HSC/05/103 E

RIA ANNEX A: HSL RISK ASSESSMENT

Introduction

A1. The European Union classifies all forms of asbestos as category 1 carcinogens. It has long been accepted that the risk from exposure to amphiboles (amosite and crocidolite) exceeds that from exposure to chrysotile. Nevertheless HSC's policy (and that of the European Union) has been that exposure to all forms of asbestos should be prevented, or exposure minimised where prevention is not reasonably practicable.

A2. The main human health effects associated with occupational exposure to asbestos are fibrosis (asbestosis), lung cancer and mesothelioma. Evidence that asbestos is associated with an increased risk of cancer at other sites is inconclusive. The rate of asbestos related diseases in the UK has been predicted to increase and high levels of incidence are found among maintenance workers (Peto et al. 1995).

A3. Health risks can be divided into two main groups, namely workers disturbing asbestos containing materials (ACMs) and other individuals, including members of the public, who may be affected by these work activities or the presence of disturbed or degraded asbestos within buildings they inhabit or visit. The first group, workers disturbing ACMs can be subdivided into a number of sub-groups:

1. Primary manufacturing of ACMs;
2. Secondary manufacture and use of ACMs;
3. Installation of ACM products;
4. Maintenance and repair of ACMs;
5. Removal / demolition of ACMs

A4. Since late 1999, except for a very few products, all manufacturing and installation of ACMs has ceased and maintenance, repair, removal and demolition of existing ACMs are the main activities of concern. This was reflected by the introduction of an explicit duty to manage ACMs in building in the updated Control of Asbestos at Work Regulations 2002 (CAW).

A5. Overall it was previously estimated (in CD159) that the following amounts of asbestos were installed into the UK:

- Approximately some 50,000 tonnes of crocidolite, mainly in the form of textile, thermal and spray insulation:
- Approximately some 500,000 tonnes of amosite, mainly in the form of asbestos insulating board, thermal and spray insulation:

- Approximately some 2.7 million tonnes of chrysotile, mainly in the form of cement products (and minor amounts of textiles).

A6. The previous estimate in 1999 (CD159) was that about a quarter of the asbestos products installed had been removed and that the majority of the remaining material would be removed over a 50 year period. It would be consistent with this to estimate that about one third of the installed asbestos has now been removed. However, this is an overall estimate and the amounts removed will vary for particular products.

Main changes to risk of UK workers from the amended EU directive

A7. The EU directive 2003/18/EC (AWPD amendments) makes a number of amendments to Council Directive 83/477/EEC "On the protection of workers from the risks related to exposure to asbestos at work", that will have implications on the risks to workers. The main changes in the directive that will have a direct influence on the risk to workers are those, which will either avoid further exposure to current groups of workers, or those that will reduce current exposures still further. As several of the changes in the EU Directive are already in place in the current UK regulations (CAW and the Asbestos (Licensing) Regulations 1987 (ASLIC)), it is necessary to evaluate the effect of the EU amendments with regard to both the additional risk reduction to the current UK Regulations and the risk reduction that may already be in place. As full compliance is normally assumed when making risk estimates, it is also necessary to determine which measures increase the compliance rather than introducing further reductions in risk.

A8. For instance, the current duty to manage (regulation 4 in CAW) and regulation 5 of CAW already enact most of the new measures in Article 10A of the AWPD amendments, which introduce measure to avoid exposure of maintenance and other workers. "Before beginning demolition or maintenance work, employers shall take, if appropriate by obtaining information from the owners of the premises, all necessary steps to identify presumed asbestos-containing materials. If there is any doubt about the presence of asbestos in a material or construction, the applicable provisions of this Directive shall be observed."

A9. However, the requirement in Article 12a that "Employers shall provide appropriate training for all workers who are, or are likely to be, exposed to asbestos containing dust," will result in increased awareness and hence compliance but in itself does not directly introduce any new reduction in risk or the number of asbestos related deaths. For example, with increased awareness training any suspected damaged or deteriorated asbestos will be more likely to be brought to the attention of the employer and result in increased compliance. Similarly, maintenance workers will be less likely to unknowingly disturb or clean up the deteriorated asbestos material.

A10. The main amendment that will result in lower exposure is the reduction of the control limits to 0.1 f/cm^3 for all types of regulated asbestos in Article 8 in conjunction with the revised Article 6 (exposure must be reduced to a minimum and in any case below the limit value). The effects of this reduction are also magnified by a change in Article 7, which introduces the use of the WHO method for the assessment of airborne fibre exposure as it will increase the numbers of fibres counted in the analysis. The changes to Articles 7 and 8, will have a direct impact on licensed asbestos removal workers who regularly work in an environment where the control limit is approached and exceeded and will lead to the use of increased controls.

A11. Other demolition workers who work with unlicensed materials may also find that they have to introduce further controls to ensure they comply with the lower control limits. Unlicensed maintenance workers will also be affected but at present as they are limited to 1 hour of work with materials for which a licence is required per week, the lower control limits are unlikely to make a significant difference to their exposure compared with the benefits of avoiding unknown and hence uncontrolled exposures. Also, with better management of the asbestos in buildings and increased training of maintenance workers, it is much less likely that unlicensed maintenance workers will be working on materials for which a licence is required in the future. However changes introduced to comply with Article 3 and in particular the new concept of "sporadic and low intensity work" may result in changes to the types of work carried out by demolition and maintenance workers and hence a change to their risks.

A12. The previous RIA for the new Duty to Manage Asbestos (in CD174) gave a detailed assessment of the best estimate of annual mortality for all workers likely to be exposed to asbestos into the future. After correcting for demolition of existing asbestos containing buildings (average of 2% per annum), this gave a total of 7,800 deaths arising from exposure to asbestos over the next fifty years (if no further action other than routine demolition is undertaken). Given the lag between exposure and death (an additional 50 years after exposure) deaths will continue to occur up to the end of this century. The average number of deaths is 78 in each future year, and the peak number is 158, which is predicted to occur in the year 2058. The figure of 7,800 excluded deaths related to purely environmental exposures (~1,200). The number of occupational exposure deaths avoided was estimated at 58% of 7,800, or 4,500, with around 2,000 as a result of indirect, or work-related, exposure. The remaining 1,300 deaths would be as a result of domestic exposure, most of which are not covered by CAW (or the amended Directive).

A13. The baseline year for this estimate was 2000 but as the Duty to manage only came into force in 2004 and the EU directive is to be implemented less than two years later, the risks and actual numbers of deaths predicted are essentially the same and the risk estimate has not been updated. The previously published figure of 4,500 has therefore been taken as the baseline of avoidable deaths. The modeling process for these risks were fully discussed and published in CD174. The principles used for the modeling are briefly outlined below before describing in detail the modeling process used for the additional reductions due to measures other than for Article 10A.

Modelling past and present risk for all workers

A14. Due to the long lag times between exposure and the onset of disease (15 – 60 years), many of the current UK asbestos-related deaths are in workers who were exposed to high airborne asbestos fibre levels during the manufacture and installation of asbestos products. The importation of asbestos into the UK (figure 1) is therefore a good predictor of the likely disease rates to these groups of workers and has been used to model the expected levels of UK disease. The quantitative epidemiological dose-response models used for risk assessment are based on the exposures and disease rates found among various cohorts of asbestos production and manufacturing workers. These have been reviewed and described by Hodgson and Darnton (2000) and the outcomes have been used to model future rates of asbestos related lung cancer and mesothelioma to maintenance, repair and removal workers.

A15. The approach taken for previous risk estimates (CD159 & CD174) to estimate potential lives saved involved the following steps:

- Step 1. Model the link between exposure and mesothelioma deaths at the population level.
- Step 2. Estimate current exposure levels.
- Step 3. Calibrate the risk generated by estimated current levels to the exposure index in population model
- Step 4. Estimate how this current level of population exposure would change over the next 50 years if no additional control action was taken
- Step 5. Use the model derived in Step 1 to predict the number of deaths over the next century which would be produced by the future exposure profile estimated in Step 4.
- Step 6. Partition these assumed deaths into those due to asbestos in commercial buildings and those in domestic buildings.

Figure 1: Asbestos imports into the UK

Step 1: Modelling the link between exposure and mesothelioma deaths at the population level.

A16. The basic approach here has been to infer the past track of asbestos exposure from year to year from the detailed pattern of male mesotheliomas by age and year (the data is single years, and single years of age to age 89). This approach assumes that the population's total exposure to asbestos can be summarised in each year by a single number and that the relationship between this summarised exposure index and future deaths from mesothelioma will take the same form as is widely assumed for the relationship between asbestos exposure and mesothelioma risk at the individual level:

$$r = CD(t-10)^k$$

A17. Here, r is mesothelioma risk at time t; D is cumulative exposure; t is time in years since exposure and C and k are parameters to be estimated. The value estimated for k is 2.6, in the middle of the range expected 2 - 3. The maximum year for exposure is estimated at 1967, with a very steep (but poorly determined) reduction in exposure after this date. When expressed at the population level further factors need to be built into the equation to reflect the age distribution of exposure. This included terms to model a possible trend in the completeness of diagnosis, and of clearance of asbestos fibres from the lung.

A18. The estimates of relative exposure potential at different ages imply that exposure is concentrated on the age group 20 to 49 and that it is occupation, especially male occupation, that provide the main source of exposures. A non-clearance model was adopted as the basis for predictions.

A19. A large (and increasing) proportion of the predicted future deaths are at ages 80 and above. This is driven both by the form of the model, and by the increasing survival to older ages in the population. Although the mesothelioma model used here fits observed mortality in occupational cohort studies quite well, it can reasonably be doubted whether the risk of mesothelioma increases indefinitely with time after exposure. The few occupational cohorts with very long follow-up all show eventual falls in mesothelioma rate. For this reason previous risk assessments have truncated their predictions at age 80. Clearly this is an approximation since there will be at least some deaths at ages 80 and over. Therefore, the population model fitted here has included deaths up to age 89. There is some indication that the fit is less satisfactory at ages 80 and over. For the purposes of mortality prediction we will limit these to deaths below age 80, though we note that this is likely to be an under estimate. The true value will lie somewhere between this total and the total predicted including deaths to age 89.

A20. Comparison of the estimated track of exposure with the figures for imports of asbestos of various types suggests that the amphibole component of imports was a much more important determinant of mesothelioma mortality than that of chrysotile. Figure 2 shows the profile of asbestos imports along with the fitted exposure index. None of the import series reflect the exposure index profile very closely, but the timing of the fall in exposure corresponds quite closely with that for amosite imports. Chrysotile imports did not fall until about ten years later. If chrysotile was a major determinant of mesothelioma mortality, the fitted exposure index might be expected to show a later fall.

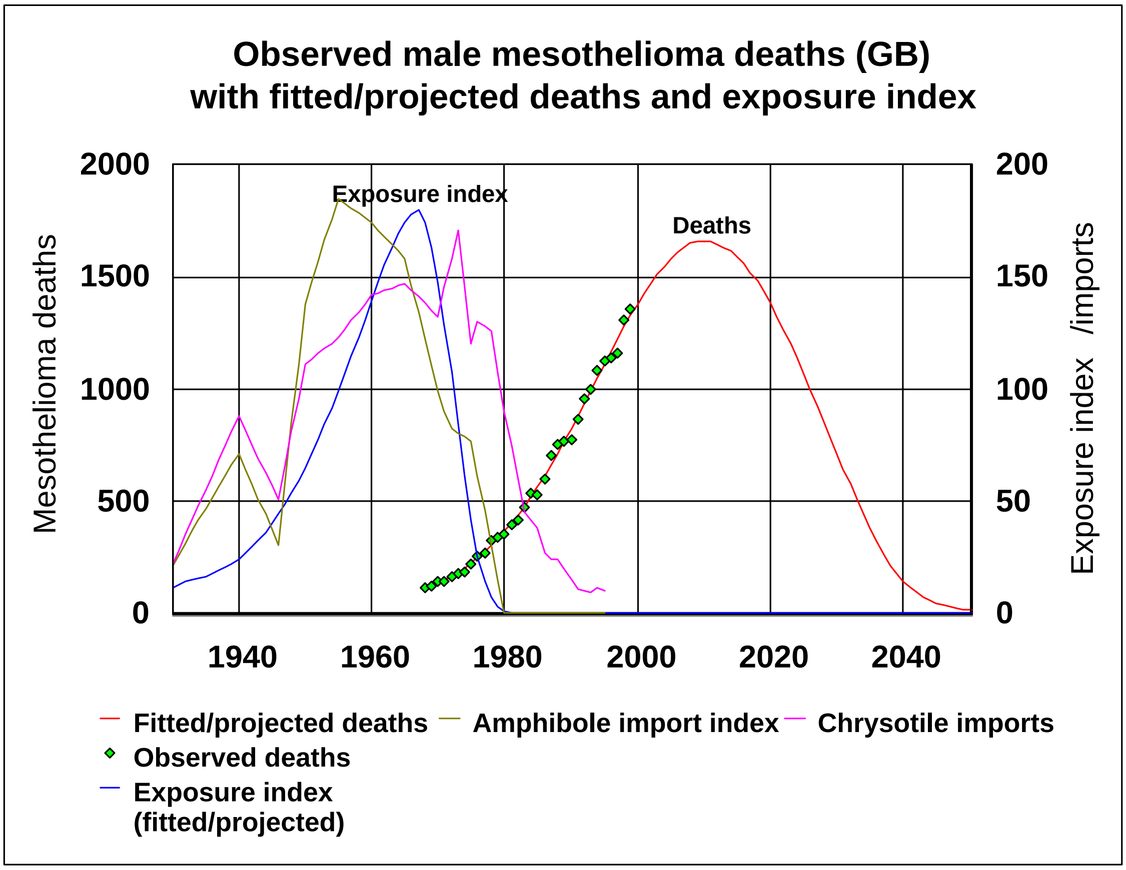

Figure 2: Comparison of fitted exposure index with import volumes

Estimating the fall in previous exposure levels

A21. If the rate of decline in the 10 years following the implied exposure peak had continued, exposure levels would have fallen to essentially trivial levels well before the year 2000. But there is no real basis for assuming this rate of decline will have continued. Its main driver will have been the rapid reduction in initial processing of imported fibre into asbestos products and their installation. Once exposure has fallen to the level generated by continued routine building maintenance and demolition (and asbestos removal), the rate of total population exposure would be expected to be fairly constant. We have no good measurement-based evidence for knowing what this level is but for the purposes of projecting mortality levels in the future the current and future path of exposure is the crucial assumption.

