Time trends in the incidence of work-related ill-health in the UK, 1996-2016: estimation from THOR surveillance data

Report to the UK Health and Safety Executive

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KEY MESSAGES

- The incidence of total work-related skin disease as reported by dermatologists to EPIDERM decreased during 1996-2006, after which it remained relatively flat until 2012, with a possible further decrease between 2012 and 2016. The annual (linear) average change in incidence (1996-2016) was -4.0% (95% CIs: -4.4, -3.5).
- Adjusting the average annual percentage change in incidence of total work-related skin disease for the impact of 'reporter fatigue' would change the estimate to -3.0% (95% CIs: -3.3, -2.6).
- The incidence of work-related contact dermatitis (CD) showed a similar annual pattern with an overall annual average change in incidence (1996-2016) of -3.9% (95% CIs: -4.4, -3.4). Analyses of shorter-term trends (2006 to 2016) suggested a similar annual average decrease of -4.1% (95% CIs: -5.4, -2.8) per year.
- The trend in incidence of skin neoplasia was markedly different depending on whether analyses were based on reports from 'core' or 'sample' dermatologists; the former suggested a decrease in incidence and the latter an increase. Of the two, it is possible that 'sample' data are more representative for this particular condition. However, for both groups the confidence intervals on the annual plots were wide and overlapping. It is therefore difficult to draw any firm conclusions about neoplasia trends from these data.
- The incidence of work-related respiratory disease as reported by chest physicians to SWORD fell between 1999 and 2007, after which it remained relatively flat. The average annual percentage change in reported incidence of total respiratory disease (1999-2016) was -3.2% (95% CIs: -3.8, -2.5).
- Adjusting the average annual percentage change in incidence of total work-related respiratory disease for the impact of 'reporter fatigue' would change the estimate to -2.1% (95% CIs: -2.7, -1.5).
- The average decrease in asthma incidence (1999-2016) was -6.8% (95% CIs: -7.9, -5.6) per year. Analyses of shorter-term trends (2007 to 2016) showed an average change of -2.3% (95% CIs: -5.3, 0.9) per year. There was some indication of an increase in incidence between 2015 and 2016 (although confidence intervals are wide and overlapping).
- An overall decrease in incidence (1999-2016) was also observed for mesothelioma and non-malignant pleural disease at -3.7% (95% CIs: -4.9, -2.4) and -1.8 (95% CIs: -2.8, -0.8), per year, respectively. However, for both a relatively flat trend was seen over the last 3 years. These results (especially when considering information from other sources) should be viewed with caution as they may reflect a shift in clinical practice rather than a 'true' trend.
- Reports from chest physicians continue to show that the incidence of pneumoconiosis has been increasing since (approximately) 2007 with an average increase of +3.4% (95% CIs: +1.5, +5.3) per year (1999-2016). For the period 2007-2016, the equivalent estimate was +8.2% (95% CIs: +4.1, +12.5). However, reports for the last four years suggest a relatively flat trend (although confidence intervals are fairly wide). The observed increase appears largely attributable to asbestos rather than other agents (e.g. silica or coal).

EXECUTIVE SUMMARY

Two constituent schemes of The Health and Occupation Research (THOR) network were funded for data collection by the Health and Safety Executive (HSE) during 2016. These were EPIDERM (dermatologists) and SWORD (chest physicians). This report describes temporal trends in incidence of work-related illness (WRI) in the UK as reported to these two schemes and updates previously submitted reports by the incorporation of a further year (2016) of data. Data were analysed in a manner (using a 'multi-level' statistical model) in which the number of reported cases over time could be investigated whilst taking into account other factors that might influence the trend, (for example, change in the number of physicians reporting or in the number of people employed in the UK.) Change in incidence has been presented either as the average, annual percentage change in incidence rate over a defined period or as graphs showing the risk for each year relative to a reference year (2016).

Analyses were carried out separately (for each scheme), for the total reported cases and then for each of the conditions of interest (for example, asthma). THOR physicians participate either on a monthly basis (termed 'core' reporters) or for one randomly allocated month per year (termed 'sample' reporters) and separate analyses were carried out for each of these groups as well as both types together. Both EPIDERM and SWORD comprise (and have done throughout the study period) a smaller 'core' group (approximately 10% of reporters) and a larger 'sample' group with most physicians remaining as either 'core' or 'sample' throughout their time in the scheme.

This is the first annual THOR trends report that includes a 'formal' adjustment to the overall trend estimates (i.e. the estimated percentage change in incidence of total work-related skin and total respiratory disease) for 'reporter fatigue' i.e. the longer a physician participates in a voluntary scheme such as THOR they might start to lose interest but still retain membership. How such 'fatigue' may manifest, implications for the trend estimates and whether/how it can be adjusted for has been an important methodological challenge for this project. The results of these analyses suggest that, for EPIDERM and SWORD, some of the observed decrease in disease incidence over time is in fact due to reporter 'fatigue' rather than a 'true trend' (adjusted estimates are provided below).

WORK-RELATED SKIN DISEASE: A total of 19330 actual cases of work-related skin disease were reported to EPIDERM (1996-2016), the main diagnoses being contact dermatitis (CD: 82%), neoplasia (12%), and urticaria (5%). The annual average change in incidence of dermatologist reported work-related skin disease (1996-2016) was -4.0% (95% CIs: -4.4, -3.5). Adjusting this estimate for the impact of excess zeros, using the 'Zero inflated negative binomial' (ZINB) model would change the estimate to -3.0% (95% CIs: -3.3, -2.6). The graphs

showing relative risk by year (compared to 2016) suggest an initial decrease in incidence (1996-2006) followed by a relatively flat trend (2006-2012) and then a further decrease between 2012 and 2016. The estimated annual change in incidence of CD was similar over both the same period (1996-2016) at -3.9% (95% CIs:-4.4, -3.4) and for the shorter period (2006-2016) at -4.1% (95% CIs: -5.4, -2.8).

A disparity between ‘core’ and ‘sample’ trends for skin cancer (neoplasia) was also observed with a decrease in incidence suggested by reports from ‘core’ reporters of -4.8% (95% CIs: -6.4, -3.2) and an increase in incidence suggested by reports from ‘sample’ reporters + 2.1% (95% CIs: -0.7, 5.0). Of the two, it is likely that ‘sample’ data are more representative for this diagnosis (EPIDERM ‘core’ reporters are a self-selected group of ‘motivated specialists’ whose main area of expertise is likely to be CD and therefore other cases, such as neoplasia, may be triaged to other e.g. ‘sample’ reporters). However, for both groups of reporters, the confidence intervals on the annual plots are wide and overlapping suggesting that dermatologists in general (or those reporting to EPIDERM) are seeing relatively few neoplasia cases and it may be that other physicians, for example oncologists, would be a better source of information about trends in incidence for this disease.

WORK-RELATED RESPIRATORY DISEASE: Case reports of work-related respiratory disease reported by chest physicians to SWORD (13083 in total, 1999-2016) were asthma (19%) with the remainder being the (primarily) asbestos related diseases; benign pleural plaques (42%), and mesothelioma (19%), as well as pneumoconiosis (9%). The average annual decrease in total work-related respiratory disease (1999-2016) was -3.2% (95% CIs: -3.8, -2.5). Adjusting for the impact of excess zeros (using the ZINB model) would change this estimate to -2.1% (95% CIs: -2.7, -1.5). For asthma, an annual average decrease in incidence (1999-2016) of -6.8% (95% CIs: -7.9, -5.6) was observed. The graphs showing relative risk by year suggested an initial decrease in incidence (1999-2007) followed by a relatively flat trend with some suggestion of an increase in incidence between 2015 and 2016 (although confidence intervals are wide and overlapping). Analyses of shorter-term trends (2007-2016) showed an average change of -2.3% (95% CIs: -5.3, 0.9) per year.

Reports by chest physicians suggested an average annual decrease in mesothelioma incidence of -3.7% (95% CIs: -4.9, -2.4) per year. The annual plots show an overall relatively flat trend for the period 1999 to 2007 followed by a fall in incidence between 2007 and 2014 and little change thereafter. An average, annual decrease in incidence was also observed for non-malignant pleural disease at -1.8 (95% CIs: -2.8, -0.8), the annual plots of which also suggested a relatively flat trend since 2014. However (especially when considering information from other sources) the results for mesothelioma in particular should be viewed very cautiously as they may reflect changes in clinical practice rather than a ‘true’ trend (such cases previously seen by SWORD reporters, may be increasingly seen by physicians specialising in lung cancer, who may not participate in SWORD).

Data from SWORD continue to suggest a possible increase in pneumoconiosis incidence since approximately 2007. The average, annual change (1999-2016) in incidence was +3.4% (95% CIs: 1.5, 5.3) and for 2007-2016 it was 8.2% (95% CIs: 4.1, 12.5). However, reports for the last four years suggest a relatively flat trend (although confidence intervals are fairly wide). The observed increase appears largely attributable to asbestos rather than other agents (e.g. silica or coal).

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1 BACKGROUND

This report describes the trend in incidence of work-related illness (WRI) based on data from two occupational disease surveillance systems supported by the Health and Safety Executive (HSE) for data collection during 2016: case reports of work-related skin disease reported to EPIDERM by dermatologists (1996-2016) and case reports of work-related respiratory disease reported to SWORD by chest physicians (1999-2016). These two schemes are part of The Health and Occupation Research (THOR) network, hosted by the Centre for Occupational and Environmental Health at the University of Manchester[1]. Trends based on data collected by the other two extant THOR schemes (THOR-GP for general practitioners and OPRA for occupational physicians) are not reported here (HSE ceased funding data collection at the end of 2015 and 2011, respectively). The report builds on previous reports submitted to the HSE on an annual basis[2-12].

The approach taken to assess change in incidence of WRI over time using surveillance data collected by THOR is based on the methodology proposed by McNamee *et al* in a report submitted to HSE in 2005[13] and subsequently published in the peer reviewed literature[14]. This method proposed using a multi-level model (MLM) which enables change over time in the number of reporters and in other reporter characteristics which could independently impact on case density to be taken into account. This method was subsequently employed to determine trends in incidence for the period 1996 to 2004[2], and in agreement with HSE, on an annual basis thereafter, thus incorporating each additional year of available data[3-12].

The main new methodological issue addressed within this body of work has been the issue of ‘reporter fatigue’ and how best to address this. Extensive analyses have been undertaken (and reported upon) to determine whether physicians participating in THOR are exhibiting ‘reporter fatigue’, and if so, how it impacts on the estimate of trend and whether it can be adjusted for[2, 5, 15-18]. The culmination of this body of work was written up and submitted for peer review and it was agreed with HSE that the annual trends estimates would not be formally adjusted for fatigue until after the publication of this article. This article has now been published[19] and as such, this is the first annual THOR trends report that includes a ‘formal’ adjustment to the overall trend estimates (i.e. the estimated percentage change in incidence of total work-related skin and total respiratory disease).

2 METHOD

A full description of the methodology employed in this study is provided hereunder.

2.1 DATA PERIOD

The data period used for the trends analysis is shown in Table 1.

Table 1 Data period for trends analyses

	Scheme start date	Data period for trends study		
		All reporters	**Core reporters**	**Sample reporters**
EPIDERM	1993	1996-2016	1996-2016	1996-2016
SWORD	1989	1999-2016	1999-2016	1999-2016

2.2 REPORTER GROUPS

Physicians reporting to THOR report either as 'core' reporters (reporting every month) or as 'sample' reporters (reporters who report one randomly allocated month a year). The composition of each of the schemes is as follows:

EPIDERM: Consultant dermatologists began reporting to EPIDERM in 1993 and initially all reporters reported at 3-month intervals[20]. In January 1996 the scheme was redesigned to consist of a 'core' group with a special interest in occupational skin disease who reported to the scheme on a monthly basis (24 dermatologists originally) with the remaining specialists (220 originally) assigned to report on a 'sample' basis. This mix of 'core' and 'sample' reporters i.e. a smaller 'core' group consisting generally of 'keen specialists' and a larger 'sample' group, continued for the period covered by the current report (1996-2016). For this scheme, analyses based on all reporters combined and separately for 'core' and 'sample' groups were carried out.

SWORD: UK wide SWORD reporting began in 1989[21] and originally physicians could report either monthly (78% of physicians originally), quarterly (19%), bi-annually (<1%) or annually (2%). This original system of reporting was modified in January 1992 (to combat potential reporter fatigue) with those physicians who had reported the most cases forming a 'core' group (approximately 10% of physicians at that time) with the remainder assigned to report on a 'sample' (monthly) basis. As for EPIDERM, this structure of a smaller group of keen specialists and a larger 'sample' group continued throughout the time period covered by these analyses (1999-2016 for SWORD). For this scheme, analyses based on all reporters combined and separately for 'core' and 'sample' groups were carried out.

Definition of an active reporter: For the purpose of the analyses it was deemed important to include only those reporters with evidence of active participation. For the THOR specialist schemes an active reporter was defined as a reporter who either returned cases or declared 'I have nothing to report' (a zero return) during the study period.

2.3 CATEGORIES OF DISEASE

Initial power calculations undertaken for the THOR specialist schemes suggested that a specific disease category should only be investigated (separately) if the number of actual cases reported during the study period exceeded 250[2]. The resulting disease groups to be included in the analysis are shown in Table 2.

Table 2 Categories of disease included in the analyses

	Clinical specialist
Total skin	**Yes**
Contact dermatitis (CD)	**Yes**
• Allergic CD	**Yes**
• Irritant CD	**Yes**
• Mixed CD	**Yes**
Other skin (other than contact dermatitis)	**Yes**
Neoplasia	**Yes**
Contact urticaria	**Yes**
Total respiratory	**Yes**
Asthma	**Yes**
Mesothelioma	**Yes**
Benign pleural disease	**Yes**
• Predominantly plaques	**Yes**
• Predominantly diffuse	**Yes**
Pneumoconiosis	**Yes**
Other respiratory disease (other than those specified above)	**Yes**

2.4 THE MULTI-LEVEL MODEL AND ITS ASSUMPTIONS

The STATA software command **xtnbreg** was used to fit longitudinal, negative binomial (i.e. over-dispersed) Poisson models with random effects.

In these models, the dependent variable was the number of actual cases, including zeros, per reporter per month; the main ‘covariate’ is calendar time. The aim of the analysis is to estimate the relationship between annual UK incidence rate and time, after adjusting for potential confounders. Numbers of cases might vary from year to year solely because of changes in the size of the UK working population, even though the rate is constant. Therefore estimated population sizes for each year (see below) were included in the model as an ‘offset’; this feature means that the model estimates change in rates, not changes in case counts.

Apart from ‘calendar time’, the other variables included in the regression models as covariates were ‘season’, ‘reporter type’ (‘core’ or ‘sample’), ‘first month/s as a new reporter’. These are factors that can influence the reported incidence levels. Further details of covariates/offsets in the model are given later in this section.

It is important to allow for the possible impact of having different reporting centres at different periods of time: some centres may have a larger, or more ‘at risk’ catchment patient population than others. In a statistical model, we can take account of such differences by allowing the incidence level to vary between centres; the analysis can then trace the pattern over time ‘within centres’. In a ‘fixed effects’ approach to this, the incidence level is estimated for each centre; in a ‘random effects’ model, the incidence levels are assumed to vary randomly between centres in each subgroup (e.g. subgroups of ‘core’ reporters and ‘sample’ reporters) but not estimated directly. In previous reports, two sets of results were presented corresponding to each of these options but, after consultation with HSE, it was decided that from 2010 onwards only results based on models with random effects would be presented. (One reason was because the fixed effects model omits all reporters who had reported only zero cases throughout the study period).

Every statistical model has to make an assumption about the form of the variability which remains after taking into account all covariates in the model. The Poisson distribution is the usual distribution assumed for count data; the Negative Binomial distribution is a more general version of a Poisson distribution which is less rigid; in the Poisson the variance and mean are constrained to be equal, but not in the Negative Binomial.

***Calendar time* –** For the main analyses, changes in incidence were estimated in two different ways: 1) ‘*non-parametric’ approach*: the model contained separate indicator variables for different years. In the current analyses, 2016 was taken as the reference year and the percentage increase or decrease in incidence compared to 2016 was estimated. These analyses had no in-built assumptions about the pattern of change over time. 2) *‘parametric’ approach* with a continuous time variable measured on a scale of years. The statistical models for these analyses assumed a systematic trend throughout the period being studied. Specifically, it was assumed that the percentage change from one year to the next is a constant throughout the relevant period. Where the assumption is valid, this parametric approach offers a more precise way of estimating change than approach 1.

Season – Seasonal variation refers to variation within a year whose pattern tends to be repeated from year to year. This short-term variation could be due to seasonal variation in illness or seasonality in reporting behaviour; the latter could occur because of holidays, for example. To address this, indicator variables for months (with June as the reference category) were included in the models. Seasonal variation should not bias the assessment of long-term changes in this study. However it could affect precision in the estimate of trend if not controlled.

Reporter type – Reporter type ('core' or 'sample') had been shown to cause variation in incidence between reporters. Thus, a variable which took the value '1' if a 'core' reporter and '0' if a 'sample' reporter was included in the models. Furthermore, for the purpose of the analysis, if a reporter changed from the 'core' reporting group to 'sample' reporting or vice versa, he or she was treated as a new reporter for the period after the change. We have previously shown[20] that there are differences in behaviour for the same reporter depending on whether they are reporting as 'core' or as 'sample'.

