in a cohort of refractory ceramic fiber workers. *Regul Toxicol Pharmacol;* **35**: 95–104.

8 APPENDIX

8.1 ESTIMATED DEATHS AND REGISTRATIONS IN THE EU FROM REFRACTORY CERAMIC FIBRES

Table 8.1.1 Forecast number of lung cancers in ages 25+ (ages 15+ for registrations), based on projected EU country populations (men only)

Lung cancer deaths	MEN					
FTY	2010	2020	2030	2040	2050	2060
Austria	2,615	3,243	3,834	4,345	4,566	4,599
Belgium	0	0	0	0	0	0
Bulgaria	3,030	3,104	3,241	3,392	3,349	3,052
Cyprus	142	193	249	311	377	442
Czech Republic	4,595	5,593	6,455	7,261	7,837	7,829
Denmark	2,270	2,825	3,260	3,495	3,581	3,630
Estonia	592	646	728	821	908	951
Finland	1,634	2,100	2,536	2,698	2,735	2,833
France	24,088	28,386	32,593	35,424	37,040	38,467
Germany (including ex-GDR from 1991)	32,083	38,243	42,953	46,852	46,647	44,632
Greece	5,601	6,390	7,345	8,363	8,990	9,046
Hungary	5,881	6,430	7,170	7,875	8,334	8,359
Ireland	1,138	1,546	2,047	2,608	3,197	3,643
Italy	28,492	33,452	38,968	44,672	48,200	47,742
Latvia	993	1,058	1,183	1,313	1,438	1,456
Lithuania	1,341	1,491	1,709	1,921	2,072	2,097
Luxembourg	171	220	282	339	374	401
Malta	141	186	228	247	267	290
Netherlands	6,956	9,038	11,071	12,289	12,481	12,361
Poland	19,203	23,459	27,456	30,446	33,211	33,853
Portugal	3,015	3,489	4,044	4,563	4,913	5,029
Romania	8,085	8,897	10,049	11,126	11,365	10,717
Slovakia	1,903	2,412	2,963	3,400	3,764	3,811
Slovenia	915	1,132	1,362	1,497	1,532	1,505
Spain	19,434	23,870	29,553	35,388	39,157	39,480
Sweden	2,014	2,426	2,797	3,026	3,237	3,433
United Kingdom	21,240	25,303	29,857	33,713	37,057	39,950
European Union (27 countries)	203,597	241,403	280,580	313,714	332,361	338,025

Lung cancer registrations FTY	MEN 2010	2020	2030	2040	2050	2060
Austria	3,195	3,838	4,514	4,960	5,120	5,164
Belgium	7,322	8,692	10,013	10,852	11,262	11,628
Bulgaria	2,684	2,717	2,857	2,967	2,899	2,741
Cyprus	0	0	0	0	0	0
Czech Republic	5,691	6,740	7,663	8,472	8,896	8,764
Denmark	2,325	2,806	3,129	3,278	3,289	3,392
Estonia	630	684	762	847	921	949
Finland	1,681	2,142	2,375	2,420	2,462	2,527
France	26,745	31,101	34,491	36,630	37,854	39,219
Germany (including ex-GDR from 1991)	38,324	44,013	49,121	51,188	50,140	48,059
Greece	6,094	6,934	7,896	8,787	9,161	8,965
Hungary	6,802	7,380	8,170	8,966	9,417	9,471
Ireland	1,252	1,689	2,180	2,721	3,274	3,530
Italy	34,941	40,490	46,453	51,486	52,717	51,737
Latvia	951	1,015	1,110	1,226	1,296	1,278
Lithuania	1,385	1,524	1,745	1,956	2,094	2,138
Luxembourg	252	326	405	467	507	544
Malta	146	186	213	228	246	256
Netherlands	8,745	11,124	12,938	13,657	13,484	13,607
Poland	22,877	27,302	31,024	34,644	36,831	36,566
Portugal	2,875	3,318	3,829	4,280	4,552	4,608
Romania	7,766	8,440	9,584	10,539	10,779	10,354
Slovakia	2,512	3,125	3,739	4,299	4,667	4,649
Slovenia	988	1,219	1,418	1,534	1,555	1,485
Spain	21,064	25,941	31,814	36,979	39,486	38,712
Sweden	1,965	2,314	2,570	2,754	2,899	3,067
United Kingdom	27,363	32,395	37,148	40,910	43,779	47,708
European Union (27 countries)	234,922	275,404	314,082	343,072	356,383	358,425

8.2 SUPPLEMENTARY TABLES - COSTS UNDER THE BASELINE SCENARIO

Table 8.2.1 Health costs - baseline scenario - Industry group breakdown - Based on a 4% discount rate

Low	Female	Male	Total
Fibre Production	€ 0	€ 2	€ 2
Finishing	€ 0	€ 5	€ 5
Installation	€ 0	€ 18	€ 18
Removal	€ 0	€ 3	€ 3
Assembly Operations	€ 0	€ 3	€ 3
Mixing/Forming	€ 0	€ 2	€ 2
Auxiliary Operations	€ 0	€ 0	€ 0
Other	€ 0	€ 0	€ 0
TOTAL	€ 0	€ 33	€ 33

High	Female	Male	Total
Fibre Production	€ 0	€ 5	€ 5
Finishing	€ 0	€ 12	€ 12
Installation	€ 0	€ 46	€ 46
Removal	€ 0	€ 8	€ 8
Assembly Operations	€ 0	€ 7	€ 7
Mixing/Forming	€ 0	€ 5	€ 5
Auxiliary Operations	€ 0	€ 0	€ 0
Other	€ 0	€ 0	€ 0
TOTAL	€ 0	€ 83	€ 83

Table 8.2.2 Health costs – baseline scenario – Industry group breakdown - Based on a declining discount rate