Step 2: Current exposure to asbestos

A22. Table 1 shows the exposure distributions and numbers exposed in the broad occupational categories described above on a typical working day. In order to calculate the level of risk this exposure pattern presents in relation to historic exposures, we estimate the annual level of deaths that would eventually be generated by the long-term continuation of this exposure pattern. Over an extended period of time the same individuals would not experience the same exposure level from day to day. Furthermore, a given individual would not be expected to spend their entire working lifetime within the same job category.

A23. In order to model the sharing of exposure over time, and the flow of individuals through these job categories over a working lifetime, we assume a turnover factor for each of the three highest exposure job categories. For example, we assume that over a working lifetime (40 years) 10 times as many people will at some time work in a demolition or asbestos removal job than are involved in these jobs on a given current day. (This is consistent with data on individuals having statutory asbestos medicals as asbestos removal workers over the past 14 years). Smaller (5-fold and 2.5-fold) working lifetime turnover factors are assumed for the larger, less specialised categories of maintenance worker and other building work respectively. These estimates are based on the Labour Force Survey, which provides estimates of time with current employer, and also on whether the respondent’s occupation has changed over the last year. However, for our purposes, this is complicated by the fact that individuals may move between both employers, and also detailed occupation, but still be exposed to asbestos.

A24. The working lifetime exposure distribution for the group of individuals who have *ever* worked as a demolition or asbestos removal worker will not be the same as that for this group of workers on a given day, but will depend on what other job categories these individuals have occupied over their working life. For these calculations we have assumed that workers in demolition and asbestos removal at some time in their working life are drawn from the "other building work" distribution. In other words this group is formed by adding to the numbers for demolition/removal on a given day a proportion of the "other building work" drawn pro-rata from the exposure distribution of that group. The average exposure in the resulting group is consequently a weighted average of the demolition/removal and other building groups for a given day.

Table 1 **Occupational exposure distributions assumed**

	Exposure distributions on a given current day					Average daily exposure distribution in working lifetime pools (taking account of turnover)				
Exposure level (f/ml)	Asbestos removal/ demolition	Regularly exposured maintenance	Other building jobs	Other occupations	Total	Asbestos removal/ demolition	Regularly exposured maintenance	Other building jobs	Other occupations	Total
10	9	120	8	0	137	9	120	7	0	137
5	17	241	77	0	335	25	241	70	0	335
1	170	2,406	774	13	3,363	247	2,406	699	11	3,363
0.5	510	7,217	7,742	131	15,599	1,275	7,221	6,989	114	15,599
0.1	1,700	24,055	38,708	1,310	65,772	5,525	24,103	35,006	1,138	65,772
0.05	3,400	48,110	77,415	13,097	142,023	11,050	48,591	71,003	11,378	142,023
0.01	3,390	48,110	154,831	523,883	730,214	18,690	67,354	189,040	455,130	730,214
0.001	3,400	48,110	557,390	2,095,531	2,704,432	58,480	125,087	700,347	1,820,518	2,704,432
0.0001	2,705	38,127	556,531	11,772,814	12,370,176	57,700	470,585	1,614,117	10,227,775	12,370,176
0.00001	1,700	24,055	154,831	11,787,364	11,967,950	17,000	457,047	1,253,487	10,240,416	11,967,950
total	17,000	240,551	1,548,306	26,194,143	28,000,000	170,000	1,202,755	3,870,765	22,756,480	28,000,000
mean level	0.057	0.057	0.010	0.00036	0.0014	0.014	0.012	0.0037	0.00036	0.0014
..with lowest two levels set to zero	0.057	0.057	0.010	0.00031	0.0014	0.014	0.012	0.0037	0.00031	0.0014
turnover	10	5	2.5							

A25. In a similar way, the extra individuals in the "ever maintenance" and "ever other building" groups are drawn from the "other occupations" group. The resulting numbers and exposure distributions are shown in the last four columns of table 1.

A26. Within each group it is assumed that all individuals have an equivalent probability of days at each exposure level. The predicted asbestos related mortality is accordingly calculated assuming a working lifetime (age 20 to age 60) exposure at the group average using the risk factors suggested by Hodgson and Darnton (2000).

A27. A further set of assumptions has to be made about the proportions of the different fibre types in the assumed exposure. Most of the fibre in asbestos products was chrysotile, but the kinds of product into which chrysotile was incorporated, and the location of these products in buildings implies that the proportion of fibres in exposures that are likely to be generated is much more heavily weighted towards the amphibole fibres than would at first seem likely. One basis for assessing the likely proportions is to assume a "release factor" to reflect the different probability that fibres of a particular type will be released. We believe that the release factor for the amphibole fibres is at least ten times that of chrysotile. Applying these factors to the amounts of the three fibre types which were imported in the 1960s (the peak period for imports) implies exposure proportions of around 10:60:30 for blue, and brown and white asbestos respectively. This is broadly in line with the limited air monitoring evidence available. The difficulty of using direct evidence of air monitoring is that this is only done in situations where exposure to asbestos is known to be taking place, or to be likely to take place. It cannot be taken to be representative of the exposures that will occur in situations where this is not known.

A28. Our best model assumes the above proportions for the proportions of the three fibre types in airborne exposure, with variants 15:50:35 and 5:50:45. The central pattern of fibre mix together with the exposure distributions shown in figure 3 imply a long term annual total of 93 mesothelioma deaths (based on overall death rates of the 1970s), of which 71 will be men. This is assuming that all the highest exposure individuals are male and the rest of the exposed population is divided in equal proportions of male and female.

Step 3: Calibration of risk generated by estimated current levels to exposure index in population model

A29. The next stage in the procedure is to calibrate the risk generated by the exposure outline above by estimated current levels to exposure index in the population model. The predictions of annual mortality levels generated by applying the risk factors from Hodgson and Darnton relate to deaths before age 80, and to a population subject to the overall death rates of the 1970s.

A30. To determine what constant level of the exposure index in the projection models corresponds to this predicted annual death rate from mesothelioma, we have to find the constant exposure level within the model which predicts the appropriate number of male mesothelioma deaths at ages up to 80 in the 1970s. The improvements in survival to the ages where mesothelioma death rates are highest between the 1970s and now (and the further improvements which are expected in the future) mean that the predicted annual total generated by a constant exposure rises over time. To generate 71 annual male deaths from mesothelioma in the 1970s from a constant exposure level in the projection model, the exposure index needs to be set at 4.2% of the peak.

Step 4: Estimating how this current level of population exposure would change over the next 50 years if no additional control action was taken.

A31. Taking exposure at 4.2% of the peak value as our assumed present level, we next estimate its future path to fall in proportion to the predicted demolition rate of the generation of buildings with high probability of containing asbestos materials. Existing regulations will apply on demolition, but the benefits of any asbestos management programme cease at this point. Data from the Valuation Office suggested an average building life of fifty years. We had therefore previously reduced both the costs and benefits attributable to the proposals by 2% each year.

A32. This figure is based on the median age of commercial buildings (around fifty years). The demolition rate for the cohort of older buildings containing asbestos will rise on a yearly basis, as these buildings reach the end of their lives. We therefore apply a demolition rate of 1% of current stock a year currently, rising to 4% by the end of the period, and giving an average of around 2%. The effect of this change is to slightly increase benefits, since commercial buildings (and therefore the on-going benefits from establishing a management system) last longer from the present. The effect is through discounting, rather than any change in the average demolition rate.

A33. We are now in a position to estimate future mortality from asbestos, in the absence of any further action (or increased compliance with existing regulation) other than routine demolition.

Step 5: Estimation of the total number of future deaths in all sectors (step 5 in the modelling procedure)

A34. Taking the best estimate annual mortality into the future, and correcting for demolition, leads to a total of 7,800 deaths arising from exposure to asbestos over the next fifty years, if no further action other than routine demolition is undertaken.

A35. Given the lag between exposure and death, these deaths continue to occur up to the end of this century. The average number of deaths is 78 in each future year, and the peak number is 158, which is predicted to occur in the year 2058. The profile of mortality is shown in graphical form in fig 3.

A36. These estimates include both deaths from lung cancer and also deaths to women. The numbers of lung cancer cases prevented in the future is more questionable than for the mesotheliomas. The uncertainties underlying this calculation are also considerable, particularly those associated with the risk factors at these - generally - low levels of exposure. By varying the key input assumptions: the risk factors taken from Hodgson and Darnton (2000), the fibre mix assumption, the size of the regularly exposed maintenance group and the turnover of individuals through exposure groups. The possible range in risk factors has a five-fold upward and eightfold downward impact on the estimated mortality levels, while the other assumptions introduce less than a twofold in total uncertainty. There are (at least) two additional sources of uncertainty. The typical levels of exposure we are now considering are at the low end of the intensity scale, and it is at least arguable (HSE's recent review of fibre toxicology has advanced this position) that there is a threshold for asbestos related lung cancers. In any case, the interaction between smoking levels and asbestos exposure, and the fact that the prevalence of smoking has fallen considerably over recent years, means that the number of lung cancers per mesothelioma is likely to be lower in the future than it has been in the past.

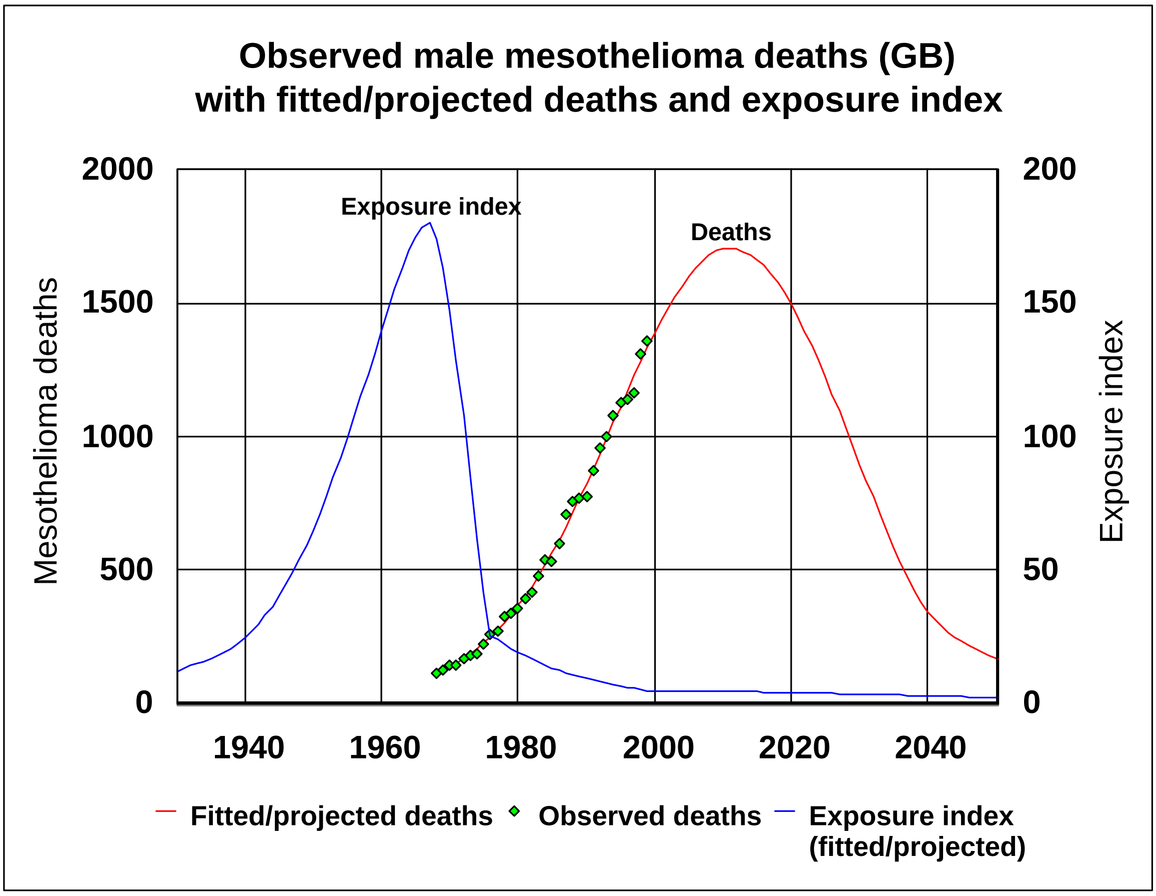

Figure 3: Best estimate of Fitted/Projected deaths

A37. The projection modeling applies to males deaths only (due to the relative lack of data for female deaths), but the risk assessment from current exposures also generates predicted numbers of female deaths which can then be used to uprate the predicted male deaths from the production model pro rata. The uprating factor for the best model is 31%, which varies depending on whether `background exposure' is included.

Step 6: Apportioning total deaths between commercial and residential premises

A38. The final step in the modelling procedure is to apportion this future mortality between commercial and residential premises. In order to calculate this, we require our mortality estimates split between the different exposed groups. The number of deaths that would occur in the different exposed groups, given the exposures and other assumptions in our risk model is given in table 2.

Table 2: Predicted annual deaths by exposed groups (for constant exposure, and 1970s life table)

Exposed groups	Number of deaths		
	Mesothelioma	Lung cancer	Total
Removal/demolition	3	1	4
Regularly exposed building workers	27	4	31
Other building workers	20	5	25
Rest of working population	25	1	26
Domestic exposure (aged 20+)	5	0	5
Domestic exposure (aged <20)	13	0	13
Total	93	11	104

A39. The model used to provide our best estimate attributes 58% of total risk to be from occupational exposure to maintenance and building workers. The other 42% of the total risk is attributable to the background exposure of the people working/living in buildings containing asbestos. Of this 42%, the model attributes 17% of total risk to residents in all housing types, with the remaining 25% attributable mainly to background exposure in commercial buildings.

A40. The DTI construction statistics gives the total value of repair and maintenance activity, broken down by a broad building type. Around 48% of repair and maintenance are conducted on commercial buildings. Of the remaining amount, 32% is conducted in private housing and 20% on public housing.

A41. Private housing is known to contain far less asbestos than local authority provided housing. A generous assumption would be that private housing - on a unit by unit basis is four times less likely to contain asbestos than publicly provided housing (or equivalently a private house containing asbestos will contain one-quarter the amount of that found in local authority accommodation that contains asbestos). This together with the above figures indicates that around 7% of total risk will be in the owner occupied sector and around 29% in the local authority and rented sectors, giving a total of 35% after rounding. Some of this risk will relate to common areas of residential accommodation, which are included in these proposals. As noted below, we cannot separate these from the costs and benefits relating to rented accommodation as a whole, which are examined in a separate document.