First month/s as a new reporter – It is conceivable that, in the first month/s of reporting, a new entrant to a surveillance scheme might include cases seen over a period longer than the assigned single month. If there was a sufficiently large 'harvest' of old cases, it could produce a false, decreasing 'trend' over time. For the THOR specialist schemes, initial investigations suggested that 'new recruit' harvesting might be occurring during the first month that a reporter actively reported to a scheme. Thus, to control for harvesting, a variable which took the value '1' if it was the first month the reporter had reported and '0' for all other months was included in the models.

Population change - Analysis of data from the UK Labour Force Survey (LFS) had shown a fairly regular increase in the size of the working population of the order of 1% a year up to 2006[22], although decreases may have occurred since then. One might perhaps expect to see an increase in cases over time because of this even if true incidence *rates* remained constant. Therefore we have accounted for this change in population base by including in the ML model an offset variable representing the UK working population, obtained from the LFS, for each year.

Table 3 Summary of model features

Feature	Description
Centre variation	Variation in incidence between centres is assumed; analysis attempts to measure change within centres
Centre number	If a reporter changed from 'core' to 'sample' (or vice versa) they were assigned a new centre number and thus treated as a new reporter in the model
Denominators/population sizes	The catchment population for each centre is assumed to increase/decrease in line with changes in the size of UK working population
Unexplained variation	Assumed to follow a Negative Binomial distribution
Active reporter	Only 'active' reporters were included in the analysis. This was defined as a reporter who either returned cases or declared 'I have nothing to report' (a zero return) at least once during the study period.
New recruit 'harvesting' of old cases	For SWORD and EPIDERM, the model assumes that this effect only occurs during the first month of reporting or the first month a reporter returned as a core reporter.
Calendar time treatment: non-parametric approach	Rate Ratio for each year compared to 2016 is estimated
Calendar time treatment: parametric approach	A linear trend over time is assumed: Rate Ratio for each year compared to the previous one is estimated

2.5 ADJUSTMENT FOR 'REPORTER FATIGUE'

A major methodological concern of this project has been the issue of reporter 'fatigue' (i.e. as membership time increases a reporter might become less committed to active participation but still retain membership), how it manifests and whether this can cause bias in time trend estimation. Investigations have focussed on two different manifestations of fatigue: an increase in non-response over time, and an increase in zero (blank) returns over time[2, 5, 15-18]. We have argued previously that an increase in non-response over time would not necessarily cause bias in trends estimation (since the rates are calculated based on responses received, not responses due to have been received); therefore results of these analyses have not been reproduced here. In contrast, an increase in zero returns over time, some of which may be 'false zeros' and which do not truly equate to 'zero cases', would mean that the trend over time would be biased downwards compared to the situation if there were no reporting fatigue.

Steps taken to investigate this particular manifestation of fatigue are summarised in Appendix 1. The most recent (and we believe improved) approach has been the application of a zero-inflated negative binomial (ZINB) model to investigate the presence of 'excess zeros' in THOR data. This approach has been written up and recently published in the peer review literature[19]. Using this approach the impact of adjusting for excess zeros on the annual average percentage change in incidence of total work-related skin disease (EPIDERM, 1996-2016) and total work-related respiratory disease (SWORD, 1999-2016) was investigated. At present, these adjustments have been carried out for total skin and total respiratory only (it cannot be assumed at this stage that the observed effect would be the same across the different diagnoses).

A brief overview of the methodology is provided below:

The zero-inflated negative binomial (ZINB) model

To account for the presence of excess zero cases within the reported data, the reported monthly number of (total work-related skin or total work-related respiratory) cases was fitted using a (ZINB) model with multi-level random effects.

This model has two parts; the first supposes that, on occasion, a reporter might send back a zero report regardless of the actual number of cases seen i.e. an excess zero. This part of the model supposes a binary decision: send back an excess zero regardless or send back the true count zero or otherwise. The second part is the usual negative binomial model for true cases, including true zero cases, each month. The model allows for two sets of predictors in the two portions of the model. These were mean centred membership year (first part of model) and calendar time (second part of model). Thus the complete model allows for the possibility of excess zeros in the data; it can estimate their frequency and can estimate the true trend after allowing for this phenomenon.

The covariate thought to influence zero case reports and therefore included in the first part of the model was peak holiday season. Covariates thought to influence the incidence of work-related illness, and therefore included in the second part of the model, were first month as a reporter and months of the year containing a bank holiday. All modelling was repeated for ‘core’ reporters only, ‘sample’ reporters only, and both ’core’ and ‘sample’ reporters.

3 RESULTS

3.1 OVERVIEW OF SCHEMES

An overview of the reporting activity of the physicians participating in EPIDERM and SWORD is provided in Appendix B and briefly described below.

3.1.1 EPIDERM (Dermatologists)

A total of 463 dermatologists have been enrolled in EPIDERM during the study period with 92% actively participating at least once (i.e. either returning cases or declaring 'I have nothing to report this month') (Table B1). An average of 188 dermatologists participated in EPIDERM each year (Figure B1) and 2016 saw a small drop in the overall number of physicians in EPIDERM (from 148 in 2015 to 146 in 2016). Response rates (cards returned/cards sent out) per year showed an initial increase between 1996 and 2001, followed by an overall decline until 2012 after which they appeared to stabilising between 60-70% (Figure B2). The number of active reporters per month has fallen slightly from an average of 21 per month in 2015 to 19 per month in 2016 (Figure B3). The average cases per active reporter also dropped slightly from 1.9 in 2015 to 1.7 in 2016 (Figure B4). Reporters to EPIDERM are predominantly 'sample' (86% in 2016) but 'core' reporters report more cases per active reporter per month (3.4) compared to 'sample' (1) (Table B2). Case reports to EPIDERM continue to be predominantly contact dermatitis (82% of total cases) with smaller proportions of neoplasia (12%) and other skin diagnoses.

3.1.2 SWORD (Chest physicians)

Active participation in SWORD during the study period was similar to EPIDERM with 93% of the 901 chest physicians enrolled during this period actively reporting at least once (Table B3). On average, 465 chest physicians participated in SWORD each year (Figure B5) and the total number of reporters in SWORD decreased slightly between 2015 and 2016 (422 to 413). Response rates (cards returned/cards sent out) increased slightly in 2016 (compared to 2015) for both 'core' reporters (54% to 63%) and 'sample' reporters (54% to 56%) (Figure B6). The average number of active reporters per month (Figure B7) increased slightly between 2015 and 2016 (27 and 29, respectively) whilst the average number of cases per active reporter remained the same at 1.2 (Figure B8). Similar to EPIDERM, the smaller group of chest physicians reporting as 'core' reported more cases per active reporter per month (3.0) than chest physicians reporting as 'sample' (0.5) (Table B4). The majority of the diagnoses (42%) reported to SWORD during the study period were benign pleural plaques. Of the remaining cases, 19% were mesothelioma, 19% asthma, 9% pneumoconiosis, and 14% 'other' respiratory disease.

3.2 TIME TRENDS BY DISEASE CATEGORY

This report continues with the approach first adopted in the trends report submitted to HSE in September 2010[7], in that the statistical uncertainty (confidence intervals) in the graphs illustrating time trends are presented in such a way as to allow the reader to assess the significance of the difference between any two years. This useful approach suggested by the then HSE liaison officer (John Hodgson) when steering the research follows the method described by Firth and de Menezes[23] which assigns a confidence (or comparison) interval to the reference category (2016 in the present analyses) and reduces the width of the confidence (comparison) intervals of non-reference categories in such a way that all pairwise comparisons between years can validly be made using these adjusted confidence intervals.

3.2.1 WORK-RELATED SKIN DISEASE - DERMATOLOGISTS

The average annual percentage change in risk of work-related skin disease, as reported by dermatologists is shown in Table 4 whilst the relative rates by year are shown in Tables 5 to 12 and Figures 1 to 8.

The annual average change in incidence of dermatologist reported work-related skin disease (1996-2016) was -4.0% (95% CIs: -4.4, -3.5). This compares to the previous estimate of -3.9% (95% CIs: -4.3, -3.4) reported in 2016 (based on data for the period 1996-2015). The graphs (Figure 1) showing relative risk by year suggest an initial decrease in incidence in the earlier part of the study period (1996-2005) followed by a relatively flat trend (2006-2012) and a further decrease between 2012 and 2016. The estimated annual change in incidence of contact dermatitis (CD) was similar at -3.9% (95% CIs:-4.4, -3.4) with a similar annual pattern (Figure 2). Analyses of shorter-term trends (2006-2016) for CD suggested an annual average decrease in CD incidence of -4.1% (95% CIs:-5.4, -2.8) per year. Analysis by type of CD indicated a steeper decrease in the incidence of allergic CD (-5.2% (95% CIs: -5.9, -4.5)) compared to irritant CD (-2.9% (95% CIs: -3.6, -2.2)) or mixed CD (-2.6% (95% CIs: -3.6, -1.5)) and these estimates remain relatively unchanged by the addition of the 2016 data. The graphs (Figure 3) showing relative risk by year continue to suggest an overall downward trend for allergic CD between 1996 and 2006 followed by a relatively flat trend. For irritant CD (Figure 4), after an initial decrease between 1999 and 2000, the trend is flat until about 2012, after which it appears to decrease to 2016.

The annual average change in incidence of dermatologist reported urticaria (Figure 6) remained largely unchanged with the addition of the 2016 data at -7.0% (95% CIs: -8.6, -5.5) compared to the previously reported -7.2% (95% CIs: -8.8, -5.5) (based on data for 1996-

2015). Similarly, the trend in incidence for neoplasia (Figure 7) suggested a decrease, of -3.1% (95% CIs: -4.5, -1.7) compared to -3.2% (95% CIs: -4.7, -1.8) reported in 2016.

There was some variation by reporter type (‘core’ versus ‘sample’). This was still most pronounced for neoplasia with data from ‘core’ reporters suggesting an annual average decrease of -4.8% (95% CIs: -6.4, -3.2) whilst data from ‘sample’ reporters suggested an increase of 2.1% (95% CIs: -0.7, 5.0) and for urticaria there was evidence of a decrease in incidence but only from ‘core’ reporters (‘core’: -7.7% (95% CIs: -9.2, -6.0); ‘sample’: 0.2% (95% CIs: -5.3, 6.0)).

Adjusting the average annual percentage change in incidence of total work-related skin disease for the impact of excess zeros (using the ZINB model) would change the estimate from -4.0% (95% CIs: -4.4, -3.5) to -3.0% (95% CIs: -3.3, -2.6).

Table 4 **Average annual percentage change in reported incidence in work-related skin disease as reported by dermatologists to EPIDERM**

		ESTIMATED % CHANGE (95% CONFIDENCE INTERVAL)		
		All reporters	Core reporters	Sample reporters
	Year (continuous)			
Total skin	1996-2016	-4.0 (-4.4, -3.5)	-4.2 (-4.6, -3.7)	-2.5 (-3.8, -1.2)
	2006-2016	-4.8 (-6.0, -3.5)	-5.6 (-6.9, -4.2)	-0.8 (-3.9, 2.4)
Contact dermatitis (CD)	1996-2016	-3.9 (-4.4, -3.4)	-3.9 (-4.5, -3.4)	-3.6 (-5.0, -2.1)
	2006-2016	-4.1 (-5.4, -2.8)	-4.9 (-6.3, -3.5)	0.8 (-2.8, 4.4)
• **Allergic CD**	1996-2016	-5.2 (-5.9, -4.5)	-5.6 (-6.3, -4.8)	-3.2 (-5.1, -1.1)
• **Irritant CD**	1996-2016	-2.9 (-3.6, -2.2)	-2.9 (-3.7, -2.2)	-2.6 (-4.8, -0.5)
• **Mixed CD**	1996-2016	-2.6 (-3.6, -1.5)	-3.0 (-4.1, -1.9)	0.2 (-3.0, 3.6)
Urticaria	1996-2016	-7.0 (-8.6, -5.5)	-7.7 (-9.2, -6.0)	0.2 (-5.3, 6.0)
Neoplasia	1996-2016	-3.1 (-4.5, -1.7)	-4.8 (-6.4, -3.2)	2.1 (-0.7, 5.0)
Other* skin	1996-2016	-5.7 (-6.6, -4.7)	-6.9 (-7.9, -5.8)	-0.2 (-2.4, 2.1)

*Other than contact dermatitis
Models adjusted for reporter type (where appropriate), season and harvesting
Population offset included in the model
The number of actual cases on which each analysis is based is provided in Table B2 on page 77

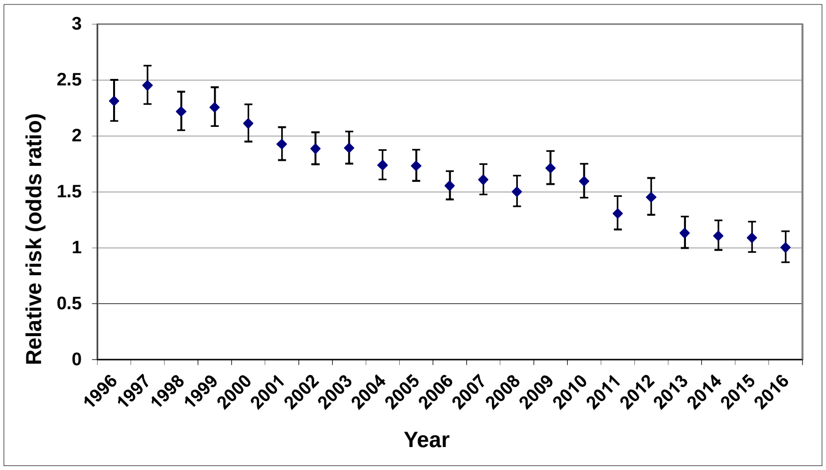
Table 5 **Relative risk by year, with 95% comparison intervals, total skin disease (2016 estimate = 1), as reported by dermatologists to EPIDERM**

	Relative risk (95% comparison interval)		
	All reporters	Core reporters	Sample reporters
YEAR			
1996	2.31 (2.13,2.5)	2.55 (2.35,2.77)	1.17 (0.86,1.59)
1997	2.45 (2.29,2.63)	2.67 (2.48,2.87)	1.72 (1.33,2.22)
1998	2.22 (2.05,2.39)	2.42 (2.23,2.62)	1.51 (1.2,1.92)
1999	2.26 (2.09,2.44)	2.44 (2.24,2.65)	1.64 (1.34,2.01)
2000	2.11 (1.95,2.28)	2.34 (2.15,2.55)	1.31 (1.05,1.63)
2001	1.93 (1.78,2.08)	2.09 (1.92,2.26)	1.45 (1.17,1.79)
2002	1.88 (1.75,2.03)	2.04 (1.88,2.21)	1.43 (1.14,1.8)
2003	1.89 (1.75,2.04)	2.11 (1.95,2.28)	1.05 (0.81,1.37)
2004	1.74 (1.61,1.87)	1.89 (1.75,2.05)	1.21 (0.96,1.53)
2005	1.73 (1.6,1.88)	1.9 (1.75,2.07)	1.13 (0.9,1.44)
2006	1.55 (1.43,1.68)	1.65 (1.51,1.8)	1.34 (1.09,1.66)
2007	1.61 (1.48,1.75)	1.78 (1.63,1.95)	1 (0.78,1.28)
2008	1.5 (1.37,1.64)	1.67 (1.52,1.84)	0.87 (0.65,1.16)
2009	1.71 (1.57,1.87)	1.87 (1.7,2.04)	1.17 (0.9,1.53)
2010	1.59 (1.45,1.75)	1.74 (1.57,1.92)	1.11 (0.84,1.46)
2011	1.31 (1.16,1.46)	1.38 (1.22,1.57)	1.07 (0.8,1.44)
2012	1.45 (1.3,1.62)	1.56 (1.37,1.76)	1.14 (0.86,1.5)
2013	1.13 (1,1.28)	1.17 (1.02,1.34)	1.01 (0.76,1.35)
2014	1.1 (0.98,1.24)	1.16 (1.02,1.32)	0.89 (0.66,1.21)
2015	1.09 (0.96,1.23)	1.1 (0.96,1.27)	1.03 (0.77,1.39)
2016	1 (0.87,1.15)	1 (0.86,1.17)	1 (0.73,1.36)

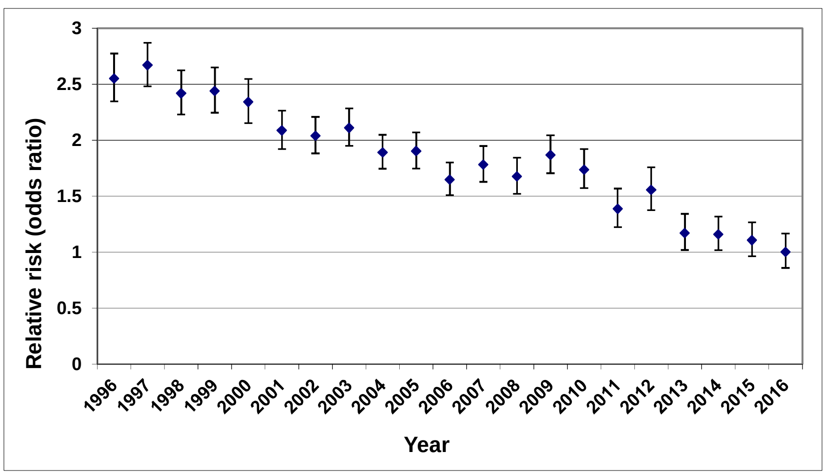
Models adjusted for reporter type (where appropriate), season and harvesting
Population offset included in the model
The number of actual cases on which each analysis is based is provided in Table B2 on page 77