Low	Female	Male	Total
Fibre Production	€ 0	€ 2	€ 2
Finishing	€ 0	€ 5	€ 5
Installation	€ 0	€ 20	€ 20
Removal	€ 0	€ 3	€ 3
Assembly Operations	€ 0	€ 3	€ 3
Mixing/Forming	€ 0	€ 2	€ 2
Auxiliary Operations	€ 0	€ 0	€ 0
Other	€ 0	€ 0	€ 0
TOTAL	€ 0	€ 36	€ 36

High	Female	Male	Total
Fibre Production	€ 0	€ 5	€ 5
Finishing	€ 0	€ 13	€ 13
Installation	€ 0	€ 51	€ 51
Removal	€ 0	€ 9	€ 9
Assembly Operations	€ 0	€ 7	€ 7
Mixing/Forming	€ 0	€ 5	€ 5
Auxiliary Operations	€ 0	€ 0	€ 0
Other	€ 0	€ 0	€ 0
TOTAL	€ 0	€ 91	€ 91

Table 8.2.3 Summary

Costs by Gender (€m)	2010-2019	2020-2029	2030-2039	2040-2049	2050-2059	2060-2069
Female	0 to 0	0 to 0	0 to 0	0 to 0	0 to 0	0 to 0
Male	14 to 34	10 to 24	7 to 18	4 to 9	2 to 4	1 to 2
Total	14 to 34	10 to 24	7 to 18	4 to 9	2 to 4	1 to 2

Table 8.2.4 Health costs – baseline scenario – Industry group breakdown - Based on a declining discount rate

Low	Female	Male	Total
Fibre Production	€ 0	€ 3	€ 3
Finishing	€ 0	€ 10	€ 10
Installation	€ 0	€ 38	€ 38
Removal	€ 0	€ 7	€ 7
Assembly Operations	€ 0	€ 5	€ 5
Mixing/Forming	€ 0	€ 4	€ 4
Auxiliary Operations	€ 0	€ 0	€ 0
Other	€ 0	€ 0	€ 0
TOTAL	€ 0	€ 68	€ 68

High	Female	Male	Total
Fibre Production	€ 0	€ 9	€ 9
Finishing	€ 0	€ 25	€ 25
Installation	€ 0	€ 99	€ 99
Removal	€ 0	€ 17	€ 17
Assembly Operations	€ 0	€ 14	€ 14
Mixing/Forming	€ 0	€ 10	€ 10
Auxiliary Operations	€ 0	€ 0	€ 0
Other	€ 0	€ 0	€ 0
TOTAL	€ 0	€ 174	€ 174

Table 8.2.5 Summary

Costs by Gender (€m)	2010-2019	2020-2029	2030-2039	2040-2049	2050-2059	2060-2069
Female	0 to 0	0 to 0	0 to 0	0 to 0	0 to 0	0 to 0
Male	16 to 41	17 to 44	15 to 38	10 to 26	6 to 16	3 to 9
Total	16 to 41	17 to 44	15 to 38	10 to 26	6 to 16	3 to 9

8.3 VALUING HEALTH BENEFITS – INTERVENTION SCENARIOS

Table 8.3.1 Proportions exposed above the exposure limits being tested for the manufacturing industry by country, forecast scenario

Forecast Scenario	1971-80	1981-90	1991-00	2001-10	2011-20	2021-30	1971-80	1981-90	1991-00	2001-10	2011-20	2021-30
OEL			1 fibres/ml						0.1 fibres/ml			
Austria	0.77	0.53	0.29	0.12	0.03	0.01	1.00	0.98	0.93	0.80	0.58	0.33
Belgium	0.77	0.53	0.29	0.12	0.03	0.01	1.00	0.98	0.93	0.80	0.58	0.33
Bulgaria	0.77	0.53	0.29	0.12	0.03	0.01	1.00	0.98	0.93	0.80	0.58	0.33
Cyprus	0.77	0.53	0.29	0.12	0.03	0.01	1.00	0.98	0.93	0.80	0.58	0.33
Czech Republic	0.77	0.53	0.29	0.12	0.03	0.01	1.00	0.98	0.93	0.80	0.58	0.33
Denmark	0.77	0.53	0.29	0.12	0.03	0.01	1.00	0.98	0.93	0.80	0.58	0.33
Estonia	0.77	0.53	0.29	0.12	0.03	0.01	1.00	0.98	0.93	0.80	0.58	0.33
Finland	0.77	0.53	0.29	0.12	0.03	0.01	1.00	0.98	0.93	0.80	0.58	0.33
France	0.77	0.53	0.29	0.12	0.03	0.01	1.00	0.98	0.93	0.80	0.58	0.33
Germany	0.77	0.53	0.29	0.12	0.03	0.01	1.00	0.98	0.93	0.80	0.58	0.33
Greece	0.77	0.53	0.29	0.12	0.03	0.01	1.00	0.98	0.93	0.80	0.58	0.33
Hungary	0.77	0.53	0.29	0.12	0.03	0.01	1.00	0.98	0.93	0.80	0.58	0.33
Ireland	0.77	0.53	0.29	0.12	0.03	0.01	1.00	0.98	0.93	0.80	0.58	0.33
Italy	0.77	0.53	0.29	0.12	0.03	0.01	1.00	0.98	0.93	0.80	0.58	0.33
Latvia	0.77	0.53	0.29	0.12	0.03	0.01	1.00	0.98	0.93	0.80	0.58	0.33
Lithuania	0.77	0.53	0.29	0.12	0.03	0.01	1.00	0.98	0.93	0.80	0.58	0.33
Luxembourg	0.77	0.53	0.29	0.12	0.03	0.01	1.00	0.98	0.93	0.80	0.58	0.33
Malta	0.77	0.53	0.29	0.12	0.03	0.01	1.00	0.98	0.93	0.80	0.58	0.33
Netherlands	0.77	0.53	0.29	0.12	0.03	0.01	1.00	0.98	0.93	0.80	0.58	0.33
Poland	0.77	0.53	0.29	0.12	0.03	0.01	1.00	0.98	0.93	0.80	0.58	0.33
Portugal	0.77	0.53	0.29	0.12	0.03	0.01	1.00	0.98	0.93	0.80	0.58	0.33
Romania	0.77	0.53	0.29	0.12	0.03	0.01	1.00	0.98	0.93	0.80	0.58	0.33
Slovakia	0.77	0.53	0.29	0.12	0.03	0.01	1.00	0.98	0.93	0.80	0.58	0.33
Slovenia	0.77	0.53	0.29	0.12	0.03	0.01	1.00	0.98	0.93	0.80	0.58	0.33
Spain	0.77	0.53	0.29	0.12	0.03	0.01	1.00	0.98	0.93	0.80	0.58	0.33
Sweden	0.77	0.53	0.29	0.12	0.03	0.01	1.00	0.98	0.93	0.80	0.58	0.33
United Kingdom	0.77	0.53	0.29	0.12	0.03	0.01	1.00	0.98	0.93	0.80	0.58	0.33
TOTAL	0.77	0.53	0.29	0.12	0.03	0.01	1.00	0.98	0.93	0.798	0.58	0.33