A42. The remaining 65% of total risk is that attributable to workers conducting maintenance activity on commercial buildings and also the background exposure to the occupants of such buildings. Forty percentage points of this total risk in commercial buildings is risks to workers conducting maintenance on the building. This is consistent with the fact that a higher proportion of buildings in the commercial sector contain asbestos, and where it is found it would also be more extensive than in residential accommodation. Commercial buildings thus account for the majority of occupational risk to workers conducting maintenance work.

A43. Looking at background risk, the split between the commercial and residential sectors is more equal, despite the fact that asbestos is more prevalent in commercial buildings This is partly due to the longer time exposure of residents of housing compared to occupants of workplaces, and also to the higher population estimates.

A44. It should be noted that the above proportions relate to *current risk.* Since our model estimates a lower demolition rate amongst the residential sector, in the future the proportion of risk in the residential sector will increase. This can be demonstrated by the fact that although the residential sector accounts for 35% of current risk, 39% of preventable deaths are estimated to occur in this sector.

A45. The total number of deaths in the commercial sector is therefore estimated at 4,700 and the total number of deaths in the residential sector is estimated at 3,100. Assuming full compliance with article 10A of the new directive, most of these deaths would be avoided.

Modelling risks and benefits from a reduced control limit

A46. The modelling approach used above for all workers, was based on estimates of the current daily exposures to the working population of 28 million, with several specific groups (see table 1) having increased exposure from direct contact and disturbance of ACMs in buildings. The numbers of workers who will be actively working with and disturbing asbestos, at or above the control limit on a daily basis is a much smaller group of ~85,000 mainly construction and maintenance workers (see table 3). The numbers of workers approaching the control limit has also been summarised.

Table 3: Summary of previously estimated numbers of workers at or above the control limit on a daily basis

Exposure level (f/ml)	Asbestos removal/ demolition	Regularly exposed maintenance workers	Other building jobs	Other occupations	Total all categories	Total Maintenance & other building jobs
≥ 0.1	2406	34039	47309	1454	85208	81348
0.05	3400	48110	77415	13097	142022	125525
All workers	17,000	240,551	1, 548,306	26,194,143	28,000,000	1,788,857
Av. days of exposure/yr.	34	34	7.33	0.013		

A47. It can be seen that the estimates made on the numbers exposed daily will also reflect the average frequency that a worker will be exposed at or above the proposed control limit of 0.1 f/ml. The estimated number of workers exposed is based on estimates before the duty to manage (regulation 4 of CAWR) came into effect in 2004. The effect of these regulations will be to substantially reduce the figures of persons exposed at or above the control limit for other building jobs and other occupations. If 100% compliance was assumed these would of course be zero. The regularly exposed maintenance workers will also be expected to greatly reduce the amount of work carried out on ACMs and particularly the types of work, which have the potential to release levels above the control limit. Increased levels of training for maintenance workers in the amended directive will also improve awareness and controls further reducing exposures.

A48. Only the removal and demolition sector is likely to have increased numbers of workers who are regularly exposed above the control limit. This sector of workers is therefore looked at in closer detail. This is also the group that has the highest frequency, duration and level of amphibole asbestos exposure and the need to monitor compliance with the control limit.

Method for estimation of the reduction of risk from the lowering of the control limit

A49. The method for estimating the reduction of risk uses the following steps:

1) derive the current arithmetic average asbestos exposure of the groups of asbestos workers who will be affected;
2) calculate their current expected lifetime risk using the HD quantitative risk assessment model with a realistic job duration and age at first exposure;

3) adjust risk parameters to allow for the use of RPE and future trends/changes etc.;
4) recalculate lifetime risks with new parameters using the HD quantitative risk assessment model.
5) Subtract the adjusted values from the current values to estimate the reduction in risk expected from those changes.
6) Express difference in terms of a benefit (e.g. the calculated numbers of asbestos related deaths avoided) and as a reduction in lifetime or annual risk

A50. The following main parameters have been assessed to estimate the exposure for three different categories of workers (Licensed asbestos removers, unlicensed demolition work and maintenance work):

- The type of activity and frequency which it is carried out;
- The types of material being disturbed or removed;
- The average concentration of airborne asbestos fibres produced by the different types of activity;

A51. The lifetime risks related to the asbestos exposure are calculated using the same model derived from Hodgson and Darnton (2000) and that was used to calculate the risks for all workers above. The main inputs into the model that will affect the calculated risk are:

- The arithmetic mean exposure;
- The age first exposed and survival age;
- The frequency and duration of the exposure;
- The type of asbestos released.

A52. The number of deaths calculated will also depend on the:

- The numbers of workers exposed in each category of work;
- The lag time allowed for the disease.

Category of work

A53. The type of ACM being disturbed defines the category of work. Due to the existing ASLIC regulations, removal work can be divided into two main categories: licensed and unlicensed. Demolition of buildings should only take place after all the ACMs have been removed. Most demolition workers should therefore only be involved in controlled removal of unlicensed material, while specialist removal contractors will remove licensed materials. As article 10A of the directive has already been substantially implemented, along with improved standards, definitions and accreditation for surveying, this should strictly limit the number of sites where residual or overlooked ACMs are still present during demolition. As the UK has a well -established system of licensing, and it is only through failure to implement the regulations that demolition workers will be exposed to the addition risks from licensed materials. The relative risks from the various types of licensed and unlicensed materials are looked at in more detail in a separate section of this RIA.

A54. Although maintenance workers have been restricted to work of short duration (< 1 hour per week per person) with licensed materials, there is no limit to the amount of work they can carry out on unlicensed ACMs. However, there is usually a difference in the scale, type and amount of disturbance and sometimes the types of controls applied between small scale maintenance work and more significant refurbishment and removal work. All work with asbestos is covered by CAWR, (2002) and one of two approved codes of practices (L27 & L28), with a duty to ensure airborne exposures to workers and the spread of asbestos are kept as low as reasonably practicable.

Estimation of exposure

The type of activity and frequency which it is carried out

A55. The type of activity or disturbance taking place is one of the main determinants of the airborne fibre concentration. Work with asbestos should be carried out in a controlled way to minimise the release of airborne fibres. However, even after many years after the adoption of controlled wet removal a significant percentage of asbestos removal is still carried out dry. On average, with licensed materials this will produce airborne concentrations some 2 orders of magnitude higher than controlled wet removal methods. Similarly the use of energetic and dusty processes to remove asbestos (e.g. dry grit blasting and sanding, as well as the use of power tools) increase exposures and there use is discouraged. The frequency that removal work is undertaken is also a basic determinant of the annual exposure / dose. Published data and HSE's own data has been used to estimate the exposures for different types of activity with asbestos materials.

Type and amount of material being disturbed or removed,

A56. Certain types of ACMs are licensed materials because of a perceived increased risk. There are many asbestos products but they fall into about 10 main groups of products. Five of them are defined as licensed materials (ASLIC, 1983, as amended 1998); sprays and coatings, lagging (including textile ropes), asbestos insulating board and decorative / textured coatings. Non-licensed asbestos products include: cement, bitumen, flooring and friction products, as well as, various other reinforced plastic and resin composites. The total amount of airborne asbestos released will depend on the volume / area of material that is being disturbed or removed.

The average concentration of airborne asbestos fibres produced by the activity,

A57. The cumulative exposure (dose) is an important metric in any risk assessment. For asbestos fibres exposure has been defined in terms of the airborne concentration of regulatory fibres (in fibres per millilitre f/ml) as counted by an approved method (e.g. MDHS 39/4 until 2006). The cumulative exposure is normally expressed in f/ml.years and is the sum of many individual exposures, where each exposure will depend on a number of variables (e.g. type of ACM/s being disturbed, type of activity/disturbance, amount of material being disturbed, type of controls, duration of activity, etc.) and on the use and effectiveness of personal and respiratory protection. Often there are only a limited number of individual exposure measurements available and these are used to estimate the arithmetic mean fibre exposure concentration. The available data (see CD174) have been updated for this review.

Modelling and calculation of lifetime risk

A58. The HD model estimates the number of lung cancers and mesotheliomas that will occur. Most of the risk is due to mesothelioma and the model is discussed in A14 and A15 is related by a power relationship to the time since first exposure. This will result in increasing numbers of asbestos related deaths in an ageing population with an increasing life expectancy.

The arithmetic mean exposure

A59. The exposure assessment is used to calculate an arithmetic mean for input into the risk model. As discussed above this is an overall estimate made from published data and data collected by HSE. As the arithmetic mean is used a few high exposures can significantly affect the mean if limited data is available.

The age first exposed and survival age

A60. For licensed asbestos removal work all workers are required to have a medical before starting work and the age at the first recorded medicals is given in figure 4. This is shown to have a mean age of 32.5 but significant numbers are exposed from the age 20 onwards.

A61. The risk model assumes exposure up to the age of 60 so the maximum duration of exposure of 40 years is possible if age of first exposure is 20. The average survival age used to calculate the lifetime risks has been retained at 80 although there is an argument for increasing this value, as life expectancy is still increasing among the general population. Instead of further increasing the survival age, a more conservative value of 20 for the age of first exposure was used in the calculations. The increased time since first exposure increases the number of lifetime deaths.

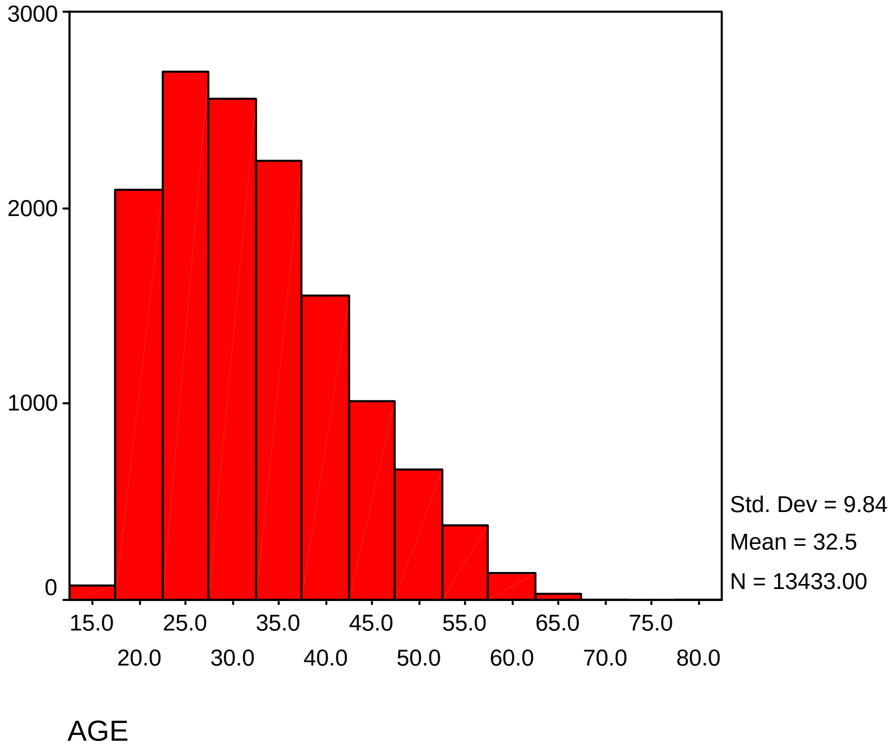

Figure 4: Age distribution for asbestos remover's first exam since 1995

The frequency and duration of the exposure

A62. The cumulative exposure is derived from the arithmetic mean exposure x frequency of exposure x average duration of exposure. Estimates of the frequency and duration of exposure were relatively easy to make for workers in the asbestos manufacturing industries but are much more problematic for maintenance and demolition workers. However, there are data for licensed asbestos removal work. Under (CAWR, 2002) employers are required to keep records of their employees frequency and duration of asbestos work and an estimate of their exposure. Unfortunately, there is no requirement to calculate, record or report the annual cumulative exposure for each employee, so no direct figures for individual workers are available to HSE from the employers but more general information is available from the notification and medical systems.

A63. Under ASLIC, (1983) all work over exceeding 2 hours with licensed materials should be notified to HSE on a ASB 5 form along with an attached plan of work. These are usually held for 3 months by HSE regional offices before disposal but there is also a central system that records some of the data supplied on the ASB5 notifications. This is held by the Health Unit of the Field operating division of HSE and three years of computerised records were available for analysis.

A64. Information on the duration of exposure to licensed asbestos removal workers are available from the records held by the Employment Medical Statistics Unit (EMSU) of HSE on the number of medical carried out for asbestos removal workers. These are usually 2 years apart so doubling the number of medicals gives an approximation to the length of time an average worker spends in the licensed asbestos removal industry. The current information is given in figure 5 and implies that a large turnover of workers takes place. The medical examinations data also show that the average years working per man is 3.09 but this assumes the full period is worked and is likely to be an overestimate. The majority of workers (71.5%) only have one examination, i.e. work for less than 2 years. Just over 90% of workers work for 5 years or less. So for practical purposes, the risk estimates based on 5 years exposure (shown in bold in Table 5) apply to virtually all workers.