Figure 1 Relative risk by year (2016 estimate = 1), with 95% comparison intervals, total skin

a) EPIDERM, all reporters



b) EPIDERM, core reporters



c) EPIDERM, sample reporters

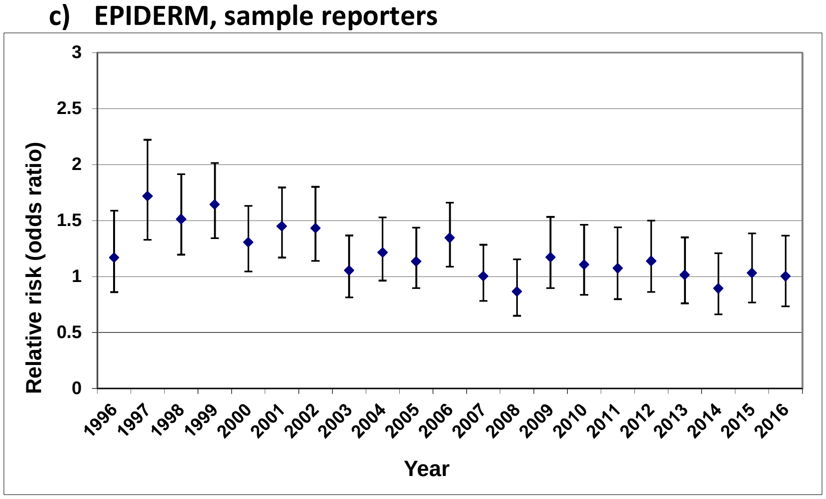


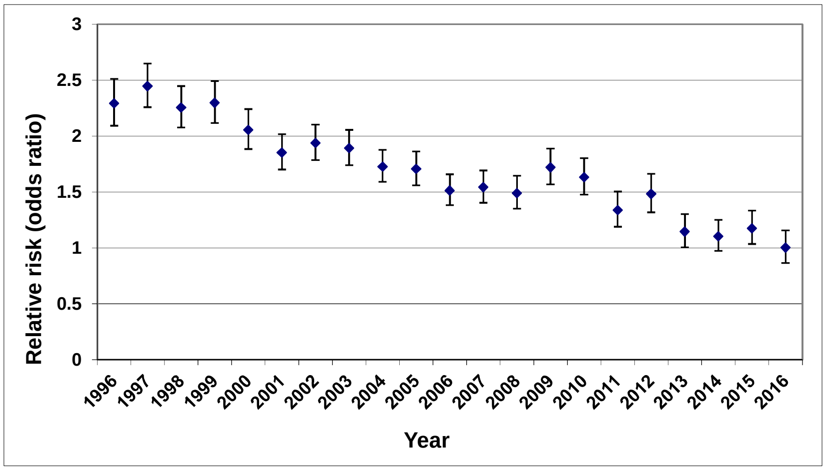
Table 6 Relative risk by year, with 95% comparison intervals, all contact dermatitis (2016 estimate = 1), as reported by dermatologists to EPIDERM

	Relative risk (95% comparison interval)		
	All reporters	Core reporters	Sample reporters
YEAR			
1996	2.29 (2.09,2.51)	2.42 (2.2,2.67)	1.57 (1.13,2.18)
1997	2.44 (2.26,2.65)	2.58 (2.37,2.8)	2.11 (1.6,2.78)
1998	2.25 (2.08,2.45)	2.38 (2.18,2.59)	1.95 (1.51,2.52)
1999	2.3 (2.12,2.49)	2.37 (2.17,2.59)	2.31 (1.87,2.84)
2000	2.06 (1.88,2.24)	2.18 (1.99,2.39)	1.68 (1.33,2.12)
2001	1.85 (1.7,2.02)	1.97 (1.8,2.16)	1.49 (1.17,1.91)
2002	1.94 (1.79,2.1)	2.04 (1.87,2.22)	1.74 (1.36,2.22)
2003	1.89 (1.74,2.06)	2.05 (1.88,2.24)	1.24 (0.93,1.64)
2004	1.73 (1.59,1.88)	1.85 (1.7,2.02)	1.24 (0.94,1.64)
2005	1.7 (1.56,1.86)	1.81 (1.64,1.98)	1.38 (1.07,1.78)
2006	1.51 (1.38,1.66)	1.6 (1.45,1.77)	1.31 (1.01,1.69)
2007	1.54 (1.4,1.69)	1.68 (1.53,1.86)	0.94 (0.7,1.27)
2008	1.49 (1.35,1.64)	1.63 (1.47,1.8)	0.9 (0.65,1.25)
2009	1.72 (1.57,1.89)	1.85 (1.68,2.04)	1.17 (0.86,1.6)
2010	1.63 (1.48,1.8)	1.75 (1.58,1.94)	1.16 (0.85,1.59)
2011	1.34 (1.19,1.5)	1.39 (1.22,1.57)	1.23 (0.89,1.69)
2012	1.48 (1.32,1.66)	1.56 (1.38,1.77)	1.23 (0.9,1.67)
2013	1.14 (1.01,1.3)	1.16 (1.01,1.34)	1.16 (0.85,1.59)
2014	1.1 (0.97,1.25)	1.13 (0.99,1.3)	1.02 (0.73,1.41)
2015	1.17 (1.03,1.33)	1.18 (1.03,1.36)	1.19 (0.87,1.63)
2016	1 (0.87,1.16)	1 (0.85,1.17)	1 (0.71,1.41)

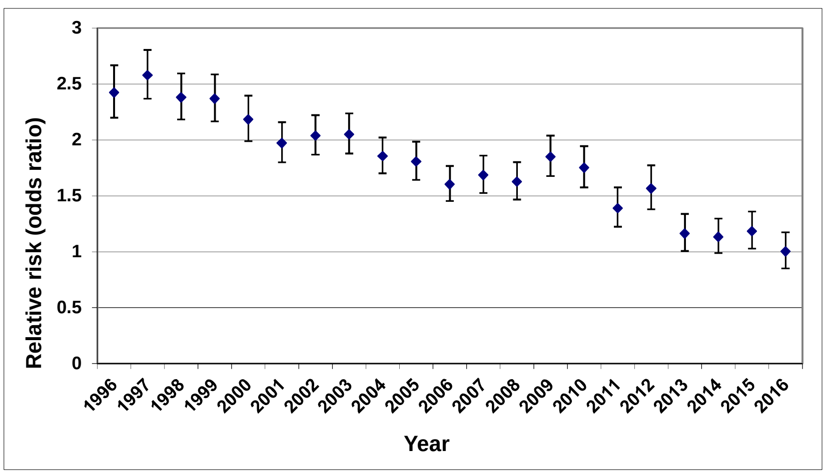
Models adjusted for reporter type (where appropriate), season and harvesting
Population offset included in the model
The number of actual cases on which each analysis is based is provided in Table B2 on page 77

Figure 2 Relative risk by year (2016 estimate = 1), with 95% comparison intervals, all contact dermatitis

a) EPIDERM, all reporters



b) EPIDERM, core reporters



c) EPIDERM, sample reporters

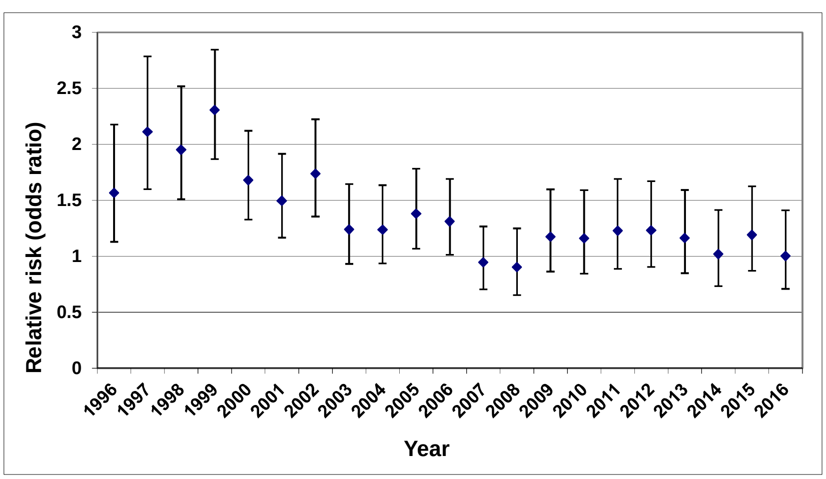


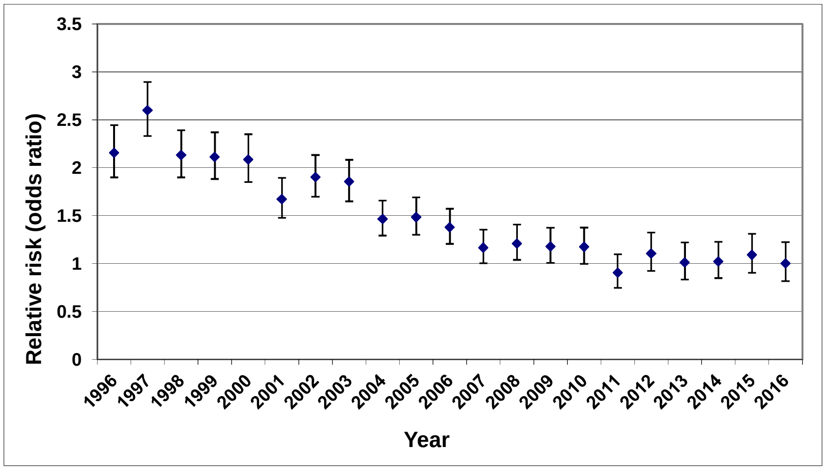
Table 7 Relative risk by year, with 95% comparison intervals, allergic contact dermatitis (2016 estimate = 1), as reported by dermatologists to EPIDERM

	Relative risk (95% comparison interval)		
	All reporters	**Core reporters**	**Sample reporters**
YEAR			
1996	2.15 (1.9,2.44)	2.23 (1.94,2.55)	1.78 (1.13,2.79)
1997	2.6 (2.33,2.89)	2.64 (2.35,2.96)	2.65 (1.83,3.85)
1998	2.13 (1.9,2.39)	2.22 (1.96,2.51)	1.69 (1.14,2.52)
1999	2.11 (1.88,2.37)	2.14 (1.89,2.43)	2.2 (1.57,3.08)
2000	2.09 (1.85,2.35)	2.16 (1.9,2.45)	1.89 (1.34,2.65)
2001	1.67 (1.48,1.89)	1.77 (1.56,2.02)	1.16 (0.77,1.77)
2002	1.9 (1.7,2.13)	1.9 (1.69,2.15)	2.23 (1.6,3.11)
2003	1.85 (1.65,2.08)	1.91 (1.69,2.16)	1.67 (1.15,2.44)
2004	1.46 (1.29,1.66)	1.51 (1.33,1.72)	1.28 (0.84,1.96)
2005	1.48 (1.3,1.69)	1.47 (1.27,1.69)	1.78 (1.25,2.52)
2006	1.38 (1.2,1.57)	1.37 (1.19,1.58)	1.64 (1.15,2.36)
2007	1.17 (1,1.35)	1.17 (0.99,1.37)	1.33 (0.89,1.99)
2008	1.21 (1.04,1.41)	1.23 (1.05,1.44)	1.23 (0.79,1.91)
2009	1.18 (1.01,1.37)	1.2 (1.02,1.41)	1.05 (0.63,1.76)
2010	1.17 (1,1.38)	1.15 (0.97,1.37)	1.43 (0.91,2.26)
2011	0.91 (0.75,1.1)	0.85 (0.69,1.05)	1.57 (0.98,2.49)
2012	1.11 (0.92,1.32)	1.13 (0.94,1.37)	1.03 (0.61,1.73)
2013	1.01 (0.83,1.22)	0.97 (0.78,1.19)	1.32 (0.84,2.07)
2014	1.02 (0.85,1.23)	1 (0.82,1.22)	1.21 (0.75,1.96)
2015	1.09 (0.9,1.31)	1.04 (0.85,1.27)	1.44 (0.92,2.26)
2016	1 (0.82,1.22)	1 (0.8,1.24)	1 (0.58,1.73)

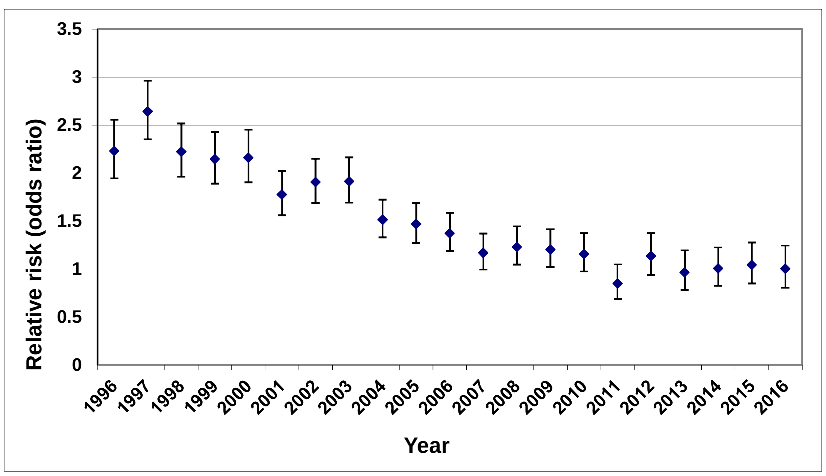
Models adjusted for reporter type (where appropriate), season and harvesting
Population offset included in the model
The number of actual cases on which each analysis is based is provided in Table B2 on page 77

Figure 3 **Relative risk by year (2016 estimate = 1), with 95% comparison intervals, allergic contact dermatitis**

a) EPIDERM, all reporters



b) EPIDERM, core reporters



c) EPIDERM, sample reporters

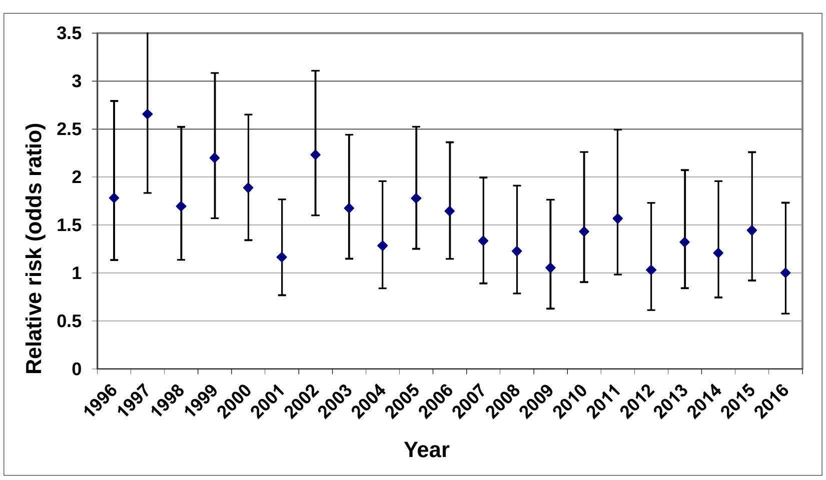


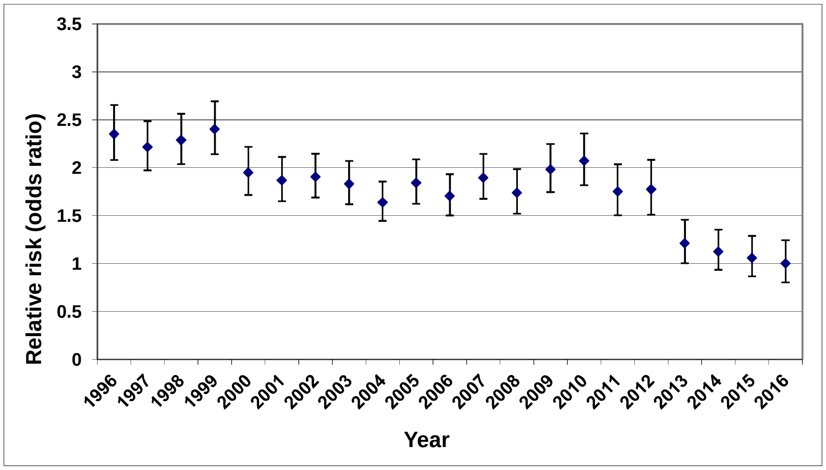
Table 8 **Relative risk by year, with 95% comparison intervals, irritant contact dermatitis (2016 estimate = 1), as reported by dermatologists to EPIDERM**

	Relative risk (95% comparison interval)		
	All reporters	**Core reporters**	**Sample reporters**
YEAR			
1996	2.35 (2.08,2.66)	2.63 (2.31,3.01)	0.9 (0.5,1.64)
1997	2.21 (1.97,2.49)	2.48 (2.19,2.81)	1.3 (0.79,2.14)
1998	2.29 (2.04,2.56)	2.49 (2.21,2.82)	1.86 (1.3,2.66)
1999	2.4 (2.14,2.69)	2.64 (2.34,2.99)	1.79 (1.27,2.51)
2000	1.95 (1.72,2.22)	2.17 (1.9,2.49)	1.33 (0.9,1.95)
2001	1.87 (1.65,2.11)	2.01 (1.76,2.3)	1.69 (1.21,2.36)
2002	1.9 (1.69,2.15)	2.11 (1.86,2.39)	1.4 (0.94,2.08)
2003	1.83 (1.62,2.07)	2.06 (1.81,2.35)	1.1 (0.71,1.71)
2004	1.64 (1.45,1.86)	1.84 (1.61,2.09)	1.03 (0.67,1.6)
2005	1.84 (1.62,2.09)	2.06 (1.8,2.35)	1.22 (0.81,1.82)
2006	1.7 (1.5,1.93)	1.92 (1.69,2.2)	1.13 (0.76,1.69)
2007	1.9 (1.68,2.14)	2.21 (1.94,2.51)	0.73 (0.45,1.2)
2008	1.74 (1.52,1.99)	2 (1.74,2.29)	0.8 (0.48,1.35)
2009	1.98 (1.75,2.25)	2.28 (2.01,2.6)	0.78 (0.45,1.34)
2010	2.07 (1.82,2.36)	2.4 (2.1,2.74)	0.8 (0.47,1.38)
2011	1.75 (1.5,2.04)	1.97 (1.68,2.3)	1.03 (0.62,1.7)
2012	1.77 (1.51,2.08)	1.94 (1.63,2.31)	1.41 (0.91,2.2)
2013	1.21 (1,1.46)	1.29 (1.06,1.58)	1.09 (0.67,1.78)
2014	1.12 (0.93,1.35)	1.17 (0.96,1.43)	0.99 (0.62,1.59)
2015	1.06 (0.87,1.29)	1.08 (0.87,1.34)	1.05 (0.65,1.69)
2016	1 (0.8,1.24)	1 (0.78,1.28)	1 (0.62,1.62)