Table 8.3.2 Proportions exposed above the exposure limits being tested for downstream users by country, forecast scenario

Forecast Scenario	1971-80	1981-90	1991-00	2001-10	2011-20	2021-30	1971-80	1981-90	1991-00	2001-10	2011-20	2021-30
OEL			1 fibres/ml						0.1 fibres/ml			
Austria	0.61	0.45	0.29	0.17	0.09	0.04	0.94	0.88	0.78	0.64	0.48	0.32
Belgium	0.61	0.45	0.29	0.17	0.09	0.04	0.94	0.88	0.78	0.64	0.48	0.32
Bulgaria	0.61	0.45	0.29	0.17	0.09	0.04	0.94	0.88	0.78	0.64	0.48	0.32
Cyprus	0.61	0.45	0.29	0.17	0.09	0.04	0.94	0.88	0.78	0.64	0.48	0.32
Czech Republic	0.61	0.45	0.29	0.17	0.09	0.04	0.94	0.88	0.78	0.64	0.48	0.32
Denmark	0.61	0.45	0.29	0.17	0.09	0.04	0.94	0.88	0.78	0.64	0.48	0.32
Estonia	0.61	0.45	0.29	0.17	0.09	0.04	0.94	0.88	0.78	0.64	0.48	0.32
Finland	0.61	0.45	0.29	0.17	0.09	0.04	0.94	0.88	0.78	0.64	0.48	0.32
France	0.61	0.45	0.29	0.17	0.09	0.04	0.94	0.88	0.78	0.64	0.48	0.32
Germany	0.61	0.45	0.29	0.17	0.09	0.04	0.94	0.88	0.78	0.64	0.48	0.32
Greece	0.61	0.45	0.29	0.17	0.09	0.04	0.94	0.88	0.78	0.64	0.48	0.32
Hungary	0.61	0.45	0.29	0.17	0.09	0.04	0.94	0.88	0.78	0.64	0.48	0.32
Ireland	0.61	0.45	0.29	0.17	0.09	0.04	0.94	0.88	0.78	0.64	0.48	0.32
Italy	0.61	0.45	0.29	0.17	0.09	0.04	0.94	0.88	0.78	0.64	0.48	0.32
Latvia	0.61	0.45	0.29	0.17	0.09	0.04	0.94	0.88	0.78	0.64	0.48	0.32
Lithuania	0.61	0.45	0.29	0.17	0.09	0.04	0.94	0.88	0.78	0.64	0.48	0.32
Luxembourg	0.61	0.45	0.29	0.17	0.09	0.04	0.94	0.88	0.78	0.64	0.48	0.32
Malta	0.61	0.45	0.29	0.17	0.09	0.04	0.94	0.88	0.78	0.64	0.48	0.32
Netherlands	0.61	0.45	0.29	0.17	0.09	0.04	0.94	0.88	0.78	0.64	0.48	0.32
Poland	0.61	0.45	0.29	0.17	0.09	0.04	0.94	0.88	0.78	0.64	0.48	0.32
Portugal	0.61	0.45	0.29	0.17	0.09	0.04	0.94	0.88	0.78	0.64	0.48	0.32
Romania	0.61	0.45	0.29	0.17	0.09	0.04	0.94	0.88	0.78	0.64	0.48	0.32
Slovakia	0.61	0.45	0.29	0.17	0.09	0.04	0.94	0.88	0.78	0.64	0.48	0.32
Slovenia	0.61	0.45	0.29	0.17	0.09	0.04	0.94	0.88	0.78	0.64	0.48	0.32
Spain	0.61	0.45	0.29	0.17	0.09	0.04	0.94	0.88	0.78	0.64	0.48	0.32
Sweden	0.61	0.45	0.29	0.17	0.09	0.04	0.94	0.88	0.78	0.64	0.48	0.32
United Kingdom	0.61	0.45	0.29	0.17	0.09	0.04	0.94	0.88	0.78	0.64	0.48	0.32
TOTAL	0.61	0.45	0.29	0.17	0.09	0.04	0.94	0.88	0.78	0.639	0.48	0.32

Table 8.3.3 Numbers and proportions of the population ever exposed in the manufacturing industry for baseline and intervention[1] scenarios (2) and (3), by country, men only