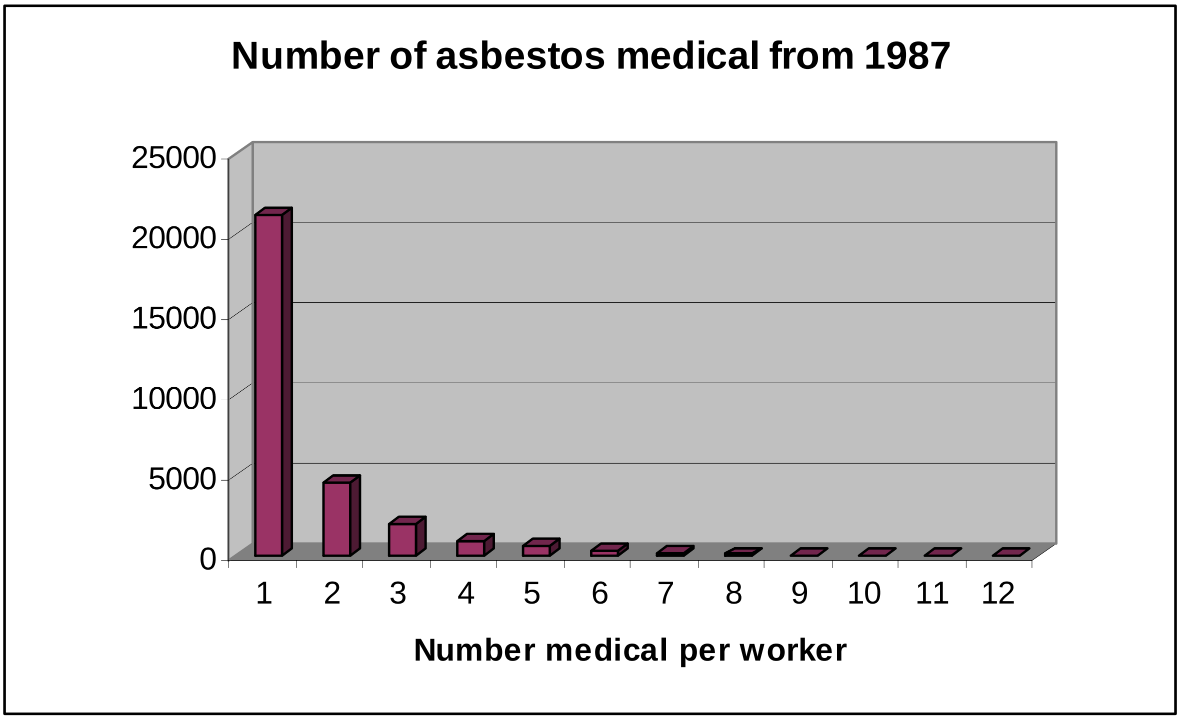

Figure 5: Numbers of asbestos medicals per worker from 1977

The type of asbestos released.

A65. It has long been recognised in UK regulations that the type of asbestos released has different effects on the disease rates. In keeping with EU regulations the differentials in the control limits between the different types of asbestos have been reduced over the last 10 years and are due to disappear altogether in 2006. However, the more recent risk models place much greater emphasis on the type of asbestos to which the person has been exposed. For example, the Hodgson and Darnton model uses a factor of 500: 100: 1 to characterise the relative risks for mesothelioma for crocidolite, amosite and chrysotile respectively. However, the older EPA IRIS model uses a single average risk factor for all three types. As removal and maintenance worker will receive a mixed exposure it is necessary to make assumptions on the fibre type. For the all worker model a mix of 10:60:30 crocidolite, amosite and chrysotile respectively was used for the best approach. The HD model is therefore very sensitive to assumptions and estimates about the type of asbestos to which people are exposed. Unfortunately this is not recorded on the main FOD database but are available if the plans of work held with the ASB 5 notifications for 3 months at the regional offices are inspected.

A66. For unlicensed work there are no notifications so no direct information was available.

Number of asbestos related deaths

The numbers of workers exposed in each category of work

A67. The number of persons exposed will determine the estimated number of asbestos related deaths. As ACMs are still present in many older buildings, the number of people potentially exposed to any asbestos due to workplace activity is large ~ 28 million (see table 1). However, the numbers of workers who will be actively working with and disturbing asbestos at or above the control limit on a daily basis is a much smaller group of ~85,000 mainly construction and maintenance workers (see table 3). The previous RIA defined regularly exposed workers as those working with ACM for more than one-tenth of their total working time. An estimate of the total size of this group of 240,000, or 13% of all building and maintenance workers, is based on a judgement of which particular trades will be most at risk from asbestos and what proportions of all workers in these trades this regularly exposed group will account for. Detailed occupational information was obtained from the Labour Force Survey. Trades falling in this group include electricians, heating engineers, fitters, and some carpenters and joiners. In addition, we tried to account for activities not identified by the standard coding, such as `cable-pulling'.

A68. According to HSE / EMSU figures, there were some 4903 medical examinations for asbestos workers in 2001 and 4798 in 2002. Examinations are required every two years. The number of workers with valid medical certificates in any one year should not be more than twice the number of examinations. It is known that some workers have their medicals before the 2 years is up and that some have medicals but work for less than 2 years. It is estimated there are currently some 9,000 licensed asbestos removal workers. In the modelling for all workers a turnover of X10 was assumed (CD 174). The numbers of people which have only one medical suggest that the turnover rate may be significantly higher than 10 over a period of 50 years. The total number of commercial and public premises currently containing asbestos is estimated to be in the region of 500,000. Given the rate of demolition of 2% on average (starting at 1% and rising to 4%) about 5,000 jobs arising from demolition in current years and 10,000 per year on average are predicted. Other groups of workers were given lower turnover rates X5 for maintenance workers and X 2.5 for other construction workers.

A69. The way the removal, demolition and maintenance workers perform their work and their use of appropriate precautions and controls will affect the exposure of other person and workers. Either those who are nearby during the work, or if debris and dust is left behind those workers who subsequently disturb the residual material (e.g. cleaners, other maintenance and construction workers, or other persons using the area). The previous update to the CAWR (2002), which introduced a new duty to manage ACMs, were designed to reduce the chances of construction or maintenance workers unknowingly or inappropriately working with ACMs. This would also result in fewer workers working with ACMs and would also limit uncontrolled exposures to workers and bystanders.

The lag time allowed for the disease.

A70. The model for all workers allowed for a further 50 years of exposure from the baseline year with a 50 year lag time from the end of the exposure for the disease to develop.

A71. Although a significant amount of asbestos has been removed in the last 5 years the accuracy to which we can predict worker numbers will make little difference if we use the same time periods as in the previous RIA.

Risk estimation for licensed asbestos removal workers

Fibre Concentration data

A72. Measurement of personal exposures to airborne fibres for licensed UK asbestos removal work on various types of ACM were available from a database compiled by HSL (Burdett and Revell, 1995 – with some further results added later). A wider data set of airborne exposures monitored from work with ACMs from literature sources has also compiled by HSL, and was published in CD 174. The literature survey has been updated for this review and unpublished measurements from the French EVALUTIL database have also been added. These two sources have been used to derive the estimated the fibre concentration but as much of the literature data is from outside the UK, where removal methods and working practices may differ, preference has generally been given to the HSL UK database for estimating exposures for licensed asbestos removal work. Although the measurements are somewhat dated they are specific to controlled wet removal as carried out in the UK. As it was likely the measurements were biased towards best practice, as HSE / HSL or other monitoring personnel were on site during the work, this is counterbalanced by the fact that there will have been improvements in proficiency of use and in the performance of the controlled wet removal methods. Therefore, it was considered that current licensed asbestos removal using controlled wetting methods would have similar exposures to the good practice measured some 10 years ago.

A73. Some licensed removal work is still reportedly carried out dry, and is non-compliant with HSE's approved codes of practice and guidance but no allowances have been made for the much higher exposures that occur during dry removal or poor wet removal.

Types and frequency of licensed asbestos removal work

A74. The database of licensed asbestos removal from FOD Health Unit (HU) has 97,940 job notifications over a period of approximately 3 years, amounting in total to 709305 working days (job-days). Because of the sample size, this is by far the most statistically reliable set of data we have. The database/ASB5s record five categories of asbestos materials, asbestos insulating board (AIB), asbestos insulation (AI), asbestos coatings (AC), textured coatings (TC) and others (OTH). One or more of these are recorded for each job with the most abundant material first. Figure 6 summarises the number of jobs by material type. It can be seen that asbestos insulating board currently accounts for 50% of all licensed removal jobs. The average time for jobs with different ACMs varies (see table 4). The shortest time was for textured coatings and the longer times were associated with multiple types of ACMs (i.e. the larger jobs are larger to have a greater variety of ACMs). Figure 7, summarises the proportion of time spent working (in terms of job days) by material type.

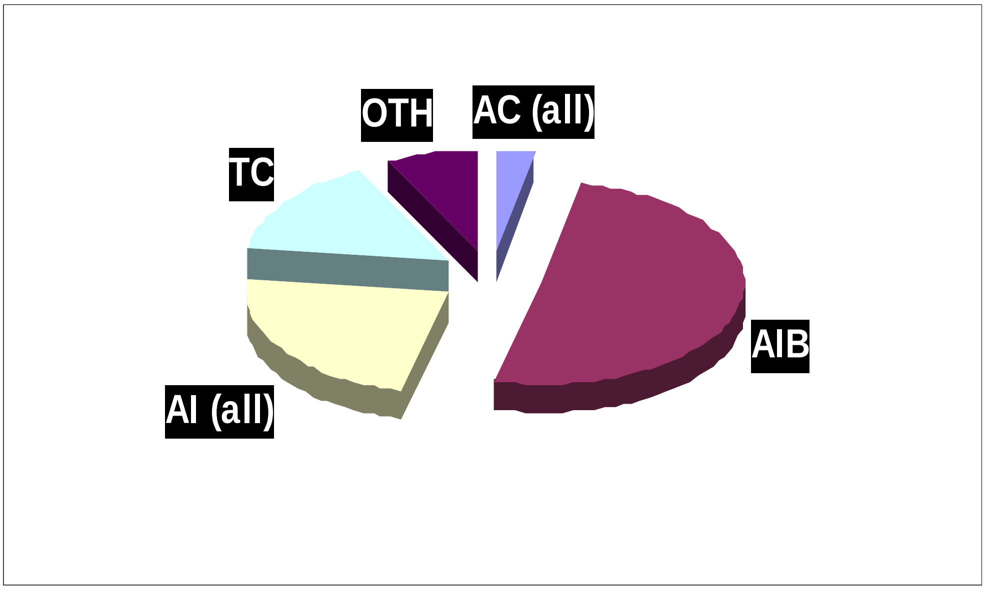

Figure 6: Relative frequency of asbestos material type encountered during licensed removal work (by number of jobs)

A75. Most removal jobs are of short duration: Nearly 30% take only one day and jobs of less than 4 days duration make up more that half the notifications. But the average duration (HU data set) is 7.2 days and there are a small number of big jobs, which make a large contribution to the number of working days. More than a quarter of the working days come from jobs lasting more than 50 days, which make up less than 2% of all jobs. Jobs for which there is a mixture of ACM types tend to take longer and employ more men than average; several types of ACM are most likely to be encountered on the larger scale jobs. The two (AC+AI+AIB) 365-day jobs make a large contribution, as they each employed 14 men, and these may well make the proportions on worker-days for each ACM untypical. There are, however, other long-duration jobs in the other ACM type categories. In general, a small number of large-scale jobs make up a large part of the working time (man-days).

A76. Although one-day jobs make up more than a quarter of the total number, they only account for about 4% of working days. The duration of TC jobs tends to be less than average, as might be expected if many of these were small-scale work on domestic premises, and so too is the number of workers. So work on TC makes up a much smaller proportion of the man-days.

A77. The HU data give a clear picture of the scale of licensed asbestos removal work. Over 30,000 jobs are notified each year, which is over 600 a week; on average, over 120 new jobs will be started each day. Licensed asbestos work amounts to nearly quarter of a million working days each year, which means there are nearly a thousand jobs in progress each day. With an around 3 workers as the average number for a job (see below), this means that nearly 3000 workers are engaged in licensed asbestos removal each day.

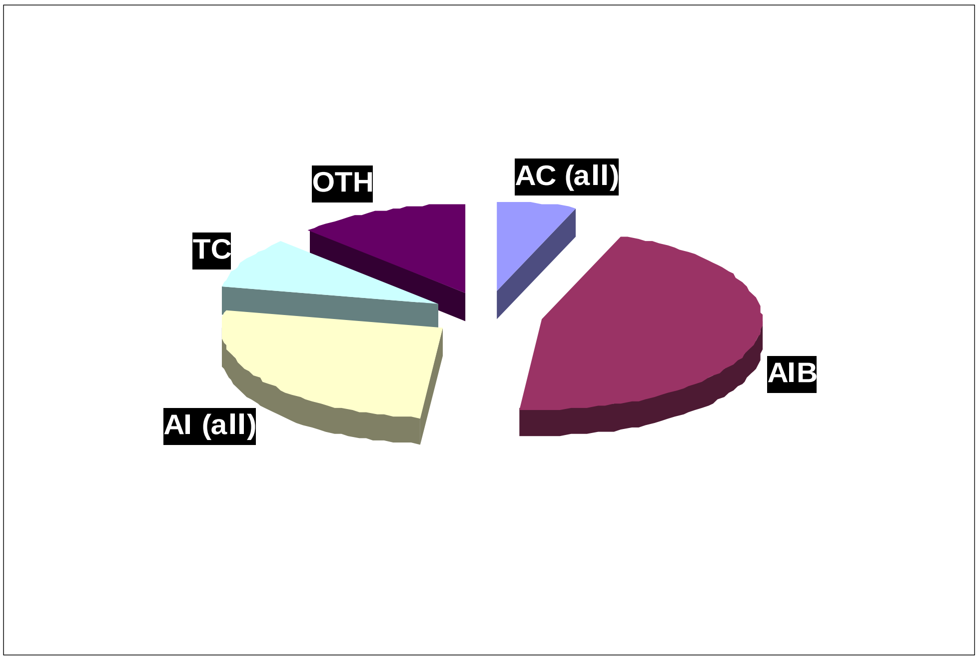

Figure 7: Relative frequency of asbestos material type encountered during licensed removal work (by number of job days)

Table 4: Summary of FOD database for licensed removal work					
	By number of jobs		By job-days		
Type of ACM	Number of Jobs	Percentage of total	Number of job days	Percentage of total	Average duration of job (days)
AC	2276	2.32%	23056	3.43%	10.1
AC & AIB	289	0.30%	4589	0.68%	15.9
AC & AI	220	0.22%	2620	0.39%	11.9
AC & AI & AIB	262	0.27%	6738	1.00%	25.7
AIB	49608	50.65%	290134	43.20%	5.8
AI	20303	20.73%	167579	24.95%	8.3
AI & AIB	2440	2.49%	39795	5.93%	16.3
Other	7245	7.40%	78891	11.75%	10.9
TC	15297	15.62%	58239	8.67%	3.8
Total	97940	100.00%	671641	100.00%	6.9

Calculation of exposure from FOD HU database

A78. By combining the fibre measurement data with the frequency of work with each category of material it was possible to calculate the average annual exposure to all asbestos removal workers in terms of job days. A fibre concentration for “other” asbestos has to be assumed to complete the exposure assessment. A weighted mean concentration in terms of number of jobs was calculated and used but if “other” was truly other non-licensed materials rather than a mixture of licensed materials the average fibre concentration would be lower.