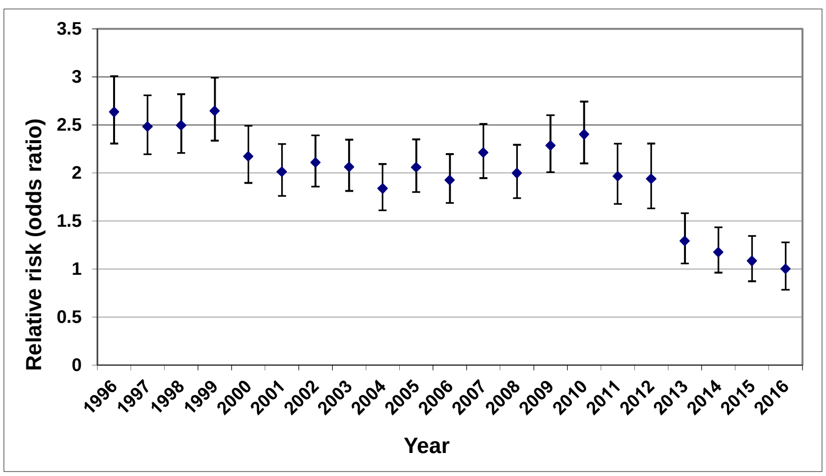
Models adjusted for reporter type (where appropriate), season and harvesting
Population offset included in the model
The number of actual cases on which each analysis is based is provided in Table B2 on page 77

Figure 4 **Relative risk by year (2016 estimate = 1), with 95% comparison intervals, irritant contact dermatitis**

a) EPIDERM, all reporters



b) EPIDERM, core reporters



c) EPIDERM, sample reporters

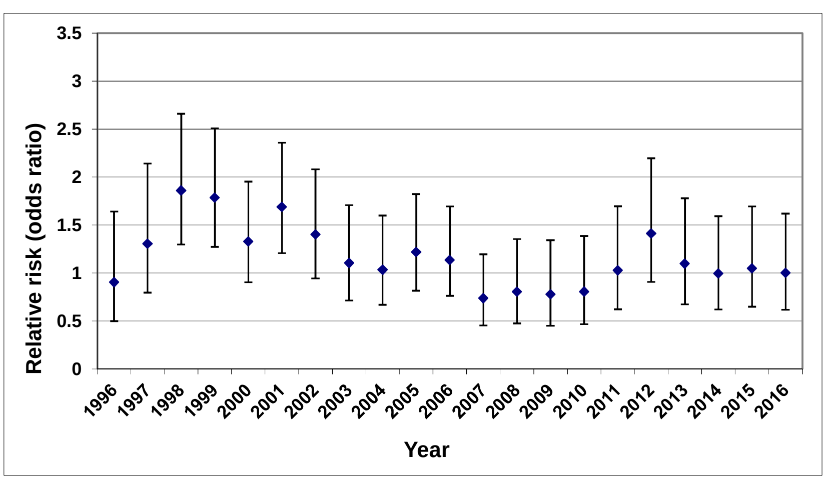


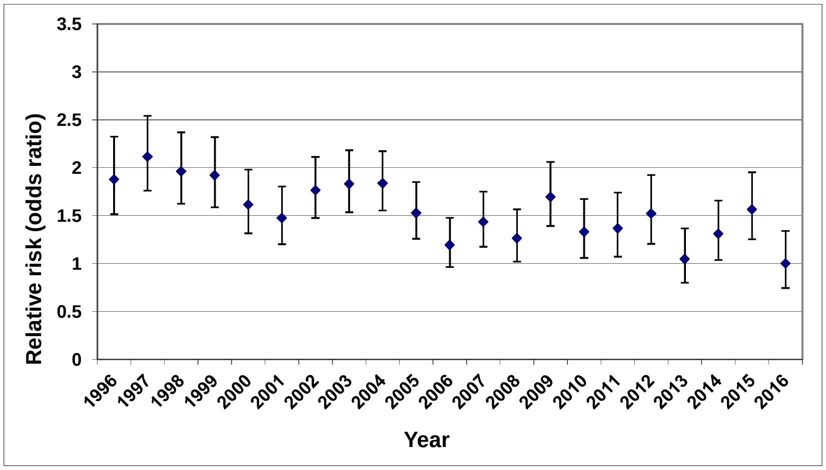
Table 9 Relative risk by year, with 95% comparison intervals, mixed contact dermatitis (2016 estimate = 1), as reported by dermatologists to EPIDERM

	Relative risk (95% comparison interval)		
	All reporters	**Core reporters**	**Sample reporters**
YEAR			
1996	1.88 (1.52,2.32)	2.26 (1.8,2.83)	0.87 (0.39,1.91)
1997	2.11 (1.76,2.54)	2.47 (2.04,3)	1.4 (0.74,2.62)
1998	1.96 (1.62,2.37)	2.31 (1.89,2.82)	1.22 (0.69,2.16)
1999	1.92 (1.59,2.32)	2.24 (1.83,2.75)	1.27 (0.76,2.11)
2000	1.61 (1.32,1.98)	1.97 (1.59,2.45)	0.74 (0.4,1.37)
2001	1.47 (1.2,1.8)	1.86 (1.51,2.29)	0.47 (0.21,1.09)
2002	1.76 (1.47,2.11)	2.15 (1.78,2.59)	0.81 (0.42,1.58)
2003	1.83 (1.54,2.18)	2.31 (1.93,2.76)	0.4 (0.16,0.97)
2004	1.84 (1.55,2.17)	2.2 (1.85,2.62)	0.9 (0.5,1.64)
2005	1.53 (1.26,1.85)	1.86 (1.52,2.28)	0.68 (0.35,1.3)
2006	1.19 (0.96,1.48)	1.41 (1.12,1.77)	0.77 (0.42,1.4)
2007	1.43 (1.18,1.75)	1.82 (1.48,2.23)	0.3 (0.12,0.79)
2008	1.26 (1.02,1.56)	1.54 (1.24,1.93)	0.43 (0.19,0.98)
2009	1.69 (1.39,2.06)	2.14 (1.75,2.61)	0.27 (0.08,0.84)
2010	1.33 (1.06,1.67)	1.49 (1.16,1.91)	1.08 (0.59,1.97)
2011	1.37 (1.07,1.74)	1.52 (1.17,1.99)	0.99 (0.54,1.83)
2012	1.52 (1.2,1.92)	1.72 (1.34,2.22)	0.99 (0.54,1.84)
2013	1.05 (0.8,1.37)	1.13 (0.84,1.52)	0.8 (0.41,1.57)
2014	1.31 (1.04,1.66)	1.42 (1.11,1.82)	1.09 (0.61,1.95)
2015	1.56 (1.25,1.95)	1.67 (1.31,2.13)	1.17 (0.67,2.06)
2016	1 (0.75,1.34)	1 (0.72,1.4)	1 (0.55,1.83)

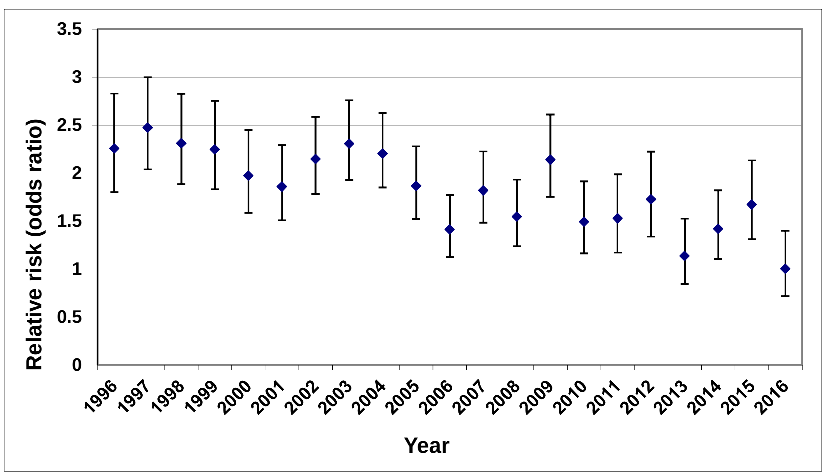
Models adjusted for reporter type (where appropriate), season and harvesting
Population offset included in the model
The number of actual cases on which each analysis is based is provided in Table B2 on page 77

Figure 5 **Relative risk by year (2016 estimate = 1), with 95% comparison intervals, mixed contact dermatitis**

a) EPIDERM, all reporters



b) EPIDERM, core reporters



c) EPIDERM, sample reporters

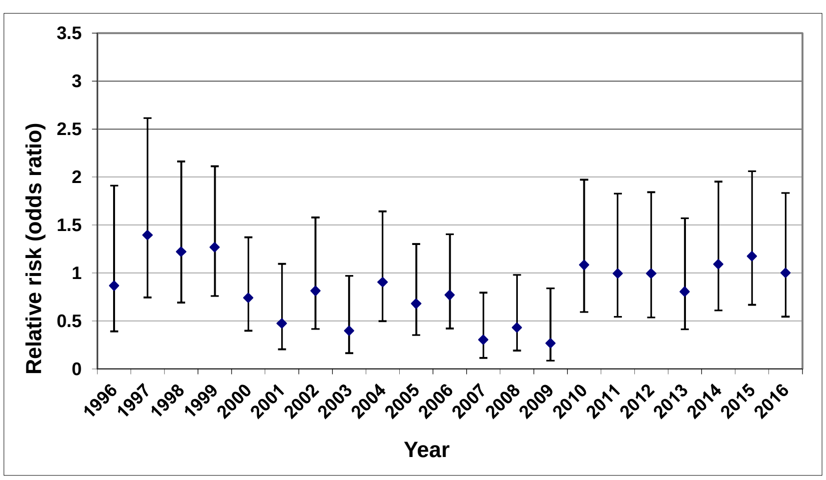


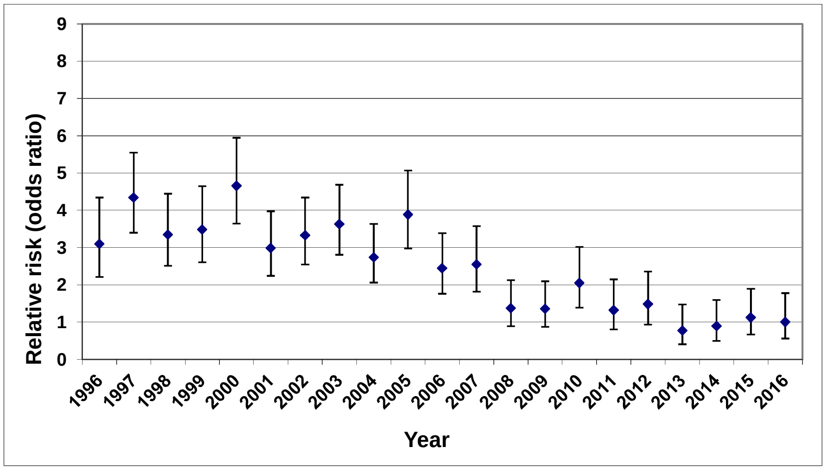
Table 10 Relative risk by year, with 95% comparison intervals, contact urticaria (2016 estimate = 1), as reported by dermatologists to EPIDERM

	Relative risk (95% comparison interval)	
	All reporters	**Core reporters**
YEAR		
1996	3.1 (2.21,4.34)	4.23 (2.98,6.01)
1997	4.34 (3.4,5.55)	5.87 (4.54,7.58)
1998	3.35 (2.52,4.45)	4.57 (3.42,6.12)
1999	3.48 (2.6,4.65)	4.49 (3.3,6.1)
2000	4.65 (3.64,5.95)	6.45 (5.03,8.26)
2001	2.98 (2.24,3.97)	3.96 (2.95,5.31)
2002	3.33 (2.55,4.34)	4.58 (3.5,5.99)
2003	3.63 (2.81,4.69)	5 (3.86,6.46)
2004	2.74 (2.06,3.64)	3.61 (2.69,4.83)
2005	3.88 (2.98,5.07)	5.28 (4.04,6.91)
2006	2.44 (1.76,3.39)	2.89 (2.04,4.1)
2007	2.55 (1.82,3.57)	3.34 (2.37,4.73)
2008	1.38 (0.89,2.13)	1.7 (1.08,2.69)
2009	1.36 (0.88,2.1)	1.67 (1.06,2.64)
2010	2.05 (1.39,3.02)	2.61 (1.75,3.89)
2011	1.32 (0.81,2.15)	1.57 (0.93,2.65)
2012	1.48 (0.93,2.36)	1.89 (1.16,3.06)
2013	0.77 (0.4,1.48)	1.04 (0.54,1.99)
2014	0.89 (0.5,1.59)	0.99 (0.53,1.87)
2015	1.12 (0.67,1.89)	1.4 (0.81,2.4)
2016	1 (0.56,1.78)	1 (0.52,1.93)

Models adjusted for reporter type (where appropriate), season and harvesting
Population offset included in the model
The number of actual cases on which each analysis is based is provided in Table B2 on page 77

Figure 6 **Relative risk by year (2016 estimate = 1), with 95% comparison intervals, contact urticaria**

a) EPIDERM, all reporters



b) EPIDERM, core reporters

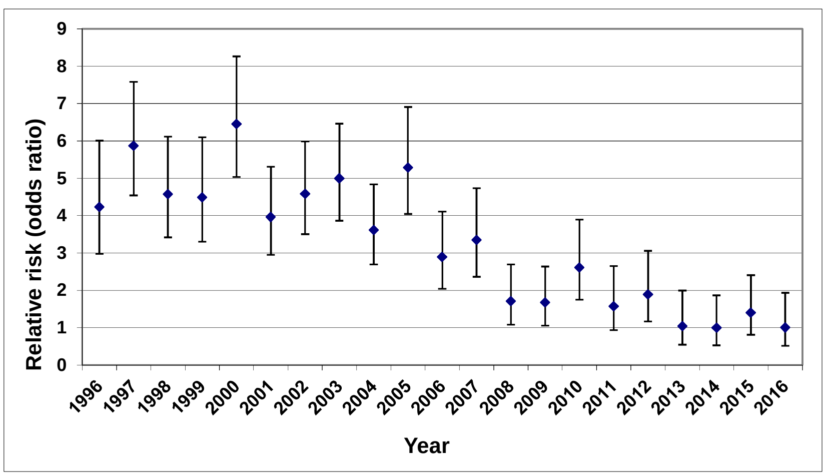


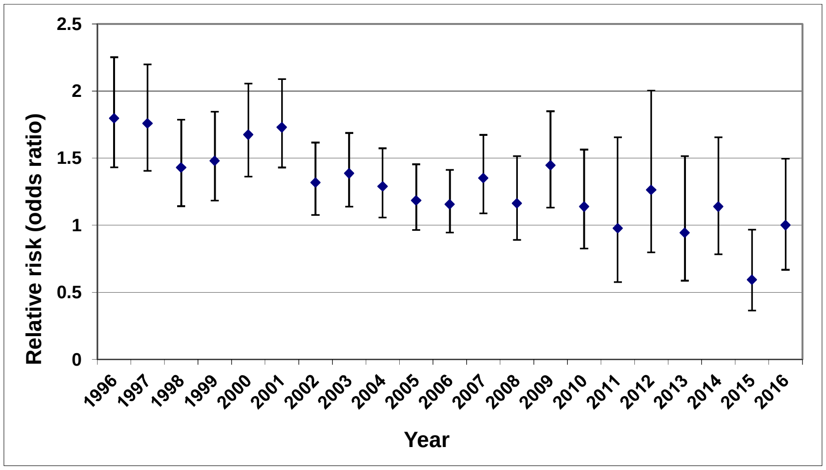
Table 11 **Relative risk by year, with 95% comparison intervals, neoplasia (2016 estimate = 1), as reported by dermatologists to EPIDERM**