Scenario[1]	All Scenarios		Baseline (trend) scenario (1)[2] - Linear employment and exposure level trends assumed to 2021-30, constant thereafter.				Intervention scenario (2) - Assume 99% compliance for OEL = 1 fibres/ml				Intervention scenario (3) - Assume 99% compliance for OEL = 0.1 fibres/ml			
Country	2010	2020	2030	2040	2050	2060	2030	2040	2050	2060	2030	2040	2050	2060
	Number ever exposed in the REP													
Austria	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Belgium	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bulgaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyprus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Czech Republic	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Denmark	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estonia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Finland	0	0	0	0	0	0	0	0	0	0	0	0	0	0
France	2,029	1,945	1,853	1,768	1,677	1,636	1,853	1,768	1,677	1,636	1,853	1,768	1,677	1,636
Germany	268	274	282	282	282	282	282	282	282	282	282	282	282	282
Greece	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hungary	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ireland	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Italy	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Latvia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lithuania	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Luxembourg	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Malta	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Netherlands	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Scenario[1] Country	All Scenarios		Baseline (trend) scenario (1)[2] - Linear employment and exposure level trends assumed to 2021-30, constant thereafter.				Intervention scenario (2) - Assume 99% compliance for OEL = 1 fibres/ml				Intervention scenario (3) - Assume 99% compliance for OEL = 0.1 fibres/ml			
	2010	2020	2030	2040	2050	2060	2030	2040	2050	2060	2030	2040	2050	2060
	Number ever exposed in the REP													
Poland	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Portugal	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Romania	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Slovakia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Slovenia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spain	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sweden	0	0	0	0	0	0	0	0	0	0	0	0	0	0
United Kingdom	741	677	586	493	426	385	586	493	426	385	586	493	426	385
TOTAL	3,039	2,896	2,721	2,543	2,385	2,303	2,721	2,543	2,385	2,303	2,721	2,543	2,385	2,303

Scenario[1] Country	All Scenarios		Baseline (trend) scenario (1)[2] - Linear employment and exposure level trends assumed to 2021-30, constant thereafter.				Intervention scenario (2) - Assume 99% compliance for OEL = 1 fibres/ml				Intervention scenario (3) - Assume 99% compliance for OEL = 0.1 fibres/ml			
	2010	2020	2030	2040	2050	2060	2030	2040	2050	2060	2030	2040	2050	2060
	Proportion of the population exposed													
Austria	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Belgium	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Bulgaria	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cyprus	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Czech Republic	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Denmark	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Estonia	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Finland	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
France	0.010	0.009	0.008	0.007	0.007	0.007	0.008	0.007	0.007	0.007	0.008	0.007	0.007	0.007
Germany	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Greece	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Hungary	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ireland	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Italy	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Latvia	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Lithuania	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Luxembourg	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Malta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Netherlands	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Poland	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Portugal	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Scenario[1] / Country	All Scenarios		Baseline (trend) scenario (1)[2] - Linear employment and exposure level trends assumed to 2021-30, constant thereafter.				Intervention scenario (2) - Assume 99% compliance for OEL = 1 fibres/ml				Intervention scenario (3) - Assume 99% compliance for OEL = 0.1 fibres/ml			
	2010	2020	2030	2040	2050	2060	2030	2040	2050	2060	2030	2040	2050	2060
	Proportion of the population exposed													
Romania	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Slovakia	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Slovenia	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Spain	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sweden	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
United Kingdom	0.004	0.003	0.002	0.002	0.002	0.001	0.002	0.002	0.002	0.001	0.002	0.002	0.002	0.001
TOTAL	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001%

Table 8.3.4 Results for baseline and intervention[1] scenarios (2) and (3) for lung cancer attributable to exposure in the manufacture industry, by country, men only

Scenario[1] / Country	All Scenarios		Baseline (trend) scenario (1)[2] - Linear employment and exposure level trends assumed to 2021-30, constant thereafter.				Intervention scenario (2) - Assume 99% compliance for OEL = 1 fibres/ml				Intervention scenario (3) - Assume 99% compliance for OEL = 0.1 fibres/ml			
	2010	2020	2030	2040	2050	2060	2030	2040	2050	2060	2030	2040	2050	2060
	Attributable Fraction													
Austria	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000%	0.00000%	0.00000%
Belgium	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000%	0.00000%	0.00000%
Bulgaria	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000%	0.00000%	0.00000%
Cyprus	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000%	0.00000%	0.00000%
Czech Republic	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000%	0.00000%	0.00000%
Denmark	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000%	0.00000%	0.00000%
Estonia	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000%	0.00000%	0.00000%
Finland	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000%	0.00000%	0.00000%
France	0.00052	0.00034	0.00015	0.00005	0.00001	0.00000	0.00015	0.00005	0.00001	0.00000	0.00015	0.00005%	0.00001%	0.00000%
Germany	0.00004	0.00003	0.00002	0.00001	0.00000	0.00000	0.00002	0.00001	0.00000	0.00000	0.00002	0.00001%	0.00000%	0.00000%
Greece	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000%	0.00000%	0.00000%
Hungary	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000%	0.00000%	0.00000%
Ireland	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000%	0.00000%	0.00000%
Italy	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000%	0.00000%	0.00000%
Latvia	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000%	0.00000%	0.00000%
Lithuania	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000%	0.00000%	0.00000%
Luxembourg	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000%	0.00000%	0.00000%
Malta	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000%	0.00000%	0.00000%
Netherlands	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000%	0.00000%	0.00000%
Poland	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000%	0.00000%	0.00000%

Scenario[1] Country	All Scenarios		Baseline (trend) scenario (1)[2] - Linear employment and exposure level trends assumed to 2021-30, constant thereafter.				Intervention scenario (2) - Assume 99% compliance for OEL = 1 fibres/ml				Intervention scenario (3) - Assume 99% compliance for OEL = 0.1 fibres/ml			
	2010	2020	2030	2040	2050	2060	2030	2040	2050	2060	2030	2040	2050	2060
	Attributable Fraction													
Portugal	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000%	0.00000%	0.00000%
Romania	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000%	0.00000%	0.00000%
Slovakia	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000%	0.00000%	0.00000%
Slovenia	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000%	0.00000%	0.00000%
Spain	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000%	0.00000%	0.00000%
Sweden	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000%	0.00000%	0.00000%
United Kingdom	0.00019	0.00012	0.00005	0.00002	0.00000	0.00000	0.00005	0.00002	0.00000	0.00000	0.00005	0.00002%	0.00000%	0.00000%
TOTAL	0.00009	0.00006	0.00003	0.00001	0.00000	0.00000	0.00003	0.00001	0.00000	0.00000	0.00003	0.00001%	0.00000%	0.00000%