Table 5: Calculated annual exposure to asbestos removal workers (average of 3-year period 2000 – 2003).			
	Arithmetic mean personal exposure	Cumulative exposure in 1 year	Percentage of total exposure
Type of ACM	(f/ml)	f/ml.job-days	
AC	14.36	110361	24.58%
AC & AIB	7.39	11297	2.52%
AC & AI	9.28	8105	1.81%
AC & AI & AIB	6.32	14202	3.16%
AIB	0.41	39652	8.83%
AI	4.2	234611	52.25%
AI & AIB	2.31	30576	6.81%
Other	?	0	0.00%
Textured coatings	0.01	194	0.04%
total		448997	100.00%

A79. Invaluable though the HU data set is, two key pieces of information for risk assessment are lacking: (i) the number of workers employed, which is required to estimate the total exposure duration of all workers, i.e. to get from job-days to man-days; (ii) the asbestos type(s) encountered in the various jobs, on which the risk is strongly dependent. The maximum number of workers is given on the ASB5 notification form but is not recorded in the HU data set. The asbestos type does not appear on the ASB5 form but is usually given in the accompanying Job Plan.

Additional information from ASB5 notifications and Job plans

A80. To obtain this additional information 903 ASB5 notifications and Job Plans (904 were examined, one being rejected as the number of workers was not given) from the Sheffield and Manchester Area Offices, covering periods of about 3 months up to October/November 2004. Table 6 gives the number of jobs and the calculated number of job days and person days from the ASB5 forms (e.g. worker-days = total number of workers on site x length of job in days). These are likely to be overestimates for duration of exposure as not all workers will be inside the enclosure removing asbestos for the entire time and during set up and take down lower exposures are likely than attributed from the air monitoring data.

Table 6: Analysis of Job Notifications in Sample of ASB5s by ACM Type

Type of ACM	Number of jobs	Job-days	Total person-days	Average person-days
AC+AI+AIB	3	735	10245	3415.0
AC+AI	2	35	205	102.5
AC+AIB+TC	2	40	220	110.0
AC+AIB	5	107	424	84.8
AC	7	77	435	62.1
AI+AIB+O	2	42	168	84.0
AI+AIB	35	405	2263	64.7
AI+O	5	113	448	89.6
AI	135	1214	5080.5	37.6
AIB+O	11	80	285	25.9
AIB+TC+O	1	2	6	6.0
AIB+TC	10	136	690	69.0
AIB	446	3868	12746.5	28.6
O	53	806	3282	61.9
TC+AI	1	4	12	12.0
TC+O	4	308	1036	259.0
TC	181	589	1665.5	9.2
Overall average				43.4
Total	903	8561	39211.5	

A81. As the required information on asbestos type was given in only 723 of the 903 plan of work / notifications examined, some figures for asbestos type(s) present in each ACM type are statistically poor. Rounded off values of the asbestos types listed against various types of ACM are given in Table 7. These were used to calculate risk factors for the ACM based on the HD relative risk factors of: chrysotile =1, amosite = 100 and crocidolite = 500. Overall, the average relative estimate of asbestos type for chrysotile: amosite: crocidolite were 10:85:5 giving a relative risk factor of 110.1 compared to chrysotile exposure only. This is somewhat different to the mix of asbestos types, estimated and used in the risk estimate for all workers (30:60:10). However, the relative risk factor for a mix of (30:60:10) =110.3, a remarkably similar overall risk.

Table 7: Information from plan of work data for the asbestos types present for different Types of ACM

ACM Type	Type of Asbestos Present (%)			Calculated risk factor
	Chrysotile (CH)	Amosite (AM)	Crocidolite (CR)	
AC *	5	75	20	175
AC + AIB	3	85	13	148
AC + AI	5	73	23	185
AC + AI+AIB	3	80	17	163
AIB	0	95	5	120
AI	5	70	25	195
AI + AIB	3	83	15	158
O	13	85	2	95
TC	100	0	0	1
All data	10	85	5	110

Calculation of relative risk

A82. Table 8 brings together all the data in tables 5 –7 above and then uses this information to calculate the relative risks. Column 2 of table 8 gives the number of jobs per year by type of ACM (column 1) derived from the HU data on notifications over a three-year period. The average number of worker-days per job for each of the ACM types and combinations of types from the ASB5 data in table 6 is entered in column 3 and multiplied by the number of jobs to obtain the total worker-days per year (column 4). Column 5 of Table 1 gives the fibre concentrations for each type of ACM derived from the HSL data (table 5). Total worker exposure in f/ml.person-days per year (column 6) is calculated by multiplying columns 4 and 5. The percentage of total worker exposure contributed by each ACM type is given in column 7. The asbestos type taken from a sample of Job Plans in table 7 and the calculated risk factors for each type of ACM are entered in column 8. Multiplying f/ml.person-days per year by the risk factor gives a value adjusted for the relative risk (column 9) from which the contribution to the total risk from each ACM types can be calculated (column 10).

A83. It is worth noting that the relative risks for the various combinations of licensed materials varies between 1% - 43%, except for textured coatings which are some three orders of magnitude lower.

Calculation of average licensed asbestos removal worker exposure for use in HD model

A84. The total worker exposure of some 4320228 f/ml.person-days per year were apportioned to the 3 asbestos types as shown at the bottom of Table 7, i.e. 10% chrysotile, 85% amosite and 5% crocidolite. The average fibre concentrations per worker have been calculated by dividing by (9000*240), i.e. based on 9000 men and 240 working days.

Table 9: Average exposure of asbestos removal workers to different types of asbestos

Asbestos type	Annual worker exposure Worker days f/ml /year	Average fibre concentration Per worker
Chrysotile	432023	0.20
Amosite	3672194	1.70
Crocidolite	216011	0.10

Table 8: Calculation of relative risks

	Number of jobs in 3-year period	Number of jobs per year	Average worker-days per job	Worker-days per year	Fibre concentration (f/ml)	Exposure (Worker-days f/ml/yr.)	Percent of total exposure	Risk Factor for asbestos type	Weighted risk from work with various ACMs	Percent of total risk by type of ACM
	1	2	3	4	5	6	7	8	9	10
Type of ACM	HU	HU	ASB5		f/ml					
AC	2276	758.7	62.1	47145.7	14.4	677012.5	15.67%	175.1	118.51	16.41%
AC & AIB	289	96.3	84.8	8169.1	7.4	60328.6	1.40%	147.5	8.90	1.23%
AC & AI	220	73.3	102.5	7516.7	9.3	69754.7	1.61%	185.1	12.91	1.79%
AC & AI & AIB	262	87.3	3415.0	298243.3	6.3	1885892.0	43.65%	163.4	308.09	42.67%
AIB	49608	16536.0	28.6	472592.3	0.4	193762.8	4.49%	120.0	23.25	3.22%
AI	20303	6767.7	37.6	254689.8	4.2	1069697.3	24.76%	195.1	208.64	28.89%
AI & AIB	2440	813.3	64.7	52587.8	2.3	121214.9	2.81%	157.5	19.09	2.64%
Other	7245	2415.0	61.9	149547.7	1.6	238610.4	5.52%	95.1	22.70	3.14%
DTC	15297	5099.0	9.2	46919.2	0.1	3955.3	0.09%	1.0	0.004	0.001%
Total	97940	32646.7	41.9	1368618.5		**4320228**	100.00%		722.10	100.00%

AC = Asbestos Coating
AIB = Asbestos Insulating Board
AI = Asbestos Insulation
DTC = Decorative Textured Coatings

Calculated risks using the Hodgson & Darnton (HD) Model (no RPE)

A85. The "best" estimate of the lifetime risk as excess deaths per 100000 has been calculated for 5, 10, 20 and 30 years exposure starting at age 20, which is the lowest starting age allowed by the model, the risk being greatest for the lowest starting age. The fibre concentrations above have been entered directly into the model with no allowance for the use of RPE and the risk estimates for each asbestos type and the total risk are given at the top of Table 10.

Table 10: Calculated values of risk using the HD model (no RPE)				
Length of exposure (years)	Chrysotile	Amosite	Crocidolite	Total
Lifetime excess deaths per 100000 after 5, 10, 20 and 30 years exposure from age 20				
5	**11.2**	**2426**	**857.5**	**3294.7**
10	18.1	5115.5	1310.7	6444.3
20	27.8	10965.2	1803.7	12796.7
30	35	16561.3	2073.5	18669.8
Annual excess deaths per million from 5, 10, 20 and 30 years exposure (Survival age 80)				
5	**2.2**	**485.2**	**171.5**	**658.9**
10	3.6	1023.1	262.1	1288.9
20	5.6	2193.0	360.7	2559.3
30	7.0	3312.3	414.7	3734.0
Lifetime excess deaths based on a total of 145000 asbestos workers in a 50-year period				
5	**16.2**	**3517.7**	**1243.4**	**4777.3**
10	26.2	7417.5	1900.5	9344.2
20	40.3	15899.5	2615.4	18555.2
30	50.8	24013.9	3006.6	27071.2

A86. Table 10 represents the best estimate of the current and predicted risk based on the many variables discussed above. A more detailed appraisal of the effect of the many variables is given in HSE/HSL report (Burdett and Chisholm, 2005). The largest variable is however in the risk model itself. The minimum and maximum estimates from the HD model being almost an order of magnitude lower and higher than the best estimate. As discussed data on the 2-yearly medical examinations of asbestos workers show that the average age at first examination (before starting work) is about 32. The distribution is skewed and most of the workers are aged around 25 at first examination with a significant number aged around 20. Taking the age at first exposure as 20 therefore errs on the side of caution and will lead to over-estimation of the risk.

A87. The medical examinations data also show that the average years working per man is 3.09 but the majority of workers (71.5%) only have one examination, i.e. work for less than 2 years. Just over 90% of workers work for 5 years or less. So for practical purposes, the risk estimates based on 5 years exposure (shown in bold in Table 5) apply to 90% of all workers.

A88. The annual risk (Table 10, middle part) is a linear estimate of the overall lifetime risk, simple division of the lifetime by the remaining life expectancy. A figure of 50 was used for the average life expectancy (this equates with the actual age of the first medical at 32 and a life expectancy of > 80 years. This value can be used to compare with the Tolerability of Risk (TOR) model currently used by HSE to categorise the scale of the risk in societal terms (R2P2). The units have been adjusted to number of premature deaths per million.

A89. To calculate the number of workers who will die from an asbestos related disease due to exposures incurred over the next 50 years; we will need to estimate of the total number of workers exposed. The information is available from the medical examinations data shows the current average years worked as an asbestos remover 3.09 years, which means a turnover of approximately 2900 workers each year, giving a total of 145000 workers in a 50-year period, assuming the current number of person employed and length of work represents the average for next 50 years. Previous predictions anticipated a rise in demolitions over time and may increase worker numbers in the short term but as removal takes place the stock of buildings with ACM's will decrease so numbers of removal workers will decline after a peak. Given that about one third of ACM's installed have been removed it is estimated that the current rate may represent a reasonable average for the next 50 years. The number of worker deaths predicted on this basis is given at the lower part of Table 10.

Calculated risks using the Hodgson & Darnton (HD) Model (with RPE)

A90. In practice, asbestos removal work should be carried out by workers using RPE with a assigned protection factor of 40 (i.e. 95% of the workers will have protection factors above this value). The risk estimates in Table 10 are therefore worst case assuming no RPE. The fibre concentrations used to assess the risk to removal workers using RPE was reduced to 1/100th of the values in Table 9 (i.e. assumes an average 99% reduction in all removal worker exposures). The calculation on the same basis as Table 10 corresponding to these reduced fibre concentrations is given in Table 11.

Table 11: Calculated values of risk using the HD model (with RPE)				
Length of exposure (years)	Chrysotile	Amosite	Crocidolite	Total
Lifetime excess deaths per 100000 after 5, 10, 20 and 30 years exposure from age 20				
5	**0.3**	**33.6**	**26.1**	**60**
10	0.5	53.4	38.9	92.8
20	0.6	79.3	50.6	130.5
30	0.7	97.2	55.3	153.2
Annual excess deaths per million from 5, 10, 20 and 30 years exposure (Survival age 80)				
5	**0.1**	**6.7**	**5.2**	**12.0**
10	0.1	10.7	7.8	18.6
20	0.1	15.9	10.1	26.1
30	0.1	19.4	11.1	30.6
Lifetime excess deaths based on a total of 145000 asbestos workers in a 50-year period				
5	**0.4**	**48.7**	**37.8**	**87.0**
10	0.7	77.4	56.4	134.6
20	0.9	115.0	73.4	189.2
30	1.0	140.9	80.2	222.1

Estimate of Risk Reduction from Changes to Control Limits

A91. Tables 12 and 13, which are calculated on the same basis as Tables 10 and 11, using the proposed 0.1 f/ml control limit, to determine the reduction in risk and numbers of deaths avoided. A proportionate effect is assumed i.e. that the average fibre concentrations for amosite and crocidolite would be reduced to half the values in Table 9 and that for chrysotile to one-third. Table 12 (without RPE) and table 13 (with RPE) summarises the risk results after recalculation based on the lower control limit. The actual number of premature deaths avoided over a 50-year period is the difference between the estimated risks at the current (tables 10 & 11) and the new (tables 12 & 13) control limits. The same approach may be used to estimate reduction in risk for any proposed change to control limits.

Table 12: Recalculated risk results from HD model for new 0.1 f/ml control limit based on 5 years exposure only and the predicted reduction in excess deaths over 50 years (no RPE)				
Risk estimate	Chrysotile	Amosite	Crocidolite	Total
Lifetime excess deaths per 100,000	4.6	1150.9	503.0	1658.5
Annual excess deaths per million	0.9	230.2	100.6	331.7
Lifetime excess deaths	6.7	1668.8	729.4	2404.8
Predicted reduction in excess deaths over 50 years.	9.6	1848.9	514.0	2372.5

Table 13: Recalculated risk results from HD model for new 0.1 f/ml control limit based on 5 years exposure only and the predicted reduction in excess deaths over 50 years (with RPE)				
Risk estimate	Chrysotile	Amosite	Crocidolite	Total
Lifetime excess deaths per 100,000	0.1	19.3	15.5	34.9
Annual excess deaths per million	0.0	3.9	3.1	7.0
Lifetime excess deaths	0.1	28.0	22.5	50.6
Predicted reduction in excess deaths over 50 years.	0.3	20.7	15.4	36.4

Non-licensed removal / demolition work

A92. The risks from removal of non-licensed ACMs is harder to estimate as no information is recorded. Many smaller removals that occur will often be classed as maintenance work as there is no limit on the duration of the work as with licensed materials. However, there are three categories of non-licensed asbestos products where more extensive removal/demolition work may often be necessary: cement, bitumen and flooring products. Each of these groups contain a number of products which will normally be broken, ripped or scraped off during the removal process giving the potential for fibre release. The average concentrations when disturbing these materials are summarised in table 14. It should be noted that these averages are based on limited amounts of data.