	Relative risk (95% comparison interval)		
	All reporters	**Core reporters**	**Sample reporters**
YEAR			
1996	1.8 (1.43,2.25)	5.29 (4,7)	0.34 (0.14,0.85)
1997	1.76 (1.41,2.2)	4.83 (3.66,6.38)	1 (0.55,1.79)
1998	1.43 (1.14,1.79)	3.81 (2.89,5.03)	0.68 (0.38,1.22)
1999	1.48 (1.18,1.85)	4.33 (3.28,5.72)	0.51 (0.27,0.95)
2000	1.67 (1.36,2.06)	4.63 (3.55,6.05)	0.74 (0.44,1.24)
2001	1.73 (1.43,2.09)	4.44 (3.39,5.82)	1.24 (0.8,1.92)
2002	1.32 (1.08,1.62)	3.46 (2.63,4.53)	0.83 (0.48,1.44)
2003	1.39 (1.14,1.69)	3.7 (2.83,4.82)	0.77 (0.45,1.32)
2004	1.29 (1.06,1.57)	3.26 (2.48,4.27)	0.97 (0.61,1.55)
2005	1.18 (0.97,1.45)	3.29 (2.5,4.32)	0.57 (0.32,1.03)
2006	1.16 (0.95,1.41)	2.68 (2.04,3.51)	1.25 (0.85,1.84)
2007	1.35 (1.09,1.67)	3.38 (2.54,4.49)	1.2 (0.78,1.84)
2008	1.16 (0.89,1.52)	3.11 (2.25,4.29)	0.76 (0.42,1.35)
2009	1.45 (1.13,1.85)	3.27 (2.4,4.45)	1.33 (0.81,2.17)
2010	1.14 (0.83,1.56)	2.46 (1.62,3.74)	1.06 (0.63,1.77)
2011	0.98 (0.58,1.65)	1.41 (0.44,4.54)	0.84 (0.47,1.51)
2012	1.26 (0.8,2)	1.1 (0.27,4.58)	1.2 (0.74,1.93)
2013	0.94 (0.59,1.51)	1.09 (0.41,2.93)	0.78 (0.44,1.39)
2014	1.14 (0.78,1.66)	1.35 (0.72,2.56)	0.79 (0.44,1.42)
2015	0.59 (0.36,0.97)	0.5 (0.22,1.15)	0.82 (0.42,1.6)
2016	1 (0.67,1.5)	1 (0.54,1.86)	1 (0.53,1.88)

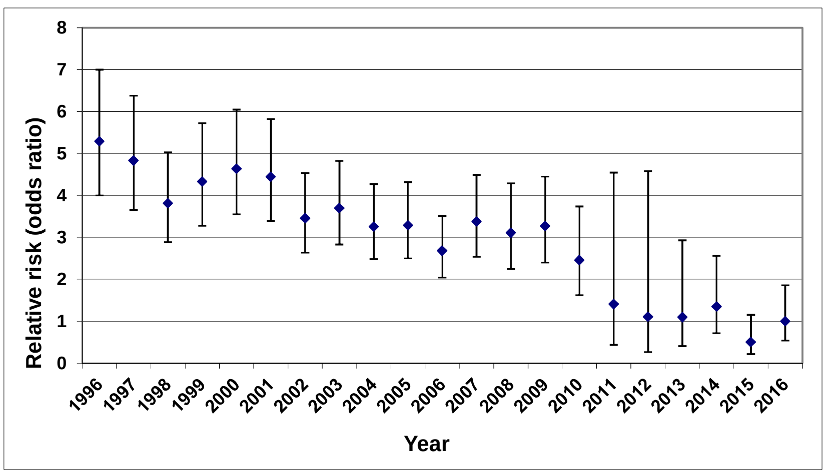
Models adjusted for reporter type (where appropriate), season and harvesting
Population offset included in the model
The number of actual cases on which each analysis is based is provided in Table B2 on page 77

Figure 7 **Relative risk by year (2016 estimate = 1), with 95% comparison intervals, neoplasia**

a) EPIDERM, all reporters



b) EPIDERM, core reporters (Note: scale change)



c) EPIDERM, sample reporters

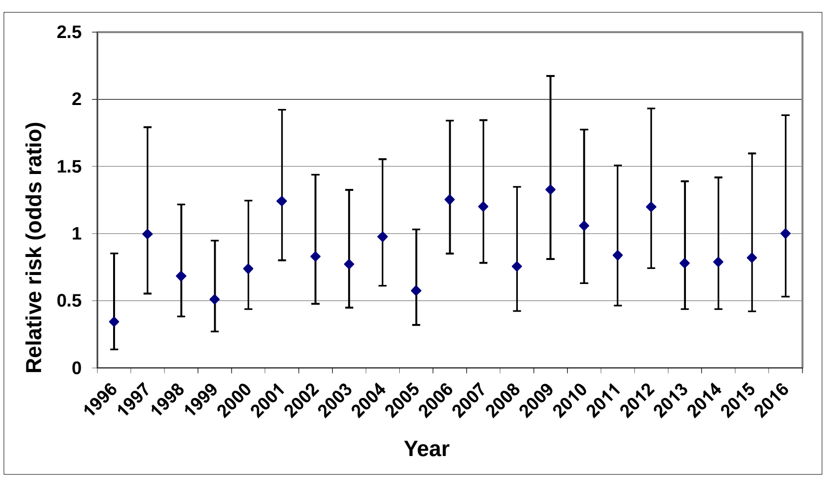


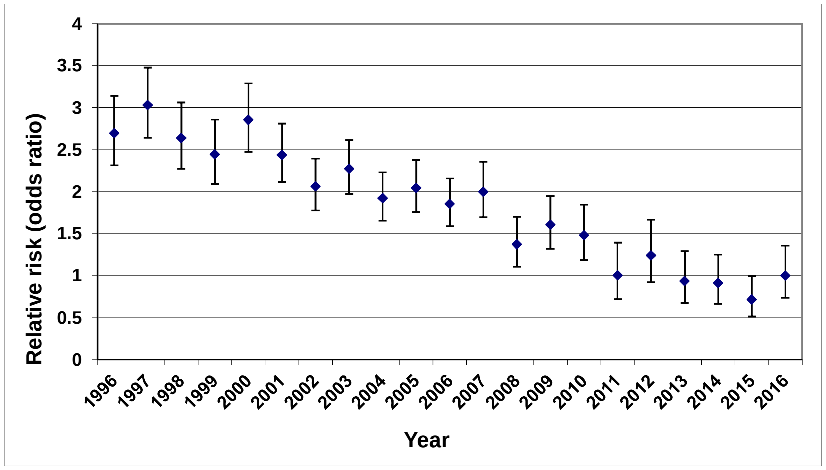
Table 12 **Relative risk by year, with 95% comparison intervals, other (than contact dermatitis) skin (2016 estimate = 1), as reported by dermatologists to EPIDERM**

	Relative risk (95% comparison interval)		
	All reporters	**Core reporters**	**Sample reporters**
YEAR			
1996	2.7 (2.31,3.14)	4.6 (3.88,5.46)	0.52 (0.28,0.98)
1997	3.03 (2.64,3.48)	4.87 (4.17,5.68)	1.07 (0.67,1.69)
1998	2.64 (2.27,3.06)	4.18 (3.56,4.9)	0.95 (0.64,1.42)
1999	2.44 (2.09,2.86)	4.06 (3.43,4.79)	0.76 (0.51,1.14)
2000	2.85 (2.47,3.29)	4.86 (4.19,5.64)	0.69 (0.45,1.05)
2001	2.44 (2.11,2.81)	3.79 (3.25,4.41)	1.06 (0.73,1.55)
2002	2.06 (1.78,2.39)	3.25 (2.78,3.8)	0.78 (0.5,1.23)
2003	2.27 (1.97,2.61)	3.69 (3.18,4.27)	0.66 (0.42,1.05)
2004	1.92 (1.65,2.23)	2.91 (2.47,3.42)	0.95 (0.65,1.39)
2005	2.04 (1.76,2.38)	3.39 (2.89,3.96)	0.6 (0.38,0.95)
2006	1.85 (1.59,2.16)	2.59 (2.17,3.08)	1.27 (0.92,1.73)
2007	2 (1.7,2.36)	3.09 (2.59,3.69)	1 (0.68,1.46)
2008	1.37 (1.1,1.7)	2.09 (1.66,2.64)	0.68 (0.42,1.12)
2009	1.6 (1.32,1.95)	2.26 (1.83,2.8)	1.12 (0.73,1.72)
2010	1.48 (1.18,1.85)	2.12 (1.65,2.72)	0.88 (0.55,1.41)
2011	1 (0.72,1.39)	1.13 (0.73,1.75)	0.82 (0.5,1.34)
2012	1.24 (0.92,1.67)	1.6 (1.1,2.33)	0.82 (0.52,1.32)
2013	0.93 (0.67,1.29)	1.15 (0.77,1.73)	0.64 (0.38,1.06)
2014	0.91 (0.67,1.25)	1.09 (0.75,1.6)	0.58 (0.34,1)
2015	0.71 (0.51,0.99)	0.76 (0.5,1.15)	0.66 (0.37,1.16)
2016	1 (0.74,1.36)	1 (0.69,1.45)	1 (0.62,1.62)

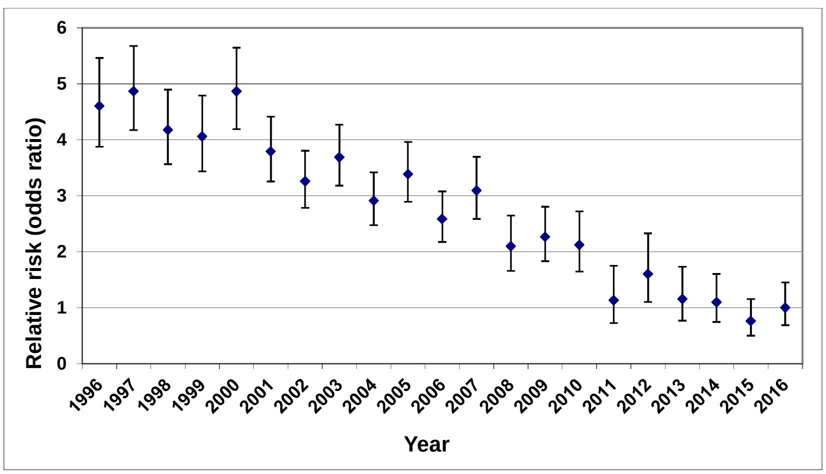
Models adjusted for reporter type (where appropriate), season and harvesting
Population offset included in the model
The number of actual cases on which each analysis is based is provided in Table B2 on page 77

Figure 8 **Relative risk by year (2016 estimate = 1), with 95% comparison intervals, skin (other than contact dermatitis)**

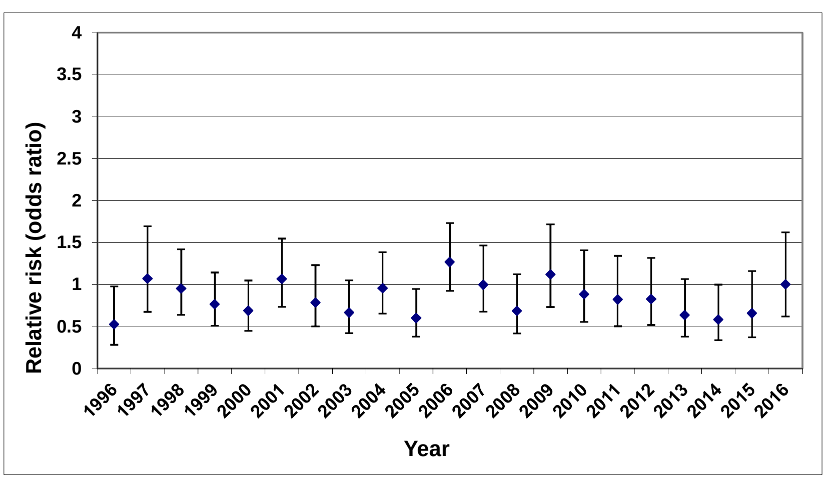
a) EPIDERM, all reporters



b) EPIDERM, core reporters (note scale change)



c) EPIDERM, sample reporters (note scale change)



3.2.2 WORK-RELATED RESPIRATORY DISEASE – CHEST PHYSICIANS

The average annual percentage change in risk of work-related respiratory disease, as reported by chest physicians to SWORD is shown in Table 13 whilst the relative rates by year are shown in Tables 14 to 21 and Figures 9 to 16.

The average annual percentage change in reported incidence of total respiratory disease (1999-2016) was -3.2% (95% CIs: -3.8, -2.5), showing little change to the previous estimate (1999-2015) of -3.1% (95% CIs: -3.8, -2.4). Similar to the pattern observed for total skin disease, the graphs (Figure 9) showing relative rates by year suggest that much of the decrease occurred in the earlier part of the study period (1996-2007 in this instance) with a relatively flat trend thereafter.

The annual average decrease in the incidence of asthma (1999-2016) was -6.8% (95% CIs: -7.9, -5.6). This compared to -7.0% (95% CIs: -8.2, -5.8) for the period 1999-2015. Figure 10 suggests a relatively flat trend since 2007 with some suggestion of an increase in incidence between 2015 and 2016 (although confidence intervals are wide and overlapping). Analyses of shorter-term trends (2007-2016) showed an average change of -2.3% (95% CIs: -5.3, 0.9) per year. An overall decrease in incidence was also observed for mesothelioma and non-malignant pleural disease at -3.7% (95% CIs: -4.9, -2.4) and -1.8 (95% CIs: -2.8, -0.8), respectively. For pneumoconiosis, an overall increase in incidence was observed at +3.4% (95% CIs: 1.5, 5.3). The graph showing relative rates by year (Figure 15) for pneumoconiosis suggests a relatively flat trend in the earlier part of the study period (1999 to 2007), followed by a general increasing trend until 2013 and then a relatively flat trend thereafter. Analysis of shorter term trends (2007 to 2016) for pneumoconiosis suggested an annual average increase of 8.2% (95% CIs: 4.1, 12.5). Overall there was little variation by reporter type (‘core’ and ‘sample’).

Adjusting the average annual percentage change in incidence of total work-related respiratory disease for the impact of reporter fatigue as implied by ‘excess zeros’ (using the ZINB model) would change the estimate -3.2% (95% CIs: -3.8, -2.5) to -2.1% (95% CIs: -2.7, -1.5).

Table 13 **Average annual percentage change in reported incidence in work-related respiratory disease as reported by chest physicians to SWORD**

		ESTIMATED % CHANGE (95% CONFIDENCE INTERVAL)		
		SWORD		
		All reporters	**Core reporters**	**Sample reporters**
	Year (continuous)			
Total respiratory	**1999-2016**	-3.2 (-3.8, -2.5)	-3.3 (-4.1, -2.5)	-2.7 (-3.8, -1.5)
	2007-2016	-3.0 (-4.5, -1.4)	-2.6 (-4.4, -0.7)	-3.7 (-6.5, -0.8)
Asthma	**1999-2016**	-6.8 (-7.9, -5.6)	-6.4 (-7.6, -5.1)	-8.9 (-11.7, -6.1)
	2007-2016	-2.3 (-5.3, 0.9)	-1.0 (-4.5, 2.6)	-11.1 (-18.9, -2.6)
Mesothelioma	**1999-2016**	-3.7 (-4.9, -2.4)	-4.0 (-5.8, -2.2)	-3.3 (-5.0, -1.5)
Non-malignant pleural disease	**1999-2016**	-1.8 (-2.8, -0.8)	-2.5 (-3.7, -1.3)	-0.2 (-2.0, 1.6)
• **Predominantly plaques**	**1999-2016**	-1.6 (-2.7, -0.4)	-2.5 (-3.8, -1.1)	0.5 (-1.6, 2.6)
• **Predominantly diffuse**	**1999-2016**	-1.8 (-3.6, 0.0)	-3.2 (-5.2, -1.1)	1.6 (-2.4, 5.8)
Pneumoconiosis	**1999-2016**	3.4 (1.5, 5.3)	4.2 (1.9, 6.5)	1.7 (-1.5, 5.1)
	2007-2016	8.2 (4.1, 12.5)	8.8 (3.9, 14.0)	7.1 (-0.9, 15.6)
Other* respiratory disease	**1999-2016**	-1.3 (-2.7, 0.2)	-1.3 (-3.0, 0.5)	-0.7 (-3.2, 2.0)

*Other than those specified above
Models adjusted for reporter type (where appropriate), season and harvesting
Population offset included in the model
The number of actual cases on which each analysis is based is provided in Table B4 on page 85

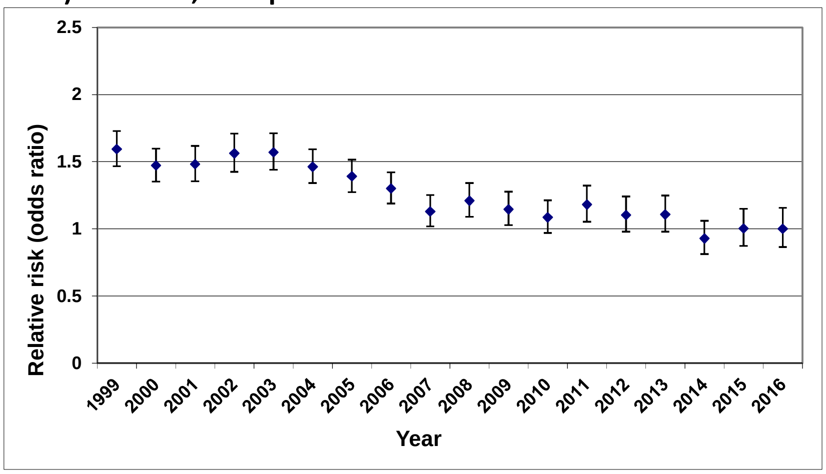
Table 14 **Relative risk by year, with 95% comparison intervals, total respiratory disease (2016 estimate = 1), as reported by chest physicians to SWORD**