Scenario[1]	All Scenarios		Baseline (trend) scenario (1)[2] - Linear employment and exposure level trends assumed to 2021-30, constant thereafter.				Intervention scenario (2) - Assume 99% compliance for OEL = 1 fibres/ml				Intervention scenario (3) - Assume 99% compliance for OEL = 0.1 fibres/ml			
Country	2010	2020	2030	2040	2050	2060	2030	2040	2050	2060	2030	2040	2050	2060
	Attributable Deaths													
Austria	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Belgium	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bulgaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyprus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Czech Republic	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Denmark	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estonia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Finland	0	0	0	0	0	0	0	0	0	0	0	0	0	0
France	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Germany	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Greece	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hungary	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ireland	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Italy	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Latvia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lithuania	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Luxembourg	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Malta	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Netherlands	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poland	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Portugal	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Scenario[1] Country	All Scenarios		Baseline (trend) scenario (1)[2] - Linear employment and exposure level trends assumed to 2021-30, constant thereafter.				Intervention scenario (2) - Assume 99% compliance for OEL = 1 fibres/ml				Intervention scenario (3) - Assume 99% compliance for OEL = 0.1 fibres/ml			
	2010	2020	2030	2040	2050	2060	2030	2040	2050	2060	2030	2040	2050	2060
	Attributable Deaths													
Romania	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Slovakia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Slovenia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spain	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sweden	0	0	0	0	0	0	0	0	0	0	0	0	0	0
United Kingdom	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Scenario[1] / Country	All Scenarios		Baseline (trend) scenario (1)[2] - Linear employment and exposure level trends assumed to 2021-30, constant thereafter.				Intervention scenario (2) - Assume 99% compliance for OEL = 1 fibres/ml				Intervention scenario (3) - Assume 99% compliance for OEL = 0.1 fibres/ml			
	2010	2020	2030	2040	2050	2060	2030	2040	2050	2060	2030	2040	2050	2060
	Attributable Registrations													
Austria	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Belgium	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bulgaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyprus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Czech Republic	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Denmark	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estonia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Finland	0	0	0	0	0	0	0	0	0	0	0	0	0	0
France	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Germany	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Greece	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hungary	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ireland	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Italy	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Latvia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lithuania	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Luxembourg	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Malta	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Netherlands	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poland	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Portugal	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Scenario[1] Country	All Scenarios		Baseline (trend) scenario (1)[2] - Linear employment and exposure level trends assumed to 2021-30, constant thereafter.				Intervention scenario (2) - Assume 99% compliance for OEL = 1 fibres/ml				Intervention scenario (3) - Assume 99% compliance for OEL = 0.1 fibres/ml			
	2010	2020	2030	2040	2050	2060	2030	2040	2050	2060	2030	2040	2050	2060
	Attributable Registrations													
Romania	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Slovakia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Slovenia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spain	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sweden	0	0	0	0	0	0	0	0	0	0	0	0	0	0
United Kingdom	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Scenario[1] Country	All Scenarios		Baseline (trend) scenario (1)[2] - Linear employment and exposure level trends assumed to 2021-30, constant thereafter.				Intervention scenario (2) - Assume 99% compliance for OEL = 1 fibres/ml				Intervention scenario (3) - Assume 99% compliance for OEL = 0.1 fibres/ml			
	2010	2020	2030	2040	2050	2060	2030	2040	2050	2060	2030	2040	2050	2060
	Attributable Years of Life Lost (YLLs)													
Austria	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Belgium	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bulgaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyprus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Czech Republic	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Denmark	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estonia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Finland	0	0	0	0	0	0	0	0	0	0	0	0	0	0
France	2	2	1	0	0	0	1	0	0	0	1	0	0	0
Germany	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Greece	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hungary	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ireland	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Italy	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Latvia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lithuania	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Luxembourg	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Malta	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Netherlands	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poland	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Portugal	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Scenario[1] Country	All Scenarios		Baseline (trend) scenario (1)[2] - Linear employment and exposure level trends assumed to 2021-30, constant thereafter.				Intervention scenario (2) - Assume 99% compliance for OEL = 1 fibres/ml				Intervention scenario (3) - Assume 99% compliance for OEL = 0.1 fibres/ml			
	2010	2020	2030	2040	2050	2060	2030	2040	2050	2060	2030	2040	2050	2060
	Attributable Years of Life Lost (YLLs)													
Romania	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Slovakia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Slovenia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spain	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sweden	0	0	0	0	0	0	0	0	0	0	0	0	0	0
United Kingdom	1	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	3	2	1	0	0	0	1	0	0	0	1	0	0	0