Risk from asbestos cement products.

Product types and uses

A93. A wide range of cement product types was developed and the main examples are summarised in table 15.

Table 15: Examples of uses of asbestos cement products		
Asbestos product	**Location / use**	**Asbestos content and type / Date last used**
Cement products: Profiled sheets.	Roofing, Wall cladding. Permanent shuttering, cooling tower elements.	10-15% asbestos (some flexible boards contain a small proportion of cellulose). Crocidolite (1950 -1969) and amosite (1945 - 1980) have been used in the manufacture of AC products, although chrysotile (used until 2000) is by far the most common type found.
Semi - compressed flat sheet and partition board.	Partitioning in farm buildings and infill panels for housing, shuttering in industrial buildings, decorative panels for facings, bath panels, soffits, linings to walls and ceilings, portable buildings, propagation beds in horticulture, domestic structural uses, fire surrounds, composite panels for fire protection, weather boarding.	As above. 10 -15% asbestos. Also 10 - 25% chrysotile and some amosite for asbestos wood used for fire doors etc. Composite panels contained ~ 4% chrysotile or crocidolite.
Fully compressed flat sheet used for tiles, slates, and board.	As above but where stronger materials are required and as cladding, decking and roof slates. (e.g. Roller skating rinks, laboratory work tops).	As for profiled sheets.

Pre formed moulded products and extruded products.	Cable troughs and conduits. Cisterns and tanks. Drains and sewer pressure pipes. Fencing. Flue pipes. Rainwater goods. Roofing components (fascias, soffits, etc.) Ventilators and ducts. Weather boarding. Window cills and boxes, bath panels, draining boards, extraction hoods, copings, promenade tiles etc.	As for profiled sheets.

Amount of asbestos cement material.

A94. Figures provided by the asbestos cement industry to HSE in the past (Simpson, 1977, 1979) have been used to estimate the amount of asbestos products released into the UK market. Two sets of figures were available: the amount of chrysotile used for production and the total production of cement products. Previous estimates (CD159, MRC, 1997) of usage, were that 2.3 million tons of chrysotile were used for roofing and cladding products and 0.4 million tons of chrysotile were used for pipe products, installed in the UK. Taking figures for other moulded products into consideration (~18%) this suggests that some 3 million tonnes of chrysotile was added to all asbestos cement products. Published estimates of production and use of asbestos cement in the 1970's is given in table 19. Figures for chrysotile use for buildings and pipes from 1940 – 1976 gave an average use of 18% for pressure pipes. Written evidence from the manufacturers show the actual amount of chrysotile in cement sheets was ~10% so this would give a maximum amount chrysotile containing asbestos cement products of some 30 million tonnes.

Table 16: Published figures for UK production and use for asbestos cement products (thousands of tonnes)					
	1973	1975(a)	1976	1975(b)*	% 1975 (b)*
Corrugated / profile sheeting	429	256	268	257	71.4
Flat sheeting	45	30	34	40	11.1
Rainwater goods	12	7	7	7	1.9
All other products	101	81	81	56	15.6
Pressure pipes	(83)	-	-	Not incl.	Not incl.
Total	587	360	376	360	
Reference	Ryder 1975	DoE, 1977	DoE, 1977	Simpson 1979	Simpson 1979
*Total home deliveries taking account of imports and exports					

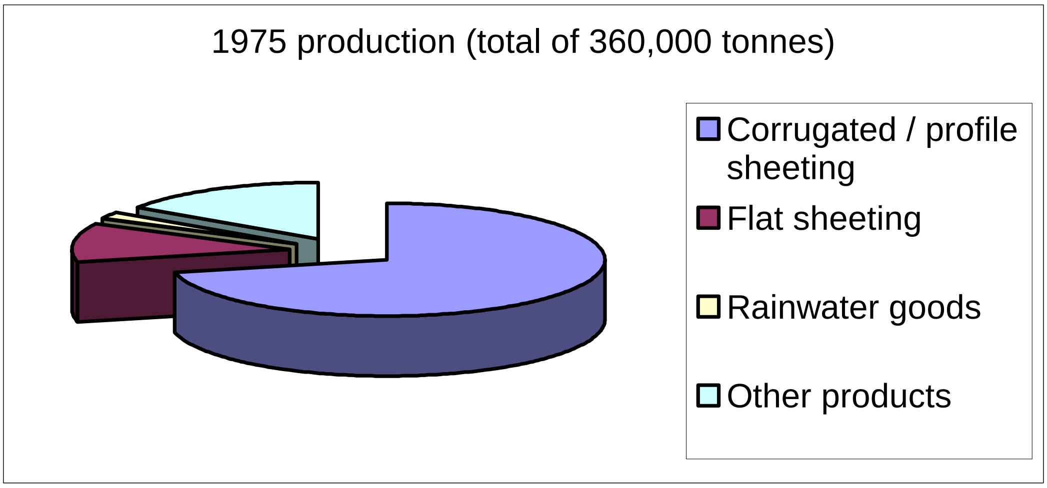

Figure 8: Types of asbestos cement used in UK home deliveries 1975 (Simpson, 1977)

A95. There are only limited figures supplied by industry for the amount of cement products produced. Production peaked in 1973, where a total of 527,000 tonnes of cement products were installed. The production in 1973 has also been estimated in terms of area (an area of some 30 million m^2 of corrugated/profile sheet and 3 million m^2 of flat sheet). Using previous estimates (Simpson, 1977) that the average asbestos cement production was around 0.4 million tonnes / year for 1945 – 1995 means that some 20 million tonnes of products were produced over this period. It can therefore be estimated that UK installation over the entire manufacturing period (1910 – 1999) is of the order of 30 million tonnes of asbestos cement products. Applying the relative percentages of product types estimated for 1975 UK home deliveries, this would suggest a total of 21.4 millions tonnes corrugated/profile sheet production, 3 .3 million tonnes of flat sheet.

A96. The two estimates based on chrysotile use and cement product deliveries are similar. However, as some cement products contained crocidolite or amosite asbestos, as well as chrysotile, the actual amount of cement products should be higher than calculated from chrysotile alone. Cement products were also imported and exported with the latter being the higher (~3% net export) which accounts for the similarity of the two estimates that around 30 million tonnes of asbestos cement products will have been installed in the UK.

A97. The use of amosite and crocidolite in asbestos cement will have an important effect on the risk. The vast majority of amosite and crocidolite imported went into non-cement products. Figures supplied to Simpson, (1979 see page 49) show that crocidolite and amosite asbestos were added to cement products from 1945 onwards. Crocidolite was not used after 1969, with figures of 574 tonnes in 1950 and 2130 tonnes in 1960 falling to low levels by the mid-sixties and to 0 by 1969. This would suggest a total of ~20,000 tonnes of crocidolite were used in the manufacture of cement products. This is about the same total amount that was estimated to have been installed for thermal and also for spray insulation.

A98. The publication in 1960 of evidence linking mesothelioma to Cape crocidolite production in South Africa and the incidence of mesotheliomas in crocidolite using factories in the UK, lead to a rapid reduction in the use of crocidolite and to its temporary replacement by amosite. Amosite was used in cement sheet and pipe material by at least two major manufacturers. The estimated UK consumption figures as given by Cape industries the main producer and importer of raw crocidolite and amosite fibres (Simpson 1977) were: 227, 1278 and 1748 tonnes, for 1960, 1970 and 1975, respectively. Amosite was voluntarily reduced by industry from 1975 and there was a rapid drop in imports with a voluntary withdrawal of most amosite from 1980. Amosite use was banned in the UK in 1985. The low figure for amosite use in 1960 some 227 tonnes compared to crocidolite 2130 tonnes, suggests that most amosite was added to asbestos cement between 1960 –1980 with around 7000 tonnes in the 60’s and 10,000 tonnes in the 70’s with a further 3,000 tonnes outside these two decades. This means that about 20,000 tonnes of amosite was added to cement products.

A99. Amosite and crocidolite was routinely used in the production of pressure pipes. Crocidolite fibre has a higher technical performance then amosite and was initially used for pressure pipes and was especially important for larger diameter pressure pipes but was increasing replaced by amosite from the mid-sixties. Typically a few percent of crocidolite or amosite would be added. Figures (Simpson 1977) for consumption in 1973 showed that 7800 tonnes of chrysotile and 1200 tonnes of amosite were used for pressure pipes. This suggests that about 1.5% amosite was added on average. In 1976 some 1100 tonnes of amosite were used in pressure pipes and 500 tonnes for building products, i.e. some 69% of the amosite used for cement products was for pressure pipes.

A100. The addition of amosite and crocidolite to profile and flat cement sheets and other moulded products tended to be much more variable. The main technical purpose for adding amosite and crocidolite was to give improved de-watering and increase the rate of curing and production. As there was an additional cost compared to chrysotile this was usually done when there was a need to increase production rates in periods of high demand or when there was disruption to the supply of chrysotile. The relative occurrence of amphibole asbestos containing cement products is therefore hard to determine. A total of 20,000 tonnes of amosite represents some 0.66% of the total chrysotile use. In terms of amount of asbestos cement materials this represents some 1 million tonnes of a total of 30 million (~3%) assuming some 2% on average was added. This may be an overestimate as higher amounts of amphibole fibres (3-4%) were reportedly added. However, as seen from the figures, amosite was predominantly added to pressure pipes, so that only about a third, ~ 1% would be present in sheets and moulded products. As a similar amount of crocidolite was used, it would also make up the same percentage as amosite.

A101. Amosite was also added along with chrysotile to another cement product known as asbestos wood, which was used on fire doors etc. This had a higher percentage of asbestos (24%) than normal cement sheets.

A102. The estimated amounts of asbestos cement products installed into the UK by product and asbestos type are summarised in table 17. The figures are based on the 1975 (b) figures in table 16, after adjustment to include ~18% cement pressure pipes production. It has been assumed that only very limited removal or replacement of pressure pipes is taking place, as it is likely they will be left in place and remain buried and inaccessible. The amount of asbestos remaining in buildings has been estimated based on product type. No previous estimates were readily available. It was assumed that cement products used in building exteriors and subject to greater weathering have been preferentially removed compared to the estimated average of about one third of asbestos cement products overall had been removed. The weighting are shown in table 18, were used to calculate the amounts of asbestos cement products remaining.

Table 17: Estimated amounts of asbestos cement products installed in the UK by product and asbestos type (thousand of tonnes) estimated on 1975 figures.

Material type	Adjusted (%)	Chrysotile only	Chrysotile and amosite containing	Chrysotile and crocidolite containing	Total
Corrugated / profile sheeting	59.1	17370	177	177	17724
Flat sheeting	9.2	2703	28	28	2759
Rainwater goods	1.6	473	5	5	483
Other products	12.9	3785	39	39	3862
Pressure pipes	17.2	0	3621	1552	5172
Total	100	24331	3869	1800	30000

Amounts of amosite and crocidolite containing materials based on 1% of each

Table 18: Estimated amounts of asbestos containing cement products remaining to be removed by product and asbestos type (in thousand tonnes).					
Material type	Proportion of material remaining	Chrysotile only	Amosite containing	Crocidolite Containing	Total
Corrugated / profile sheeting	0.5	8684.8	88.6	88.6	8862.1
Flat sheeting	0.66	1784.3	18.2	18.2	1820.7
Rainwater goods	0.5	236.6	2.4	2.4	241.4
Other products	0.75	2838.6	29.0	29.0	2896.6
Pressure pipes	0.98	0.0	3548.3	1520.7	5069.0
Total		13544.3	138.2	138.2	13820.7

A103. Assuming an average density of ~1600 kg.m^{-3} for sheet cement products and an average thickness of 6.35 mm 1 tonne of asbestos cement represents an area of ~ 100 m^2 of flat sheet and an area of ~ 70 m^2 for profile sheet. This means that there remains some 800 km^2 of asbestos cement sheeting still to be removed of which some 8 km^2 contains some crocidolite and 8 km^2 contains some amosite.

Number of persons handling the asbestos

A104. The number of secondary employees directly handling the cement products was also given for 1975 (Simpson, 1977) (see table 19). At the present time no asbestos cement products would be handled by builder’s merchants and since installation is no longer taking place, rather fewer workers will be handling/removing asbestos cement products on a regular basis. Roof repair and replacement and/or demolition specialists would make up the main group exposed to regular contact with profile cement sheet. A larger number of general builders may occasionally remove profile cement sheets from smaller buildings (e.g. sheds, garages and from internal partitions etc.) and some moulded products (e.g. rainwater goods, water tanks, flues etc). The estimated numbers of workers carrying out demolition and removal work with asbestos cement over the next 50 years are given in table 20.

Table 19: Numbers of secondary employees handling cement products 1975	
Type of job/activity	Estimated number of people
Roofing contractors	18,000
Builders merchants	12,000
Others	22,000

Table 20 : Estimated number of workers removing asbestos products			
Type of job/activity	Current number of workers exposed	Total number of workers exposed to remove remaining asbestos	Percentage of work time working directly with asbestos cement
Demolition and specialist roof removal	10,000*	50,000	10
General builders occasionally removing small amounts of asbestos products	100,000*	500,000	0.5
*			

A105. Assuming the remaining sheeting material is removed over the next 50 years, the figures for demolition and specialist removers represents an average handling / removal rate of sheeting material of ~100 – 200 m^2 per worker per day.

Typical fibre release

Work on asbestos cement products

A106. Examples of exposure data for this type of work, mostly on AC roofing, are summarised in Table 21. The removal and replacement of asbestos cement is also given, as this material does not require a licensed asbestos contractor to carry out the work. The airborne fibre concentrations measured for work on AC sheeting, mainly roofing, cover a very wide range, from below the detection limit to 1.1 f/ml. The data compiled by CONSAD quoted in HEI (1991) give 0.12 f/ml as the estimated exposure for roofing repair and this is broadly in agreement with the detailed measurements from the literature. The range of fibre concentrations reflects the many factors, which contribute to exposure, which are discussed most comprehensively by Brown (1987).