	Relative risk (95% comparison interval)		
	All reporters	**Core reporters**	**Sample reporters**
YEAR			
1999	1.59 (1.47,1.73)	1.44 (1.3,1.6)	2.06 (1.75,2.43)
2000	1.47 (1.35,1.6)	1.37 (1.24,1.53)	1.77 (1.49,2.1)
2001	1.48 (1.35,1.62)	1.43 (1.3,1.59)	1.59 (1.32,1.91)
2002	1.56 (1.43,1.71)	1.56 (1.4,1.73)	1.53 (1.26,1.85)
2003	1.57 (1.44,1.71)	1.62 (1.47,1.78)	1.3 (1.06,1.59)
2004	1.46 (1.34,1.59)	1.49 (1.35,1.63)	1.3 (1.07,1.58)
2005	1.39 (1.27,1.52)	1.33 (1.21,1.47)	1.56 (1.3,1.87)
2006	1.3 (1.19,1.42)	1.21 (1.1,1.35)	1.58 (1.32,1.89)
2007	1.13 (1.02,1.25)	1.01 (0.89,1.14)	1.48 (1.23,1.79)
2008	1.21 (1.09,1.34)	1.09 (0.96,1.24)	1.5 (1.25,1.8)
2009	1.15 (1.03,1.28)	1.06 (0.93,1.21)	1.35 (1.11,1.65)
2010	1.08 (0.97,1.21)	1.03 (0.9,1.17)	1.2 (0.96,1.49)
2011	1.18 (1.05,1.32)	1.08 (0.95,1.24)	1.43 (1.17,1.76)
2012	1.1 (0.98,1.24)	1.04 (0.9,1.2)	1.26 (1.01,1.58)
2013	1.11 (0.98,1.25)	0.99 (0.85,1.15)	1.42 (1.16,1.75)
2014	0.93 (0.81,1.06)	0.82 (0.69,0.96)	1.22 (0.97,1.54)
2015	1 (0.87,1.15)	0.93(0.79,1.09)	1.22(0.95,1.57)
2016	1 (0.87,1.16)	1 (0.84,1.18)	1 (0.77,1.31)

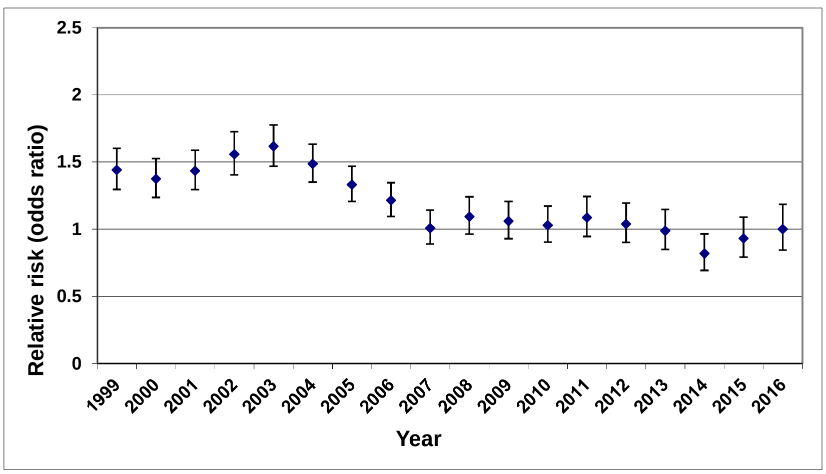
Models adjusted for reporter type (where appropriate), season and harvesting
Population offset included in the model
The number of actual cases on which each analysis is based is provided in Table B4 on page 85

Figure 9 **Relative risk by year (2016 estimate = 1), with 95% comparison intervals, total respiratory disease**

a) SWORD, all reporters



b) SWORD, core reporters



c) SWORD, sample reporters

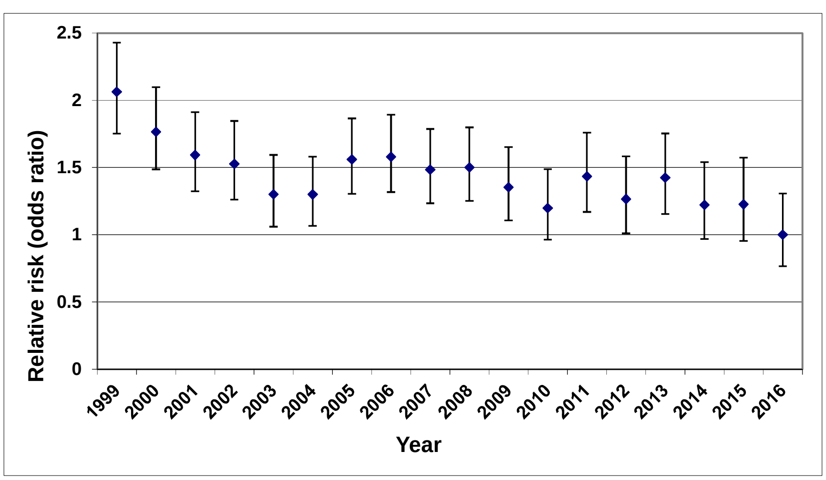


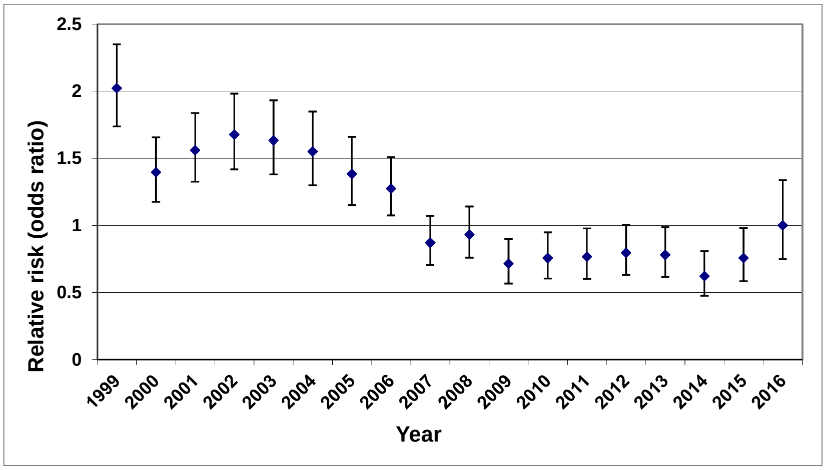
Table 15 **Relative risk by year, with 95% comparison intervals, asthma (2016 estimate = 1), as reported by chest physicians to SWORD**

	Relative risk (95% comparison interval)		
	All reporters	**Core reporters**	**Sample reporters**
YEAR			
1999	2.02 (1.74,2.35)	1.57 (1.33,1.87)	9.43 (6.78,13.11)
2000	1.4 (1.18,1.66)	1.08 (0.89,1.31)	6.34 (4.3,9.36)
2001	1.56 (1.32,1.84)	1.32 (1.11,1.57)	4.4 (2.73,7.07)
2002	1.68 (1.42,1.98)	1.42 (1.19,1.7)	4.62 (2.88,7.42)
2003	1.63 (1.38,1.93)	1.42 (1.18,1.7)	3.69 (2.21,6.16)
2004	1.55 (1.3,1.85)	1.36 (1.13,1.64)	3.22 (1.87,5.54)
2005	1.38 (1.15,1.66)	1.16 (0.94,1.41)	4.24 (2.66,6.74)
2006	1.27 (1.08,1.51)	1.03 (0.85,1.23)	5.63 (3.65,8.69)
2007	0.87 (0.71,1.07)	0.71 (0.56,0.89)	3.25 (1.87,5.63)
2008	0.93 (0.76,1.14)	0.75 (0.6,0.93)	3.98 (2.4,6.61)
2009	0.71 (0.57,0.9)	0.59 (0.46,0.76)	2.45 (1.27,4.74)
2010	0.76 (0.6,0.95)	0.62 (0.48,0.79)	2.9 (1.55,5.42)
2011	0.77 (0.6,0.98)	0.66 (0.51,0.85)	2.06 (0.98,4.36)
2012	0.8 (0.63,1)	0.66 (0.51,0.84)	2.84 (1.44,5.61)
2013	0.78 (0.62,0.99)	0.65 (0.5,0.84)	2.36 (1.17,4.76)
2014	0.62 (0.48,0.81)	0.51 (0.38,0.68)	2.26 (1.07,4.79)
2015	0.76(0.58,0.98)	0.7(0.53,0.91)	1.37(0.51,3.69)
2016	1 (0.75,1.34)	1 (0.73,1.37)	1 (0.32,3.13)

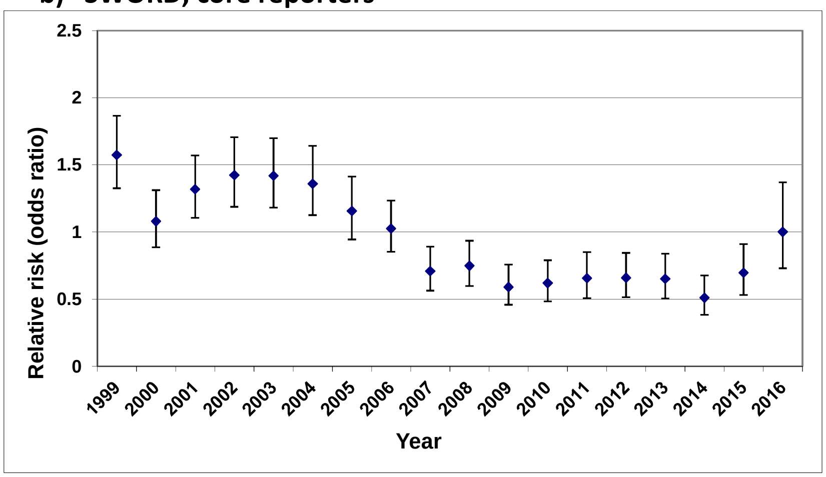
Models adjusted for reporter type (where appropriate), season and harvesting
Population offset included in the model
The number of actual cases on which each analysis is based is provided in Table B4 on page 85

Figure 10 **Relative risk by year (2016 estimate = 1), with 95% comparison intervals, asthma**

a) SWORD, all reporters



b) SWORD, core reporters



c) SWORD, sample reporters (note scale change)

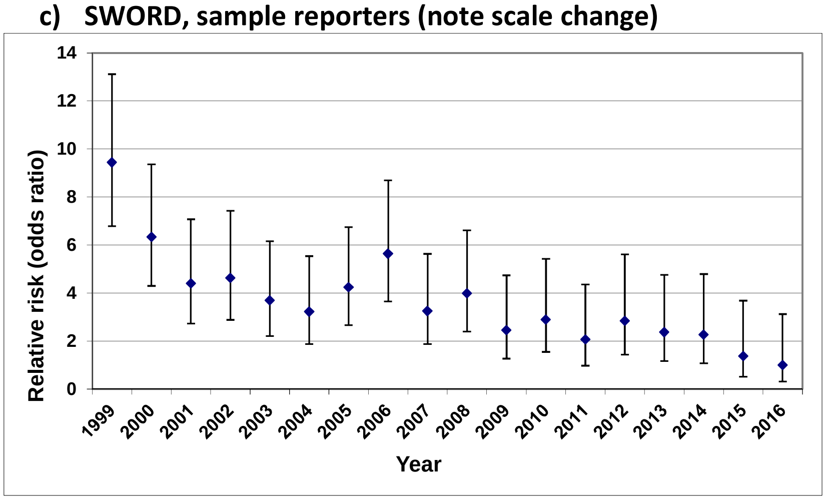


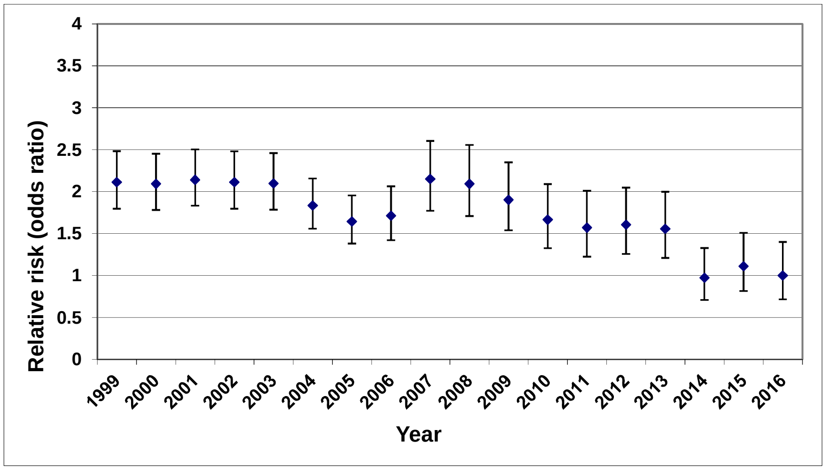
Table 16 **Relative risk by year, with 95% comparison intervals, mesothelioma (2016 estimate = 1), as reported by chest physicians to SWORD**

	Relative risk (95% comparison interval)		
	All reporters	**Core reporters**	**Sample reporters**
YEAR			
1999	2.11 (1.8,2.48)	1.98 (1.6,2.46)	2.4 (1.86,3.09)
2000	2.09 (1.78,2.45)	2.18 (1.78,2.67)	2.04 (1.56,2.67)
2001	2.14 (1.83,2.5)	2.16 (1.77,2.63)	2.23 (1.73,2.89)
2002	2.11 (1.8,2.48)	2.2 (1.8,2.7)	2.06 (1.56,2.73)
2003	2.1 (1.79,2.46)	2.27 (1.87,2.76)	1.86 (1.4,2.46)
2004	1.83 (1.56,2.16)	2.03 (1.67,2.47)	1.56 (1.15,2.12)
2005	1.64 (1.38,1.96)	1.72 (1.39,2.13)	1.58 (1.18,2.12)
2006	1.71 (1.42,2.06)	1.93 (1.52,2.44)	1.49 (1.09,2.04)
2007	2.15 (1.77,2.6)	2.13 (1.62,2.82)	2.19 (1.69,2.85)
2008	2.09 (1.71,2.56)	2.72 (2.08,3.58)	1.58 (1.17,2.15)
2009	1.9 (1.54,2.35)	2.28 (1.73,3.02)	1.54 (1.11,2.14)
2010	1.66 (1.32,2.09)	1.77 (1.3,2.41)	1.6 (1.15,2.22)
2011	1.57 (1.22,2.01)	1.81 (1.3,2.51)	1.37 (0.95,1.97)
2012	1.61 (1.26,2.05)	1.41 (0.98,2.04)	1.86 (1.35,2.56)
2013	1.56 (1.21,2)	1.27 (0.84,1.9)	1.88 (1.37,2.57)
2014	0.97 (0.71,1.33)	0.82 (0.5,1.33)	1.17 (0.77,1.78)
2015	1.11(0.82,1.51)	0.89(0.55,1.42)	1.43(0.95,2.15)
2016	1 (0.71,1.4)	1 (0.61,1.63)	1 (0.62,1.6)

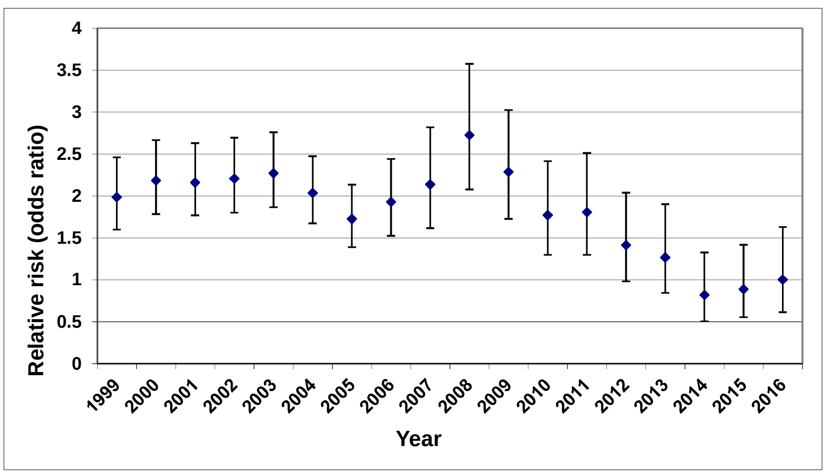
Models adjusted for reporter type (where appropriate), season and harvesting
Population offset included in the model
The number of actual cases on which each analysis is based is provided in Table B4 on page 85

Figure 11 Relative risk by year (2016 estimate = 1), with 95% comparison intervals, mesothelioma

a) SWORD, all reporters



b) SWORD, core reporters



c) SWORD, sample reporters

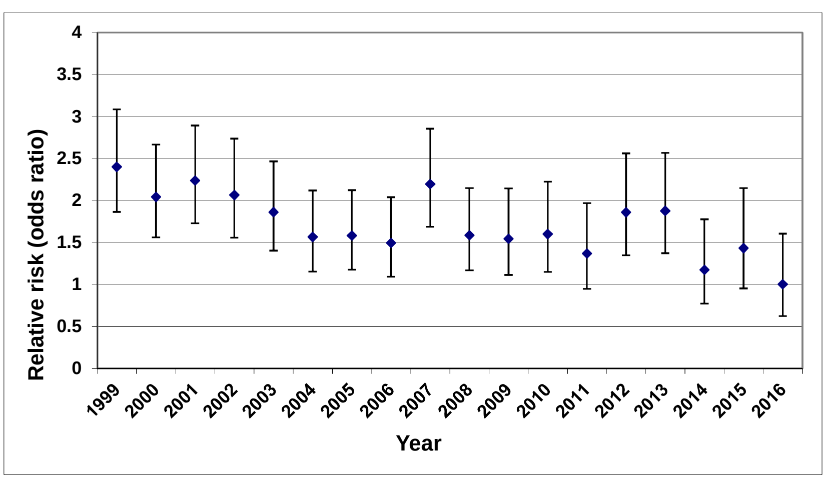


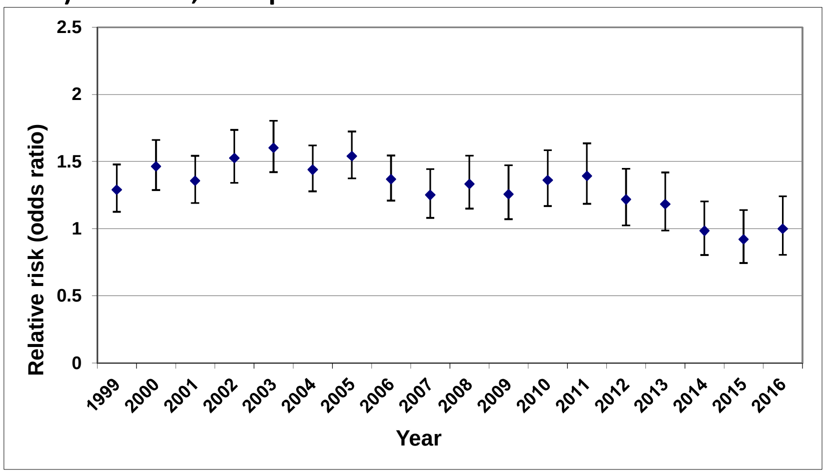
Table 17 **Relative risk by year, with 95% comparison intervals, benign pleural plaques (2016 estimate = 1), as reported by chest physicians to SWORD**