Scenario[1]	All Scenarios		Baseline (trend) scenario (1)[2] - Linear employment and exposure level trends assumed to 2021-30, constant thereafter.				Intervention scenario (2) - Assume 99% compliance for OEL = 1 fibres/ml				Intervention scenario (3) - Assume 99% compliance for OEL = 0.1 fibres/ml			
Country	2010	2020	2030	2040	2050	2060	2030	2040	2050	2060	2030	2040	2050	2060
	Attributable Years of Life Lived with Disability (DALYs)													
Austria	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Belgium	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bulgaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyprus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Czech Republic	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Denmark	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estonia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Finland	0	0	0	0	0	0	0	0	0	0	0	0	0	0
France	2	2	1	0	0	0	1	0	0	0	1	0	0	0
Germany	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Greece	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hungary	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ireland	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Italy	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Latvia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lithuania	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Luxembourg	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Malta	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Netherlands	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poland	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Portugal	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Scenario[1] / Country	All Scenarios		Baseline (trend) scenario (1)[2] - Linear employment and exposure level trends assumed to 2021-30, constant thereafter.				Intervention scenario (2) - Assume 99% compliance for OEL = 1 fibres/ml				Intervention scenario (3) - Assume 99% compliance for OEL = 0.1 fibres/ml			
	2010	2020	2030	2040	2050	2060	2030	2040	2050	2060	2030	2040	2050	2060
	Attributable Years of Life Lived with Disability (DALYs)													
Romania	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Slovakia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Slovenia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spain	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sweden	0	0	0	0	0	0	0	0	0	0	0	0	0	0
United Kingdom	1	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	3	2	1	0	0	0	1	0	0	0	1	0	0	0

[1] Intervention scenarios have been estimated assuming baseline exposure and employment levels
[2] Change from 2010 in baseline scenario is due to trends in 'historic' (pre 2005) part of REP

Note: numbers and proportions ever exposed remain constant across the baseline and intervention scenarios

Table 8.3.5 Numbers and proportions of the EU population ever exposed in the manufacture industry, men only

Scenario[1] / Industry sector	All Scenarios		Baseline (trend) scenario (1)[2] - Linear employment and exposure level trends assumed to 2021-30, constant thereafter.				Intervention scenario (2) - Assume 99% compliance for OEL = 1 fibres/ml				Intervention scenario (3) - Assume 99% compliance for OEL = 0.1 fibres/ml			
	2010	**2020**	**2030**	**2040**	**2050**	**2060**	**2030**	**2040**	**2050**	**2060**	**2030**	**2040**	**2050**	**2060**
	Number ever exposed in the REP													
Fibre Production	1,196	1,140	1,071	1,001	939	907	1,071	1,001	939	907	1,071	1,001	939	907
Finishing	164	156	147	137	128	124	147	137	128	124	147	137	128	124
Installation	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Removal	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Assembly Operations	201	192	180	169	158	153	180	169	158	153	180	169	158	153
Mixing/Forming	130	124	116	109	102	99	116	109	102	99	116	109	102	99
Auxiliary Operations	827	788	740	692	649	627	740	692	649	627	740	692	649	627
Other	520	496	466	436	409	394	466	436	409	394	466	436	409	394

Scenario[1]	All Scenarios		Baseline (trend) scenario (1)[2] - Linear employment and exposure level trends assumed to 2021-30, constant thereafter.				Intervention scenario (2) - Assume 99% compliance for OEL = 1 fibres/ml				Intervention scenario (3) - Assume 99% compliance for OEL = 0.1 fibres/ml			
Industry sector	2010	2020	2030	2040	2050	2060	2030	2040	2050	2060	2030	2040	2050	2060
	Proportion of the population exposed													
Fibre Production	0.0007	0.0006	0.0006	0.0005	0.0005	0.0005	0.0006	0.0005	0.0005	0.0005	0.0006	0.0005	0.0005	0.0005
Finishing	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Installation	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Removal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Assembly Operations	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Mixing/Forming	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Auxiliary Operations	0.0005	0.0004	0.0004	0.0004	0.0003	0.0003	0.0004	0.0004	0.0003	0.0003	0.0004	0.0004	0.0003	0.0003
Other	0.0003	0.0003	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002

Table 8.3.6 Occupation attributable fractions, deaths, registrations, YLLs and DALYs for lung cancer in the manufacturing industry, men only

Scenario[1]	**All Scenarios**		**Baseline (trend) scenario (1)[2] - Linear employment and exposure level trends assumed to 2021-30, constant thereafter.**				**Intervention scenario (2) - Assume 99% compliance for OEL = 1 fibres/ml**				**Intervention scenario (3) - Assume 99% compliance for OEL = 0.1 fibres/ml**			
Industry sector	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**2030**	**2040**	**2050**	**2060**	**2030**	**2040**	**2050**	**2060**
	Attributable Fraction													
Fibre Production	0.00007	0.00004	0.00002	0.00001	0.00000	0.00000	0.00002	0.00001	0.00000	0.00000	0.00002	0.00001	0.00000	0.00000
Finishing	0.00001	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Installation	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Removal	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Assembly Operations	0.00001	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Mixing/Forming	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Auxiliary Operations	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Other	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

Scenario[1] / Industry sector	All Scenarios		Baseline (trend) scenario (1)[2] - Linear employment and exposure level trends assumed to 2021-30, constant thereafter.				Intervention scenario (2) - Assume 99% compliance for OEL = 1 fibres/ml				Intervention scenario (3) - Assume 99% compliance for OEL = 0.1 fibres/ml			
	2010	2020	2030	2040	2050	2060	2030	2040	2050	2060	2030	2040	2050	2060
	Attributable Deaths													
Fibre Production	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Finishing	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Installation	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Removal	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Assembly Operations	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mixing/Forming	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Auxiliary Operations	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Scenario[1] Industry sector	All Scenarios		Baseline (trend) scenario (1)[2] - Linear employment and exposure level trends assumed to 2021-30, constant thereafter.				Intervention scenario (2) - Assume 99% compliance for OEL = 1 fibres/ml				Intervention scenario (3) - Assume 99% compliance for OEL = 0.1 fibres/ml			
	2010	2020	2030	2040	2050	2060	2030	2040	2050	2060	2030	2040	2050	2060
	Attributable Registrations													
Fibre Production	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Finishing	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Installation	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Removal	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Assembly Operations	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mixing/Forming	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Auxiliary Operations	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Scenario[1]	All Scenarios		Baseline (trend) scenario (1)[2] - Linear employment and exposure level trends assumed to 2021-30, constant thereafter.				Intervention scenario (2) - Assume 99% compliance for OEL = 1 fibres/ml				Intervention scenario (3) - Assume 99% compliance for OEL = 0.1 fibres/ml			
Industry sector	2010	2020	2030	2040	2050	2060	2030	2040	2050	2060	2030	2040	2050	2060
	Attributable Years of Life Lost (YLLs)													
Fibre Production	2	2	1	0	0	0	1	0	0	0	1	0	0	0
Finishing	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Installation	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Removal	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Assembly Operations	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mixing/Forming	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Auxiliary Operations	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Scenario[1]	All Scenarios		Baseline (trend) scenario (1)[2] - Linear employment and exposure level trends assumed to 2021-30, constant thereafter.				Intervention scenario (2) - Assume 99% compliance for OEL = 1 fibres/ml				Intervention scenario (3) - Assume 99% compliance for OEL = 0.1 fibres/ml			
Industry sector	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**2030**	**2040**	**2050**	**2060**	**2030**	**2040**	**2050**	**2060**
	Attributable Years of Life Lived with Disability (DALYs)													
Fibre Production	2	2	1	0	0	0	1	0	0	0	1	0	0	0
Finishing	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Installation	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Removal	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Assembly Operations	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mixing/Forming	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Auxiliary Operations	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 8.3.7 Numbers and proportions of the EU population ever exposed in downstream uses of refractor ceramic fibres, men only