A107. For removal of AC roofing and wall sheets whole (or in pieces if accidental breakage occurs), there is some evidence that wetting or sealing the sheets prior to removal does reduce exposure but the reduction is not as great as might have been expected. These types of AC sheet are dense and usually have a hard and smooth outer surface because they have to be reasonably weatherproof. Unfortunately this will make it difficult for water (or sealant) to penetrate into the body of the sheet and wetting or sealing may therefore not be very effective.

A108. There is also some evidence that AC sheets that are weather-damaged may give higher exposure levels on removal. Removal of the exterior walls gives lower exposures than removal of roofing which is more exposed to the weather. Exposures when installing new AC sheets or roofing are generally much lower than for removal, probably because the sheets are unweathered and have to be handled more carefully.

A109. In contrast, exposures are higher when roof sheets are being removed as part of demolition than when they are being replaced or repaired; handling of the sheets was noted as being faster and much more vigorous during demolition with more visible dust being generated (Brown, 1987). According to Brown (1987), the key to reducing exposure during roof removal is a combination of careful handling and wetting before stacking to minimise abrasion of the AC sheets.

Table 21: work on asbestos cement roofs personal exposure to asbestos

All work on asbestos cement roofing and sheets	Range	Reference
	Not detected/<0.01 - 1.1 f/ml	(from data below)
Roof Repair "Representative"	Not detected - 0.3 f/ml	(CONSAD, 1990)
Roof Removal "Representative"	Not detected - 0.2 f/ml	(CONSAD, 1990)
Dry - replacing corrugated AC	0.01, <0.01 f/ml	(Roberts, 1985)
Collecting sheets and cleaning	0.24 f/ml	(Roberts, 1985)
Removal of corrugated sheets (detachment and sliding to gutter)	0.047 f/ml	(Preat, 1993)
Throwing sheets into lorry	0.161 f/ml	(Preat, 1993)
Removal of corrugated sheets (detachment, stacking, placing in pallets)	0.028, 0.038 f/ml	(Preat, 1993)
Removal of corrugated sheets (detachment)	0.018 f/ml	(Preat, 1993)
Stacking of sheets of pallets	0.032 f/ml	(Preat, 1993)
Removal of slates (detached with hammer)	0.064 f/ml	(Preat, 1993)
Sliding slates to gutter; throwing to ground	0.195 f/ml	(Preat, 1993)
Removal of slates (detachment and stacking)	0.037, 0.044 f/ml	(Preat, 1993)
Removal of slates (detachment and placing in container on roof)	0.050, 0.176 f/ml	(Preat, 1993)
Removal of slates (pulling off, stacking on elevator, broken slates thrown to ground)	0.100, 0.122 f/ml	(Preat, 1993)
Removal of slates (detachment with hammer, sliding to gutter)	0.068 f/ml	(Preat, 1993)
Bringing slates down and throwing into container	0.056 f/ml	(Preat, 1993)
Wet (but not effective)	Mean 0.020 f/ml	(Lange & Thomulka, 2000)

Roof Replacement		
Dry replacement (severely weathered) - unfastening, removal, stacking, disposal, installation of new roofing	0.03 - 0.24 f/ml	(Brown, 1987)
Dry unfastening, removal, disposal, installation of new roofing (no stacking)	0.03, 0.03 f/ml	(Brown, 1987)
Dry replacement (severely weathered)	0.04 - 0.27 f/ml	(Brown, 1987)
Dry removal (painted)	0.07 - 0.32 f/ml	(Brown, 1987)
Wet removal (painted) and replacement (careful handling and wetting as stacked)	Not detected - 0.07 f/ml	(Brown, 1987)
Replacement (severely weathered) after lignin sulphonate treatment	0.23 f/ml	(Brown, 1987)
Replacement (severely weathered) after sealing with acrylic resin	0.03 - 0.08 f/ml	(Brown, 1987)
Replacement (severely weathered) after sealing with acrylic resin	0.04 - 0.26 f/ml	(Brown, 1987)
Roof Removal - Demolition		
Dry (building collapsed)	0.10 - 0.47 f/ml	(Brown, 1987)
Dry (from scissors lift)	0.04 - 0.12 f/ml	(Brown, 1987)
Sheets stacked in confined space	0.30 - 0.53 f/ml	(Brown, 1987)
Sheets stacked in confined space (accumulated dust under laps and ridges)	0.34 - 1.1 f/ml	(Brown, 1987)
Wet	0.05 - 0.06 f/ml	(Brown, 1987)
Wet (sheets staked in confined space)	0.10 - 0.13 f/ml	(Brown, 1987)
Wet (sheets staked in confined space; accumulated dust under laps and ridges)	0.29 - 0.68 f/ml	(Brown, 1987)
Sealed with acrylic resin	0.11 - 0.32 f/ml	(Brown, 1987)
Sealed with acrylic resin (sheets stacked in confined space; accumulated dust under laps and ridges)	0.41 - 0.76 f/ml	(Brown, 1987)

A110. The updated result in a database for removals of asbestos cement sheets under various conditions (mostly dry) are shown in table 22. A weighted mean of 0.08 f/ml was calculated for all personal data but clearly a lower mean exposure is obtained when precautions to wet the sheets before removal are taken. However as unusually the static samples gave a higher value than personal samples the figure of 0.08 f/ml were used for risk calculations and assumes no improvement in control of releases. A similar exposure for the removal of rainwater goods and other moulded cement products was assumed.

Table 22: Summary of all results in HSL database for asbestos cement work.

	Type of sample	No of data /site entries	Mean (f/ml)	SD	Minimum of means	Maximum of means	No of samples	Sum (mean * number)	Weighted mean (f/ml)
All	All	51	0.189	0.757	0	5.45	245	48.184	0.197
	Personal	36			0.0015	0.23	94	7.665	0.082
	Static	8			0	0.4	103	24.486	0.238
	Unspecified	7			0.008	5.45	48	16.033	0.334
Dry	All				0				
	Personal	7	0.124	0.076	0.03	0.23	39	4.450	0.114
	Static								
	Unspecified								
Not Known	All	43	0.203	0.825	0	5.45	198	43.494	0.220
	Personal	28	0.057	0.052	0.0015	0.195	47	2.975	0.063
	Static	8	0.120	0.149	0	0.4	103	24.486	0.238
	Unspecified	7	0.881	2.019	0.008	5.45	48	16.033	0.334
Wet	All								
	Personal	1	0.03		0.03	0.03	8	0.240	0.030
	Static								
	Unspecified								

Risk estimation

A111. The risk was estimated using the Hodgson and Darnton model using the following parameters:

Average exposure = 0.08 f/ml
Percentage of time working with asbestos = 10% for demolition and specialist roof removal workers and 0.5% for general builders.
Actual average exposures = 0.008 f/ml for demolition and specialist roof removal workers and 0.0004 f/ml for general builders.
Start age = 20
Duration 10,20 & 30 years

A112. The predicted numbers of lifetime deaths (per 100,000) were calculated based on a ratio of relative exposure to crocidolite, amosite and chrysotile (0.01, 0.01, and 0.98). The annual risk of death was calculated on the same basis as for licensed removal workers and the actual number of deaths, were based on the expected populations of exposed demolition and unlicensed roof removal workers (see table 23) and general building workers (see table 24) over the next 50 years.

Table 23: Calculated values of risk using the HD model (no RPE) due to the demolition and removal of asbestos cement sheeting, rainwater and moulded products (Demolition and roof removal workers).

Length of exposure (years)	Chrysotile	Amosite	Crocidolite	Total
Lifetime excess deaths per 100000 after 10, 20 and 30 years exposure from age 20				
10	0.9	0.1	1.3	2.4
20	1.2	0.2	1.8	3.2
30	1.4	0.2	2.0	3.6
Annual excess deaths per million from 10, 20 and 30 years exposure (Survival age 80)				
10	0.19	0.03	0.26	0.48
20	0.25	0.04	0.36	0.65
30	0.27	0.05	0.40	0.72
Lifetime excess deaths based on a total of 50,000 demolition workers in a 50-year period				
10	0.94	0.14	0.65	1.73
20	1.23	0.20	0.90	2.34
30	1.36	0.24	1.00	2.60

Table 24: Calculated values of risk using the HD model (no RPE) due to the demolition and removal of asbestos cement sheeting, rainwater and moulded products (General Building workers).

Length of exposure (years)	Chrysotile	Amosite	Crocidolite	Total
Lifetime excess deaths per 100,000 after 10, 20 and 30 years exposure from age 20				
10	0.10	0.01	0.10	0.21
20	0.13	0.02	0.20	0.35
30	0.14	0.02	0.20	0.36
Annual excess deaths per million from 10, 20 and 30 years exposure (Survival age 80)				
10	0.020	0.003	0.020	0.042
20	0.025	0.004	0.040	0.069
30	0.028	0.004	0.040	0.072
Lifetime excess deaths based on a total of 500,000 general building workers exposed over a 50-year period				
10	0.98	0.14	0.50	1.62
20	1.27	0.18	1.00	2.45
30	1.39	0.20	1.00	2.59

A113. These are best estimates and give annual risk of death of less than 1 per million. Rates below 1in a million are regarded as an acceptable risk in the HSE TOR model (R2P2). The number of premature deaths from exposure to asbestos to remove all remaining asbestos cement is some 3-5 persons depending on the duration of exposure and the absence of any RPE or controls. The effect of lowering of the control limit to 0.1 f/ml would be minimal as the average personal exposure from the database was 0.08 f/ml, although some specific operations may be reduced to achieve compliance this is unlikely to make a significant difference.

Other non-licensed asbestos products and activities

A114. As there are no detailed records of work with unlicensed materials, the types and amounts of products produced can be used to estimate the types of materials likely to be disturbed or removed and the frequency, which it is carried out. Table 25 gives an overview of asbestos usage in the 1970's for a number of product groups. Figure 9 shows the information for 1973 the peak year for production where: ~16% were licensed materials (insulating board and other insulation). 37.4% were cement products (32.2%) and pipes. About 14% were friction products and textiles (rarely found in buildings) and the remaining 32.6% were materials which may be used in buildings. On a first analysis there appears to be about the same amount of other unlicensed asbestos products in buildings as asbestos cement products, and possibly twice as much as products requiring licensed asbestos removal.

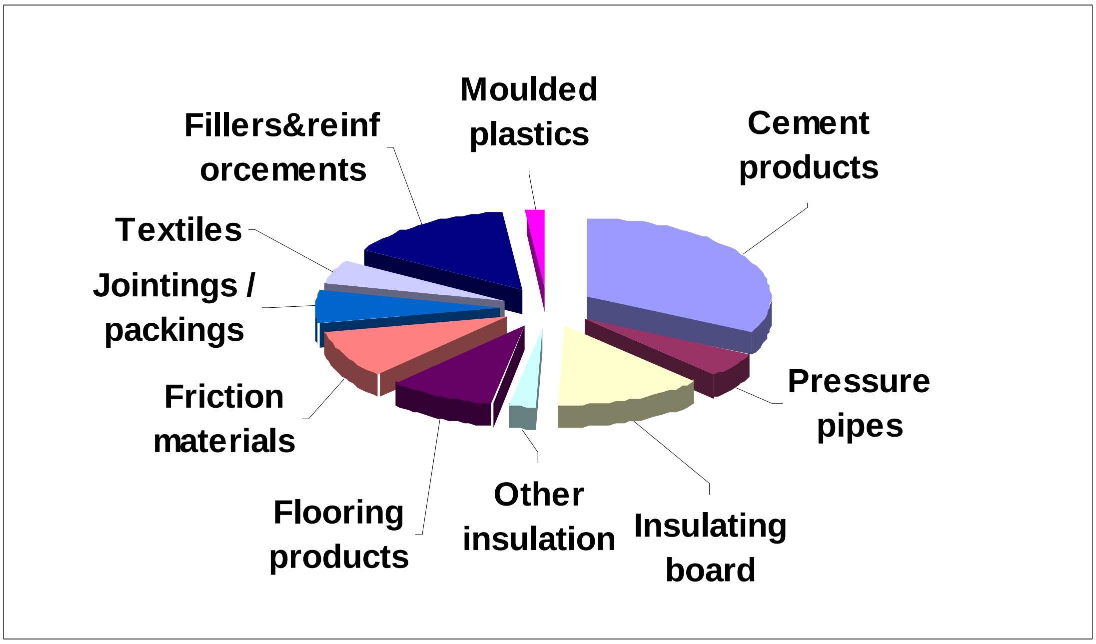

Figure 9: Relative asbestos fibre use by product type in 1973.

A115. Airborne fibre concentrations during removal and maintenance work with some of these unlicensed materials are summarised in table 26 and given in more detail in tables 27 & 28.

Table 25: Asbestos fibre use in the UK (thousands of tonnes)				
	1970	1973	1976	1978
Asbestos cement products for buildings	52.5	55.6	42.9	32.9
Asbestos cement pressure pipes	Not given	9.0	8.1	Not given
Fire-resistant insulating board	18.5	22.5	14.5	11.4
Other insulation (incl. spray)	4	4	0.4	1.5
Floor tiles and coverings	20.5	16.2	15.8	12.5
Friction materials	15	17	15.7	10.6
Jointings and packings	9	11.4	10	6.6
Other textile materials	9	8.3	6.3	5.3
Fillers and reinforcements (felts, millboard, paper, underseals, mastics, adhesives)	21.5	25.7	28.4	17.2
Moulded plastics	4.5	2.8	1.2	2.0
Total	154.5	172.5	143.3	100.0

Table 26: Summary of results in HSL database for various types of non-licensed materials								
Type of material	No of data /site entries	Mean (f/ml)	SD	Minimum of means	Maximum of means	No of samples	Sum (mean number)	Weighted mean (f/ml)
Cement sheet	51	0.19	0.76	0	5.45	245	48.18	0.20
Gaskets & packings	11	0.14	0.13	0.01	0.40	27	4.93	0.18
Floortile, mastics & bitumen	98	0.15	0.37	0.00	3	184	23.41	0.13
Roofing felt	2	0.013		0.006	0.02	30	0.36	0.012

Table 27: Results in HSL database for work with asbestos containing floor tile, mastics and bitumen products									
	Type of sample	No of data /site entries	Mean (f/ml)	SD	Minimum of means	Maximum of means	No of samples	Sum (mean number)	Weighted mean (f/ml)
All	All	98	0.15	0.37	0.00	3	184	23.41	0.13
	Personal								
	Static								
	Unspecified								
Dry	All	37	0.10	0.21	0.01	1.29	59	4.57	0.08
	Personal	6	0.05	0.05	0.02	0.14	28	1.18	0.04
	Static	29	0.07	0.04	0.01	0.17	29	2.05	0.07
	Unspecified	2	0.67	0.88	0.05	1.29	2	1.34	0.67
Not Known	All	47	0.16	0.45	0.00	3	110	14.92	0.14
	Personal	32	0.07	0.09	0.00	0.33	73	5.61	0.08
	Static	9	0.09	0.11	0.01	0.31	14	1.24	0.09
	Unspecified	6	0.76	1.15	0.00	3	23	8.08	0.35
Wet	All	14	0.21	0.41	0.02	1.34	15	3.92	0.26
	Personal	3	0.35	0.52	0.03	0.95	4	2.00	0.50
	Static	9	0.04	0.01	0.02	0.054	9	0.33	0.04
	Unspecified	2	0.80	0.77	0.25	1.34	2	1.59	0.80
Wet personal -all data from EVALUTIL - 2 entries for road-planing (asbestos in road surfacing) using a machine. Does not include samples with gypsum fibres.									