	Relative rates (95% comparison interval)		
	All reporters	Core reporters	Sample reporters
YEAR			
1999	1.29 (1.13,1.48)	1.34 (1.15,1.57)	1.42 (1.06,1.9)
2000	1.46 (1.29,1.66)	1.59 (1.38,1.84)	1.32 (0.99,1.76)
2001	1.36 (1.19,1.54)	1.56 (1.36,1.79)	0.92 (0.65,1.31)
2002	1.53 (1.34,1.74)	1.75 (1.52,2.01)	1.07 (0.76,1.5)
2003	1.6 (1.42,1.8)	1.83 (1.62,2.08)	1.05 (0.76,1.47)
2004	1.44 (1.28,1.62)	1.6 (1.41,1.82)	1.13 (0.83,1.54)
2005	1.54 (1.38,1.72)	1.61 (1.42,1.82)	1.7 (1.32,2.19)
2006	1.37 (1.21,1.55)	1.33 (1.15,1.53)	1.76 (1.37,2.26)
2007	1.25 (1.08,1.44)	1.28 (1.08,1.51)	1.3 (0.97,1.73)
2008	1.33 (1.15,1.54)	1.27 (1.06,1.53)	1.56 (1.2,2.02)
2009	1.26 (1.07,1.47)	1.25 (1.04,1.51)	1.31 (0.98,1.76)
2010	1.36 (1.17,1.59)	1.44 (1.21,1.71)	1.21 (0.88,1.66)
2011	1.39 (1.19,1.64)	1.41 (1.16,1.7)	1.41 (1.04,1.9)
2012	1.22 (1.03,1.45)	1.24 (1.01,1.52)	1.23 (0.88,1.71)
2013	1.18 (0.99,1.42)	1.18 (0.95,1.47)	1.21 (0.87,1.68)
2014	0.98 (0.8,1.2)	0.98 (0.77,1.24)	1.03 (0.71,1.5)
2015	0.92(0.74,1.14)	0.8(0.62,1.05)	1.29(0.9,1.85)
2016	1 (0.81,1.24)	1 (0.77,1.3)	1 (0.68,1.48)

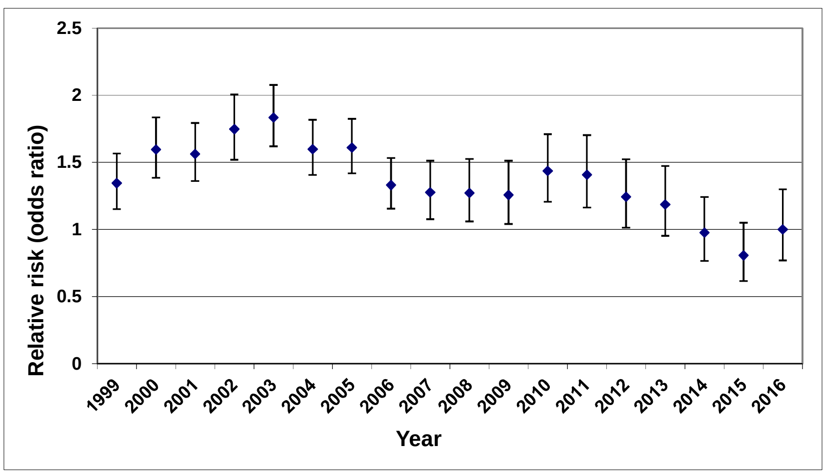
Models adjusted for reporter type (where appropriate), season and harvesting
Population offset included in the model
The number of actual cases on which each analysis is based is provided in Table B4 on page 85

Figure 12 Relative risk by year (2016 estimate = 1), with 95% comparison intervals, benign pleural plaques

a) SWORD, all reporters



b) SWORD, core reporters



c) SWORD, sample reporters

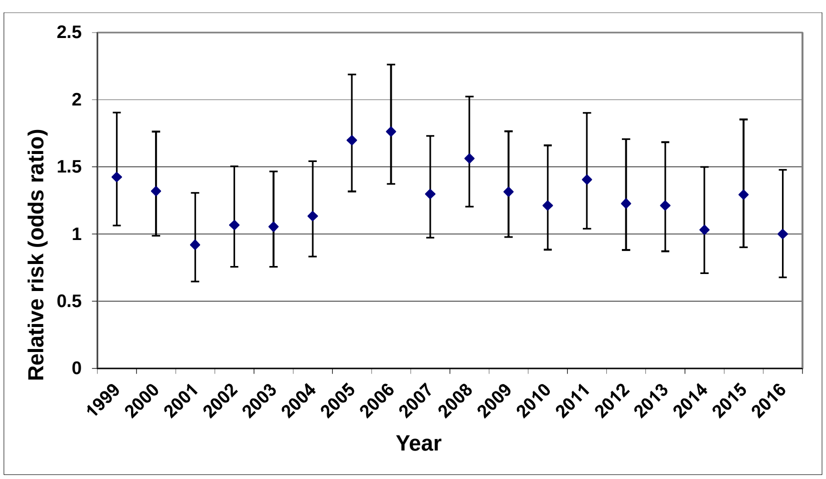


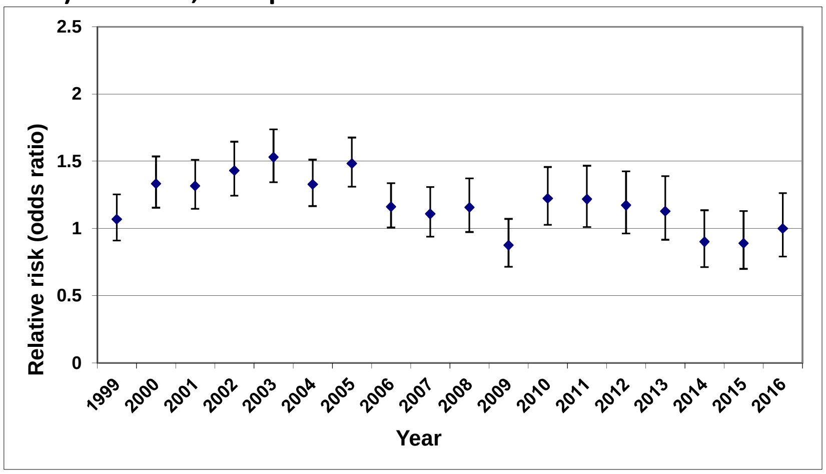
Table 18 **Relative risk by year, with 95% comparison intervals, benign pleural plaques – predominantly plaques (2016 estimate = 1), as reported by chest physicians to SWORD**

	Relative risk (95% comparison interval)		
	All reporters	**Core reporters**	**Sample reporters**
YEAR			
1999	1.07 (0.91,1.25)	1.2 (1.01,1.42)	0.75 (0.49,1.16)
2000	1.33 (1.16,1.54)	1.38 (1.18,1.62)	1.41 (1.03,1.94)
2001	1.32 (1.15,1.51)	1.43 (1.23,1.67)	1.12 (0.78,1.61)
2002	1.43 (1.24,1.64)	1.56 (1.34,1.82)	1.17 (0.81,1.68)
2003	1.53 (1.35,1.74)	1.66 (1.45,1.91)	1.25 (0.89,1.77)
2004	1.33 (1.17,1.51)	1.47 (1.28,1.69)	0.91 (0.62,1.34)
2005	1.48 (1.31,1.68)	1.5 (1.31,1.71)	1.82 (1.39,2.39)
2006	1.16 (1.01,1.34)	1.1 (0.94,1.3)	1.58 (1.18,2.11)
2007	1.11 (0.94,1.31)	1.12 (0.93,1.35)	1.16 (0.83,1.64)
2008	1.16 (0.97,1.37)	1.15 (0.94,1.4)	1.23 (0.88,1.71)
2009	0.88 (0.72,1.07)	0.98 (0.79,1.23)	0.57 (0.35,0.93)
2010	1.22 (1.03,1.46)	1.22 (0.99,1.49)	1.3 (0.92,1.85)
2011	1.22 (1.01,1.47)	1.23 (0.98,1.53)	1.21 (0.84,1.75)
2012	1.17 (0.96,1.43)	1.13 (0.9,1.43)	1.36 (0.95,1.95)
2013	1.13 (0.92,1.39)	1.06 (0.83,1.37)	1.34 (0.94,1.91)
2014	0.9 (0.71,1.14)	0.81 (0.6,1.08)	1.18 (0.79,1.77)
2015	0.89(0.7,1.13)	0.72(0.53,0.98)	1.48(1,2.18)
2016	1 (0.79,1.26)	1 (0.76,1.32)	1 (0.64,1.57)

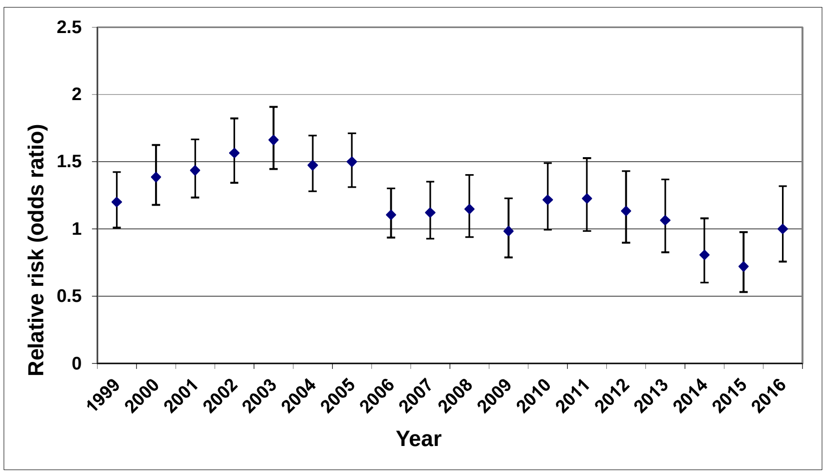
Models adjusted for reporter type (where appropriate), season and harvesting
Population offset included in the model
The number of actual cases on which each analysis is based is provided in Table B4 on page 85

Figure 13 Relative risk by year (2016 estimate = 1), with 95% comparison intervals, benign pleural plaques – predominantly plaques

a) SWORD, all reporters



b) SWORD, core reporters



c) SWORD, sample reporters

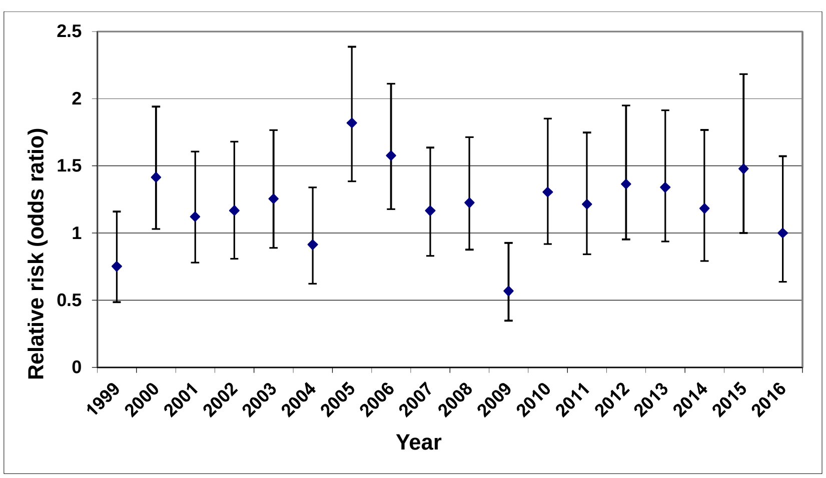


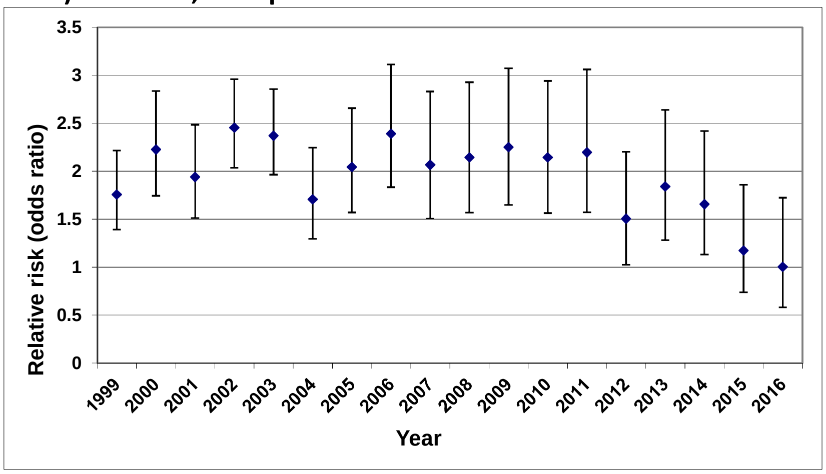
Table 19 **Relative risk by year, with 95% comparison intervals, benign pleural plaques – predominantly diffuse (2016 estimate = 1), as reported by chest physicians to SWORD**

	Relative risk (95% comparison interval)		
	All reporters	**Core reporters**	**Sample reporters**
YEAR			
1999	1.76 (1.39,2.22)	2.51 (1.91,3.29)	1 (0.41,2.43)
2000	2.22 (1.74,2.83)	3.2 (2.52,4.08)	0.91 (0.38,2.21)
2001	1.94 (1.51,2.48)	2.77 (2.15,3.58)	0.75 (0.28,2.01)
2002	2.45 (2.04,2.96)	3.41 (2.67,4.36)	1.52 (0.72,3.2)
2003	2.37 (1.96,2.85)	3.34 (2.63,4.24)	1.13 (0.51,2.52)
2004	1.7 (1.29,2.25)	2.49 (1.92,3.23)	0.52 (0.17,1.64)
2005	2.04 (1.57,2.66)	2.62 (2.02,3.39)	2.4 (1.35,4.29)
2006	2.39 (1.83,3.11)	2.64 (2.02,3.46)	3.21 (1.98,5.2)
2007	2.06 (1.5,2.83)	2.19 (1.55,3.08)	2.48 (1.43,4.3)
2008	2.14 (1.57,2.93)	2.28 (1.62,3.21)	2.58 (1.52,4.38)
2009	2.25 (1.65,3.07)	2.39 (1.71,3.33)	2.98 (1.76,5.05)
2010	2.14 (1.56,2.94)	2.92 (2.16,3.94)	0.6 (0.19,1.88)
2011	2.19 (1.57,3.06)	2.51 (1.77,3.57)	2.24 (1.16,4.3)
2012	1.5 (1.03,2.2)	1.93 (1.32,2.81)	0.81 (0.26,2.51)
2013	1.84 (1.28,2.64)	2.14 (1.46,3.13)	1.77 (0.87,3.61)
2014	1.65 (1.13,2.42)	1.99 (1.35,2.95)	1.21 (0.5,2.9)
2015	1.17(0.74,1.86)	1.41(0.87,2.27)	0.8(0.25,2.51)
2016	1 (0.58,1.72)	1 (0.52,1.93)	1 (0.37,2.71)

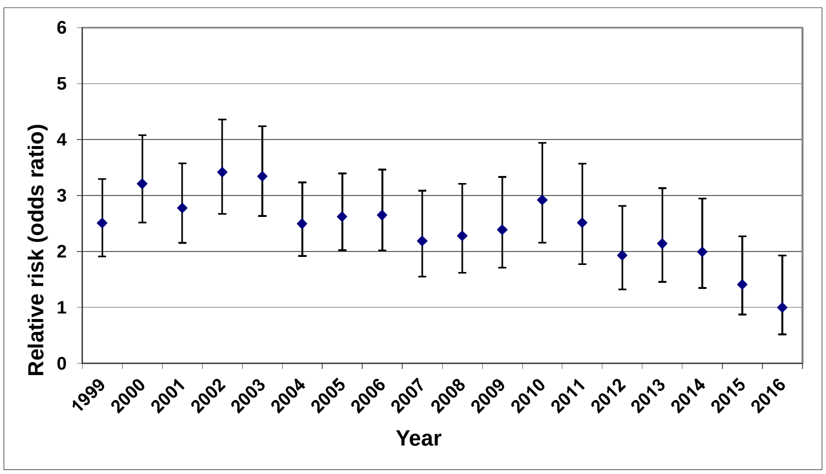
Models adjusted for reporter type (where appropriate), season and harvesting
Population offset included in the model
The number of actual cases on which each analysis is based is provided in Table B4 on page 85