Scenario[1]	**All Scenarios**		**Baseline (trend) scenario (1)**[2] **- Linear employment and exposure level trends assumed to 2021-30, constant thereafter.**				**Intervention scenario (2) - Assume 99% compliance for OEL = 1 fibres/ml**				**Intervention scenario (3) - Assume 99% compliance for OEL = 0.1 fibres/ml**			
Industry sector	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**2030**	**2040**	**2050**	**2060**	**2030**	**2040**	**2050**	**2060**
	Number ever exposed in the REP													
Fibre Production	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Finishing	2,182	2,227	2,280	2,278	2,276	2,276	2,280	2,278	2,276	2,276	2,280	2,278	2,276	2,276
Installation	9,164	9,352	9,578	9,570	9,560	9,560	9,578	9,570	9,560	9,560	9,578	9,570	9,560	9,560
Removal	1,582	1,614	1,653	1,652	1,650	1,650	1,653	1,652	1,650	1,650	1,653	1,652	1,650	1,650
Assembly Operations	1,169	1,193	1,222	1,221	1,220	1,220	1,222	1,221	1,220	1,220	1,222	1,221	1,220	1,220
Mixing/Forming	852	870	891	890	889	889	891	890	889	889	891	890	889	889
Auxiliary Operations	4,742	4,840	4,956	4,952	4,947	4,947	4,956	4,952	4,947	4,947	4,956	4,952	4,947	4,947
Other	12,011	12,258	12,553	12,542	12,530	12,530	12,553	12,542	12,530	12,530	12,553	12,542	12,530	12,530

Scenario[1] Industry sector	All Scenarios		Baseline (trend) scenario (1)[2] - Linear employment and exposure level trends assumed to 2021-30, constant thereafter.				Intervention scenario (2) - Assume 99% compliance for OEL = 1 fibres/ml				Intervention scenario (3) - Assume 99% compliance for OEL = 0.1 fibres/ml			
	2010	2020	2030	2040	2050	2060	2030	2040	2050	2060	2030	2040	2050	2060
	Proportion of the population exposed													
Fibre Production	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000%
Finishing	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001%
Installation	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005%
Removal	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001%
Assembly Operations	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001%
Mixing/Forming	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000%
Auxiliary Operations	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003%
Other	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007%

Table 8.3.8 Occupation attributable fractions, deaths, registrations, YLLs and DALYs for lung cancer in downstream users of refractory ceramic fibres, men only

Scenario[1]	**All Scenarios**		**Baseline (trend) scenario (1)**[2] **- Linear employment and exposure level trends assumed to 2021-30, constant thereafter.**				**Intervention scenario (2) - Assume 99% compliance for OEL = 1 fibres/ml**				**Intervention scenario (3) - Assume 99% compliance for OEL = 0.1 fibres/ml**			
Industry sector	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**2030**	**2040**	**2050**	**2060**	**2030**	**2040**	**2050**	**2060**
	Attributable Fraction													
Fibre Production	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Finishing	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000
Installation	0.0005	0.0004	0.0002	0.0001	0.0001	0.0000	0.0002	0.0001	0.0000	0.0000	0.0002	0.0001	0.0000	0.0000
Removal	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Assembly Operations	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Mixing/Forming	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Auxiliary Operations	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Other	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Scenario[1]	All Scenarios		Baseline (trend) scenario (1)[2] - Linear employment and exposure level trends assumed to 2021-30, constant thereafter.				Intervention scenario (2) - Assume 99% compliance for OEL = 1 fibres/ml				Intervention scenario (3) - Assume 99% compliance for OEL = 0.1 fibres/ml			
Industry sector	2010	2020	2030	2040	2050	2060	2030	2040	2050	2060	2030	2040	2050	2060
	Attributable Deaths													
Fibre Production	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Finishing	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Installation	1	1	1	0	0	0	1	0	0	0	1	0	0	0
Removal	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Assembly Operations	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mixing/Forming	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Auxiliary Operations	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Scenario[1] / Industry sector	All Scenarios		Baseline (trend) scenario (1)[2] - Linear employment and exposure level trends assumed to 2021-30, constant thereafter.				Intervention scenario (2) - Assume 99% compliance for OEL = 1 fibres/ml				Intervention scenario (3) - Assume 99% compliance for OEL = 0.1 fibres/ml			
	2010	2020	2030	2040	2050	2060	2030	2040	2050	2060	2030	2040	2050	2060
	Attributable Registrations													
Fibre Production	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Finishing	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Installation	1	1	1	0	0	0	1	0	0	0	1	0	0	0
Removal	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Assembly Operations	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mixing/Forming	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Auxiliary Operations	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Scenario[1]	All Scenarios		Baseline (trend) scenario (1)[2] - Linear employment and exposure level trends assumed to 2021-30, constant thereafter.				Intervention scenario (2) - Assume 99% compliance for OEL = 1 fibres/ml				Intervention scenario (3) - Assume 99% compliance for OEL = 0.1 fibres/ml			
Industry sector	2010	2020	2030	2040	2050	2060	2030	2040	2050	2060	2030	2040	2050	2060
	Attributable Years of Life Lost (YLLs)													
Fibre Production	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Finishing	4	3	2	1	1	0	2	1	0	0	2	1	0	0
Installation	15	13	9	5	3	1	9	5	2	0	9	5	2	0
Removal	3	2	2	1	0	0	2	1	0	0	2	1	0	0
Assembly Operations	2	2	1	1	0	0	1	1	0	0	1	1	0	0
Mixing/Forming	1	1	1	0	0	0	1	0	0	0	1	0	0	0
Auxiliary Operations	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Scenario[1]	All Scenarios		Baseline (trend) scenario (1)[2] - Linear employment and exposure level trends assumed to 2021-30, constant thereafter.				Intervention scenario (2) - Assume 99% compliance for OEL = 1 fibres/ml				Intervention scenario (3) - Assume 99% compliance for OEL = 0.1 fibres/ml			
Industry sector	2010	2020	2030	2040	2050	2060	2030	2040	2050	2060	2030	2040	2050	2060
	Attributable Years of Life Lived with Disability (DALYs)													
Fibre Production	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Finishing	4	3	2	1	1	0	2	1	0	0	2	1	0	0
Installation	16	14	10	6	3	1	10	5	2	0	10	5	2	0
Removal	3	2	2	1	0	0	2	1	0	0	2	1	0	0
Assembly Operations	2	2	1	1	0	0	1	1	0	0	1	1	0	0
Mixing/Forming	1	1	1	1	0	0	1	0	0	0	1	0	0	0
Auxiliary Operations	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0