Table 28: Summary of all results in HSL database for gaskets and packings									
	Type of sample	No of data /site entries	Mean (f/ml)	SD	Minimum of means	Maximum of means	No of samples	Sum (mean * number)	Weighted mean (f/ml)
All	All	11	0.14	0.13	0.01	0.40	27	4.93	0.18
Dry	All								
	Personal								
	Static								
	Unspecified								
Not Known	All	5	0.18	0.16	0.01	0.40	14	3.17	0.23
	Personal	3	0.27	0.15	0.10	0.40	10	3.00	0.30
	Static	2	0.04	0.04	0.01	0.07	4	0.17	0.04
	Unspecified								
Wet	All								
	Personal	6	0.11	0.10	0.01	0.28	13	1.76	0.14
	Static								
	Unspecified	2	0.80	0.77	0.25	1.34	2	1.59	0.80

Risk estimation for other non-licensed materials

A116. The type of asbestos is a key determinant of the risk using the Hodgson and Darnton model. The type of asbestos used in the other unlicensed products (e.g. flooring, reinforced plastics, fillers and reinforcements) is almost all chrysotile asbestos and only high performance gaskets and packings in corrosive environments are likely to be amphibole asbestos. The percentage of amosite and crocidolite usage compared to chrysotile in other in other unlicensed (non-cement) materials is likely to be very small (<0.01%). With limited data and a variety of materials it is difficult to derive a single figure for exposure. As the majority of the work will involve flooring, mastics and roofing felt, which all release low average airborne fibre concentrations, same parameters as used for asbestos cement have been applied to the unlicensed non-cement products. These were:

Average exposure = 0.08 f/ml to chrysotile only
Percentage of time working with asbestos = 10% for demolition and specialist roof removal workers and 0.5% for general builders.
Actual average exposures = 0.008 f/ml for demolition and 0.0004 f/ml for general builders.
Start age = 20
Duration 10,20 & 30 years

A117. When applied to the same populations of workers 50,000 demolition workers and 500,000 general building workers over the next 50 years, the same estimates as for chrysotile in tables 23 and 24 are found i.e. a total of 2 excess deaths. A reduction in the control limit to 0.1 f/ml are unlikely to make a significant difference to much of the demolition and removal work and these figures assume no RPE is used. A maximum benefit of 1 life has been assumed.

Effect of a reduction in control limit for maintenance and other workers who may incidentally disturb ACMs.

Numbers of maintenance workers affected by the new control limit

A118. The provisions in article 10A of the new EU directive, “Before beginning demolition or maintenance work, employers shall take, if appropriate by obtaining information from the owners of the premises, all necessary steps to identify presumed asbestos-containing materials”, limits the likelihood of significant exposure to maintenance or other workers from unknowing disturbance of ACMs. Also, article 3 requires that exposures above the control limit for maintenance and other workers will not be exceeded. Therefore if full compliance with articles 10A and 3 are assumed (as used to estimate the numbers of workers protected in paragraph A44) this means that the additional lives saved from a lower control limit are already accounted for in the estimates.

A119. Article 3 of the new Directive specifically limits maintenance activities which do not have to be notified etc (ie unlicensed work) to sporadic and low intensity work below the control limit and restricts such work to specific types of materials :

a) short, non-continuous maintenance activities in which only non-friable materials are handled,

(b) removal without deterioration of non-degraded materials in which the asbestos fibres are firmly linked in a matrix,
(c) encapsulation or sealing of asbestos-containing materials which are in good condition.

A120. Compliance with Article 3 will therefore restrict any maintenance work with licensed materials and it is arguable nearly all maintenance work will be on unlicensed ACMs, which predominantly contain chrysotile. However, until the exact impact of the “sporadic and low intensity work” is better defined, the impact of the current arrangements has been calculated for both licensed and unlicensed materials.

Estimates of numbers of maintenance workers

A121. In the RIA for the new EU directive it was estimated that some 1.8 million workers are likely to disturb asbestos during routine work activity. The major groups affected are electricians (280,000); carpenters and joiners (260,000); plumbers and heating engineers (170,000); painters and decorators (150,000) and other construction and maintenance workers (around 500,000). Non maintenance workers (for example surveyors and valuers, building managers and inspectors and civil engineers) account for another 500,000 workers, although we believe that their exposure would be typically very low.

A122. The estimated exposure before any of the directive is implemented, was that some 200,000 workers are currently exposed at levels above the current control limit of 0.2 f/ml for a proportion of their working time. A large amount of this exposure will be inadvertent, and exposure will be far lower than this if efforts are made at control. A reduction in the control limit to 0.1 f/ml over a 4-hour TWA would increase this number to a total of 400,000 maintenance workers of a total of 1.8 million.

A123. If full compliance is not assumed or realised there will be some additional benefits from the lower control limit for up to 200,000 of the estimated 1. 8 million regularly exposed maintenance & other building workers (see table 1 & 3). Although, given the limited information on the main variables (e.g. type of materials, type of asbestos, frequency and duration of exposures above or at the old control limit) the net benefit is difficult to estimate. It is also unlikely to be realised in practice, given the low likelihood that an accurate assessment or sampling will take place, for most maintenance work.

Calculation of the maximum theoretical benefit based on the current circumstances

A124. A maximum theoretical benefit can be calculated by assuming that some 200,000 maintenance workers would have been fully complying with the 0.2 f/ml limit and from 2006 would have taken further measures to fully comply with the 0.1 f/ml limit. (note: the effect of reducing chrysotile from 0.3 to 0.1f/ml are also calculated). The fibre type they are exposed to has been taken as the same as for licensed materials and an assumption that each of these workers carries out1 hour a week of maintenance work on licensed materials for half of the working year (i.e. 24 x 1 hour per year). This is equivalent to one half of the maximum allowed at present and represent 1% contact time with licensed ACM's.

A125. Maintenance work on unlicensed materials is not restricted to 1 hour per week. Table 26, gives the weighted means of the HSL database of air monitoring measurements and shows these materials are in the range of 0.1 –0.2 f/ml. However, these include some high static measurement and the results for personal exposures should be taken into account e.g. tables 22 for AC cement and table 27 for floor tile, mastics and bitumen products which show average personal exposures below 0.1 f/ml. The exception is table 28 for work with gasket and packings, where the results are based on simulations rather than actual maintenance work. As shown in figure 9, the majority of the ACMs used in buildings are chrysotile based and relatively few jobs will exceed the new control limit. Using figure 9 it can be seen that about 30% of the ACMs in buildings are licensed (mainly groups: other insulation and AIB) and about 70% are unlicensed (exclude friction products and pressure pipes) therefore it has been assumed that for each hour of maintenance work on licensed products there is two hours work on unlicensed chrysotile products at 0.2 f/ml. This assumes an average of 3% exposure at the 0.2 f/ml control limit.

A126. The risk for amosite and crocidolite materials was calculated (see table 29) based on 30 years of exposure from age 20, using the HD model for an exposure at 0.2 f/ml for 24 hours of a 2400 hour working year and subtracting the risk from an exposure at 0.1 f/ml for 24 hours of a 2400 hour working year for amosite and crocidolite. Similarly for chrysotile the 0.3 f/ml risk was subtracted from the calculated risk for an exposure at 0.1 f/ml, but the cumulative exposure at 0.3 was doubled to account for unlicensed materials. The results of these differences are summarised for the best estimates and adjusted for likelihood each fibre type will be encountered in a licensed (1%) and unlicensed (3%) situation, using the ratios of 0.05:0.85:2.1 for crocidolite, amosite and chrysotile respectively. The annual excess deaths were calculated assuming a 60 - year survival from age 20 and that over the next 50 years a turnover of x3 occurs in the 200,000 maintenance workers who may be affected. As no reduction for removal of ACMs in the intervening period have been made and a long duration of exposure has been assumed, this hypothetical value is likely to be a considerable overestimate of the benefits in terms of premature deaths avoided.

Table 29 : Calculated best values of risk using the HD model for the reduced risk from lowering the control limit from 0.2 f/ml to 0.1 f/ml for amosite and crocidolite and 0.3 to 0.1 f/ml for chrysotile for maintenance work on licensed and unlicensed ACMs after adjusting for types of materials encountered and frequency (No RPE).				
Length of exposure (years)	Crocidolite	Amosite	Chrysotile	Total
Lifetime excess deaths per 100,000 after 30 years exposure from age 20				
30	1.05	5.44	1.92	8.41
Annual excess deaths per million from 30 years exposure (Survival age 80)				
30	6.3	32.64	11.52	50.46
Lifetime excess deaths based on a total of 0.6 million maintenance workers over a 50-year period				
30	6.3	32.64	11.52	50.46

Table 30: Calculated best values of risk using the HD model for the reduced risk from lowering the control limit from 0.2 f/ml to 0.1 f/ml for amosite and crocidolite and 0.3 to 0.1 f/ml for chrysotile for maintenance work on licensed and unlicensed ACMs after adjusting for types of materials encountered and frequency .(X10 APR RPE).				
Length of exposure (years)	Crocidolite	Amosite	Chrysotile	Total
Lifetime excess deaths per 100,000 after 30 years exposure from age 20				
30	0.33	0.85	0.105	1.29
Annual excess deaths per million from 30 years exposure (Survival age 80)				
30	2.01	5.1	0.63	7.74
Lifetime excess deaths based on a total of 0.6 million maintenance workers over a 50-year period				
30	2.01	5.1	0.63	7.74

A127. The same calculation has been done assuming x10 APF respiratory protection is worn by the maintenance workers, as required by guidance and approved code of practice for table 30. Again it must be stressed these are hypothetical calculations based on an exact reduction being achieved over a prolonged period of 30 years with an early age of first exposure and a continuous high amount of contact with licensed materials throughout the entire time.

Actual benefits to maintenance workers

A128. In practice, compliance with the articles 3, 10A and 12 of the new directive it is expected to result in many fewer (or no) maintenance workers working with crocidolite and amosite asbestos containing materials, and these will be either avoided or removed prior to the work by a specialist asbestos removal contractor.

A129. If compliance with articles 3, 10 and 12 of the directive is achieved and RPE and controls stipulated in HSE guidance is followed, the net benefit of the reduction in the control limit over 50 years will be the avoidance of 1-2 premature deaths amongst maintenance workers.

Uncertainty of the estimates

A130. Although only the “best” estimate has been calculated there are a number of uncertainties in the estimates. By far the greatest uncertainty is present in the epidemiology and the linear extrapolation from the available dose-response relationships. The HD model also calculates both a minimum and maximum value of deaths based on the epidemiology. The various estimates for the number of deaths for asbestos cement exposure due to uncertainty in the epidemiological model are given in table 31. This is a substantial range and hence the best estimate only has been used. Other variations due to limited exposure data, frequency of exposure and duration will also affect the best estimate. These are likely to produce a variation of approximately a factor of two on the best estimate.

Table 31: Estimates from HD model of total number of deaths over 50 year period from asbestos exposure due to the demolition and removal of asbestos cement sheeting.

Duration (yrs)	Best	Max	Min
Demolition and specialist roof removal workers			
10	1.7	8.4	0.2
20	2.3	11.2	0.4
30	2.6	12.9	0.4
General Building workers			
10	1.6	12.3	0.1
20	2.5	15.6	0.1
30	2.6	17.1	0.1

Summary of risks

A131. The ‘best’ estimate of the numbers of asbestos-related deaths from the exposure patterns before the duty to manage came into effect were:

1) 9000 in total, including both occupational and non-occupational exposure, of which
2) 4700 occurred in maintenance and removal workers in the commercial sector;
3) 3100 occurred in maintenance and removal workers in the residential sector.

A132. These deaths would arise from exposures taking place over the next 50 years and occur over the next 100 years.

A133. The figure of 7,800 excluded deaths related to purely environmental exposures (~1,200). The number of occupational exposure deaths avoided was estimated at 58% of 7,800, or 4,500, with around 2,000 as a result of indirect, or work-related, exposure. The remaining 1,300 deaths would be as a result of domestic exposure, most of which are not covered by CAW (or the amended Directive).

A134. The numbers of these deaths which can be avoided, depends on the level of compliance, awareness and training, so that ACMs are managed and only disturbed in a controlled way. Within these totals, assuming RPE is worn, it is calculated that some 87 excess deaths will occur among some 145,000 asbestos removal workers who are working with licensed materials. A lowering of the control limits to 0.1 f/ml will prevent an additional 36 asbestos related deaths among licensed asbestos removal workers wearing the recommended RPE (assuming an average nominal protection factor of 100). The importance of the RPE and the lower control limit is shown by that some 2372 deaths would be avoided by full compliance with the 0.1 f/ml control limit, if no RPE was worn.

A135. For all work on unlicensed materials (assuming no RPE is worn) between 3-6 deaths will be prevented, depending on the duration of the exposures. Often some level of RPE would be worn and the number of preventable deaths would decrease to ~ 1. The lowering of the control limit is unlikely to have a significant effect in reducing the number of deaths for work on unlicensed materials.

A136. If full compliance with articles 3 and 10A of the new directive is assumed, the lowering of the control limit for maintenance and other building workers will have a small effect (<7 premature deaths), compared to the number of lives saved by avoiding exposures.

A137. It is worth noting that the relative risks for the various combinations of licensed materials varies between 1% - 43%, except for textured coatings, which are some three orders of magnitude lower (0.001%). It is questionable that the risk from textured coatings is significant enough to be included as requiring a licensed removal.

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