[1] Intervention scenarios have been estimated assuming baseline exposure and employment levels
[2] Change from 2010 in baseline scenario is due to trends in 'historic' (pre 2005) part of REP

Note: numbers and proportions ever exposed remain constant across the baseline and intervention scenarios

8.4 HEALTH BENEFITS USING DIFFERENT DISCOUNT RATES

COLOUR KEY
No discount
Using the EU IA guidance - 4%
Using a declining discount rate (4% going to 3%)

Table 8.4.1 No discounting

LOW COST (€m)	Intervention option 1 - Introduce OEL at 1 fibres/ml	Intervention option 2 - Introduce OEL = 0.1 fibres/ml
Fibre Production	€ 0	€ 0
Finishing	€ 1	€ 1
Installation	€ 3	€ 4
Removal	€ 1	€ 1
Assembly Operations	€ 0	€ 0
Mixing/Forming	€ 0	€ 0
Auxiliary Operations	€ 0	€ 0
Other	€ 0	€ 0
TOTAL	€ 5	€ 6

HIGH COST (€m)	Intervention option 1 - Introduce OEL at 1 fibres/ml	Intervention option 2 - Introduce OEL = 0.1 fibres/ml
Fibre Production	€ 0	€ 0
Finishing	€ 2	€ 2
Installation	€ 9	€ 10
Removal	€ 2	€ 2
Assembly Operations	€ 1	€ 1
Mixing/Forming	€ 1	€ 1
Auxiliary Operations	€ 0	€ 0
Other	€ 0	€ 0
TOTAL	€ 15	€ 17

Table 8.4.2 Standard EU IA 4% discount rate

LOW COST (€m)	Intervention option 1 - Introduce OEL at 1 fibres/ml	Intervention option 2 - Introduce OEL = 0.1 fibres/ml
Fibre Production	€ 0	€ 0
Finishing	€ 0	€ 0
Installation	€ 1	€ 1
Removal	€ 0	€ 0
Assembly Operations	€ 0	€ 0
Mixing/Forming	€ 0	€ 0
Auxiliary Operations	€ 0	€ 0
Other	€ 0	€ 0
TOTAL	€ 1	€ 1

HIGH COST (€m)	Intervention option 1 - Introduce OEL at 1 fibres/ml	Intervention option 2 - Introduce OEL = 0.1 fibres/ml
Fibre Production	€ 0	€ 0
Finishing	€ 0	€ 0
Installation	€ 1	€ 2
Removal	€ 0	€ 0
Assembly Operations	€ 0	€ 0
Mixing/Forming	€ 0	€ 0
Auxiliary Operations	€ 0	€ 0
Other	€ 0	€ 0
TOTAL	€ 2	€ 3

Table 8.4.3 Declining discount rate

LOW COST (€m)	Intervention option 1 - Introduce OEL at 1 fibres/ml	Intervention option 2 - Introduce OEL = 0.1 fibres/ml
Fibre Production	€ 0	€ 0
Finishing	€ 0	€ 0
Installation	€ 1	€ 1
Removal	€ 0	€ 0
Assembly Operations	€ 0	€ 0
Mixing/Forming	€ 0	€ 0
Auxiliary Operations	€ 0	€ 0
Other	€ 0	€ 0
TOTAL	€ 1	€ 2

HIGH COST (€m)	Intervention option 1 - Introduce OEL at 1 fibres/ml	Intervention option 2 - Introduce OEL = 0.1 fibres/ml
Fibre Production	€ 0	€ 0
Finishing	€ 1	€ 1
Installation	€ 2	€ 2
Removal	€ 0	€ 0
Assembly Operations	€ 0	€ 0
Mixing/Forming	€ 0	€ 0
Auxiliary Operations	€ 0	€ 0
Other	€ 0	€ 0
TOTAL	€ 4	€ 4

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