Figure 14 Relative risk by year (2016 estimate = 1), with 95% comparison intervals, benign pleural plaques – predominantly diffuse

a) SWORD, all reporters



b) SWORD, core reporters (note scale change)



c) SWORD, sample reporters

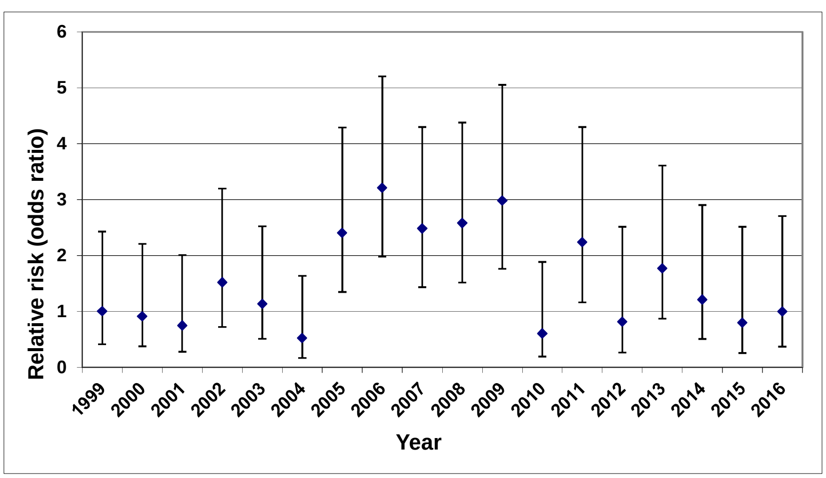


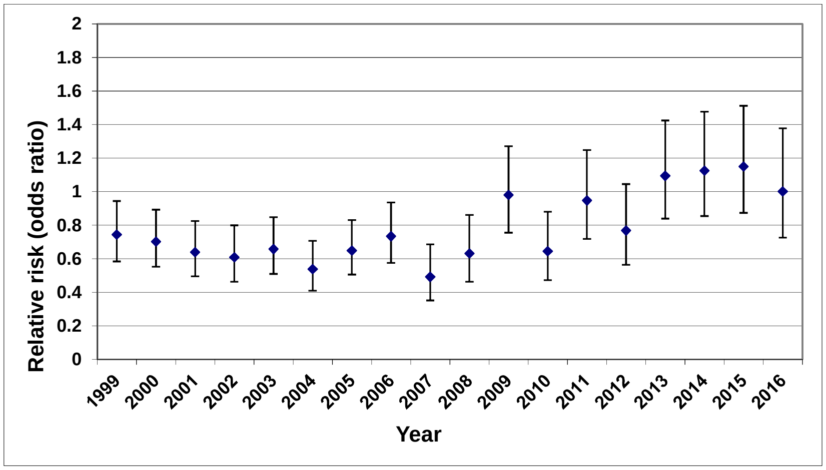
**Table 20	Relative risk by year, with 95% comparison intervals, pneumoconiosis (2016 estimate = 1), as reported by chest physicians to SWORD**

	Relative risk (95% comparison interval)		
	All reporters	Core reporters	Sample reporters
YEAR			
1999	0.74 (0.58,0.94)	0.57 (0.43,0.76)	1.62 (1.04,2.54)
2000	0.7 (0.55,0.89)	0.62 (0.47,0.81)	1.01 (0.58,1.78)
2001	0.64 (0.5,0.82)	0.52 (0.38,0.7)	1.27 (0.76,2.12)
2002	0.61 (0.46,0.8)	0.58 (0.43,0.78)	0.53 (0.24,1.18)
2003	0.66 (0.51,0.85)	0.62 (0.47,0.82)	0.61 (0.29,1.28)
2004	0.54 (0.41,0.71)	0.54 (0.4,0.72)	0.3 (0.11,0.81)
2005	0.65 (0.51,0.83)	0.58 (0.44,0.77)	0.89 (0.5,1.6)
2006	0.73 (0.57,0.94)	0.69 (0.53,0.9)	0.86 (0.47,1.57)
2007	0.49 (0.35,0.69)	0.39 (0.26,0.59)	0.9 (0.51,1.6)
2008	0.63 (0.46,0.86)	0.56 (0.39,0.81)	0.92 (0.51,1.67)
2009	0.98 (0.76,1.27)	0.97 (0.72,1.29)	0.92 (0.5,1.71)
2010	0.64 (0.47,0.88)	0.65 (0.46,0.91)	0.57 (0.26,1.26)
2011	0.95 (0.72,1.25)	0.86 (0.62,1.19)	1.31 (0.76,2.25)
2012	0.77 (0.56,1.04)	0.71 (0.5,1.01)	0.98 (0.51,1.9)
2013	1.09 (0.84,1.42)	0.97 (0.71,1.34)	1.57 (0.96,2.57)
2014	1.12 (0.85,1.48)	0.93 (0.66,1.31)	1.89 (1.17,3.05)
2015	1.15(0.87,1.51)	1.14(0.84,1.56)	1.29(0.7,2.36)
2016	1 (0.73,1.38)	1 (0.69,1.46)	1 (0.5,1.99)

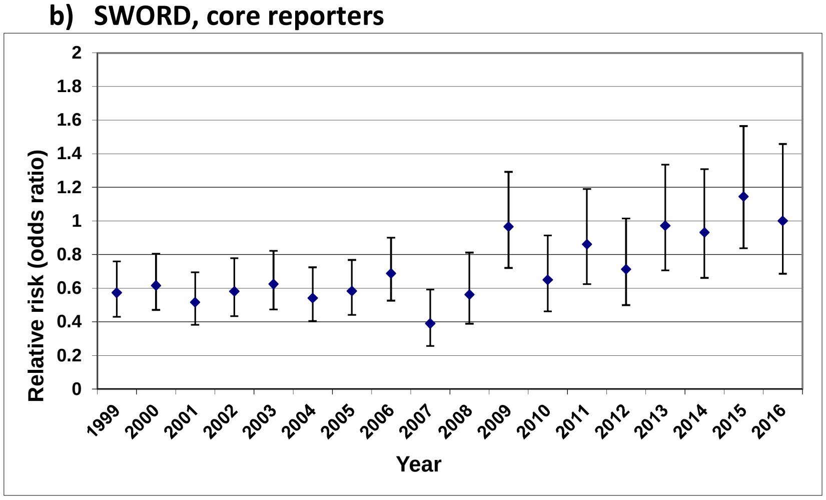
Models adjusted for reporter type (where appropriate), season and harvesting
Population offset included in the model
The number of actual cases on which each analysis is based is provided in Table B4 on page 85

Figure 15 **Relative risk by year (2016 estimate = 1), with 95% comparison intervals, pneumoconiosis**

a) SWORD, all reporters



b) SWORD, core reporters



c) SWORD, sample reporters (note scale change)

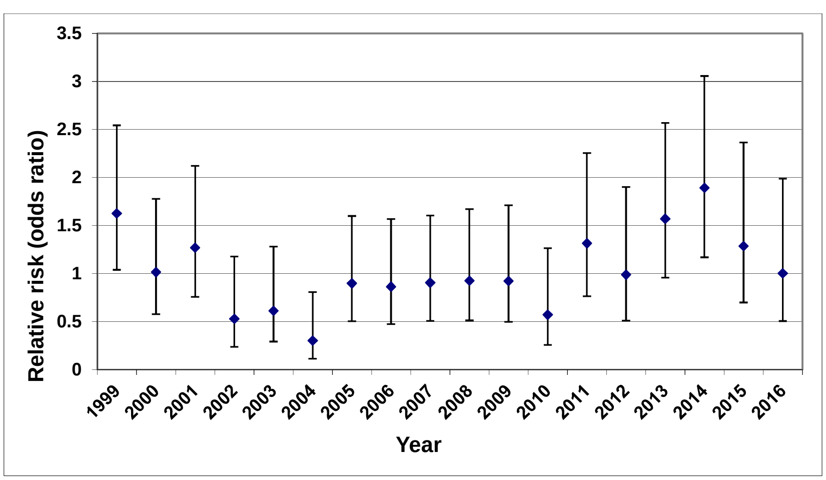


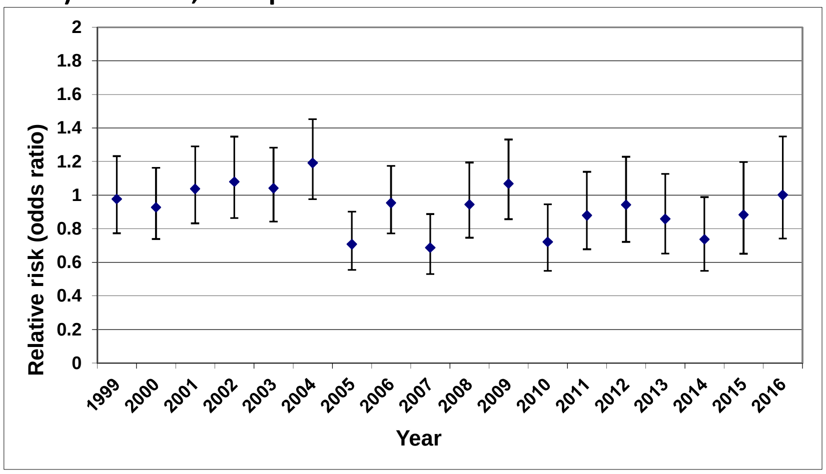
Table 21 **Relative risk by year, with 95% comparison intervals, other (than those investigated separately) respiratory disease (2016 estimate = 1), as reported by chest physicians to SWORD**

	Relative risk (95% comparison interval)		
	All reporters	**Core reporters**	**Sample reporters**
YEAR			
1999	0.98 (0.77,1.23)	1.03 (0.79,1.36)	0.75 (0.47,1.21)
2000	0.93 (0.74,1.16)	0.88 (0.67,1.16)	1.04 (0.69,1.56)
2001	1.04 (0.83,1.29)	1.02 (0.79,1.33)	1.07 (0.71,1.61)
2002	1.08 (0.86,1.35)	1.17 (0.91,1.52)	0.78 (0.49,1.25)
2003	1.04 (0.84,1.28)	1.12 (0.88,1.42)	0.82 (0.52,1.31)
2004	1.19 (0.98,1.45)	1.32 (1.05,1.65)	0.87 (0.56,1.35)
2005	0.71 (0.55,0.9)	0.73 (0.55,0.97)	0.68 (0.41,1.12)
2006	0.95 (0.77,1.18)	1.06 (0.84,1.34)	0.65 (0.39,1.09)
2007	0.69 (0.53,0.89)	0.71 (0.52,0.96)	0.62 (0.37,1.04)
2008	0.94 (0.75,1.19)	1.03 (0.79,1.34)	0.75 (0.46,1.23)
2009	1.07 (0.86,1.33)	1.07 (0.83,1.4)	1.02 (0.67,1.56)
2010	0.72 (0.55,0.95)	0.84 (0.63,1.13)	0.4 (0.2,0.8)
2011	0.88 (0.68,1.14)	0.74 (0.53,1.04)	1.26 (0.83,1.93)
2012	0.94 (0.72,1.23)	1.12 (0.84,1.5)	0.5 (0.26,0.97)
2013	0.86 (0.65,1.13)	0.78 (0.55,1.12)	0.99 (0.63,1.55)
2014	0.74 (0.55,0.99)	0.76 (0.54,1.08)	0.74 (0.42,1.31)
2015	0.88(0.65,1.2)	1.02(0.72,1.45)	0.61(0.32,1.18)
2016	1 (0.74,1.35)	1 (0.68,1.46)	1 (0.61,1.63)

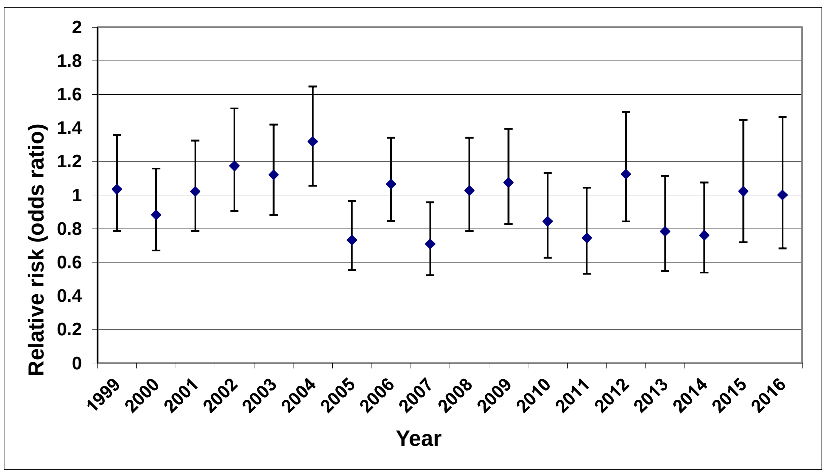
Models adjusted for reporter type (where appropriate), season and harvesting
Population offset included in the model
The number of actual cases on which each analysis is based is provided in Table B4 on page 85

Figure 16 Relative risk by year (2016 estimate = 1), with 95% comparison intervals, other (than those investigated separately) respiratory disease

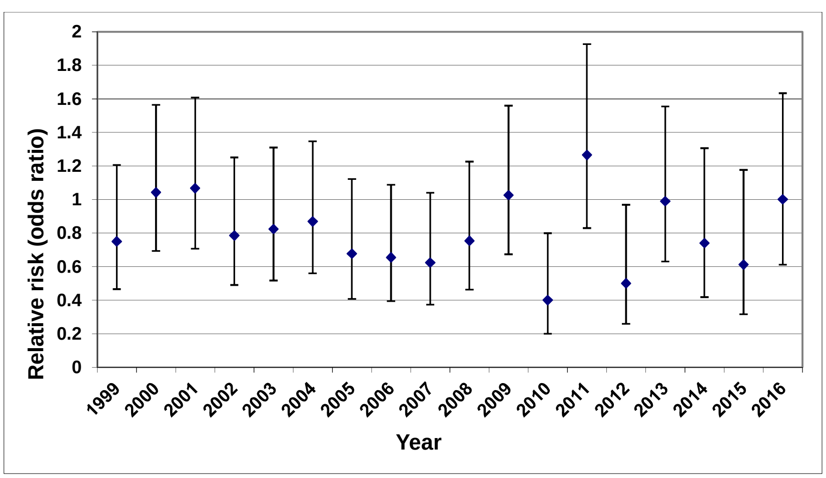
a) SWORD, all reporters



b) SWORD, core reporters



c) SWORD, sample reporters



4 DISCUSSION

This report describes temporal trends in the incidence of WRI in the UK as reported to the two constituent schemes of the occupational surveillance system THOR which were funded by HSE for data collection during 2016. These schemes were EPIDERM (dermatologists) and SWORD (chest physicians). The report updates on previous reports submitted to HSE[2-12] by the incorporation of a further year (2016) of data. The method employed has been described in full in both the current and preceding reports. Essentially, a longitudinal, negative binomial (i.e. over-dispersed) Poisson model with random effects was fitted to the data. This enabled change over time in the number of reporters and in other reporter characteristics which could independently impact on case density to be taken into account.

Therefore, one of the main methodological challenges with this body of work has been the impact of reporter 'fatigue' (i.e. a reporter may lose interest in reporting over time but still retain membership), how this manifests and whether it can be adjusted for. An extensive body of work has been undertaken to investigate this issue, details of which are provided in previous reports. The culmination of this work was an investigation of whether fatigue may be manifesting as an excess of zero reports in the data, and whether the proportion of 'excess zeros' has increased the longer a reporter has participated in the scheme, and this work has now been published in the peer reviewed literature[19]. The results of these investigations suggested that for both EPIDERM and SWORD, there is some evidence of fatigue manifesting in this way but that the magnitude is different for the two schemes and tended to be greater for sample compared to core reporters. It was previously agreed with HSE, that the trend estimates presented in the annual reports would not be formally adjusted for fatigue until after the methodology has been through the peer review process. As this has now happened, this report is the first annual trends report to include an adjustment to the estimate of the average annual change in incidence. As discussed previously, this has been provided for total skin disease and total respiratory disease only.

An abridged commentary by category of illness is provided in the following sections.

SKIN (EPIDERM): Data reported to EPIDERM by dermatologists currently provide the only HSE funded source of THOR data on skin disease with approximately 19300 actual cases reported in the period 1996-2016. Trends based on data collected by the two other THOR schemes collecting reports of work-related skin disease - THOR-GP (GPs) and OPRA (occupational physicians) - are not currently reported but have been documented previously[2-12]. Reports from dermatologists suggest an average, annual decrease in incidence of total work-related skin disease of 4%. As previously reported, this estimate has remained fairly constant (3-4%) since trends were first reported (for the period 1996-2004). The annual plots suggest some variation from year to year with an initial decrease in incidence (1996-2007) followed by a levelling out (2007-2012) and then a further drop between 2012 and 2016. Investigations of fatigue have suggested it is present (manifesting as an increase in zeros over membership time) in both EPIDERM 'core' and 'sample' reporters, but that it appears to be more extensive in the latter. This could be because 'sample' reporters may be less committed to the scheme or have less sophisticated systems than the 'core' reporters who tend to have a strong interest in the area and who tend to work in larger referral centres. Since 'sample' reporters contribute less data overall compared to 'core' reporters (12%), the impact of adjusting the overall estimate for fatigue is relatively small, changing the annual, average decrease from 4% to 3% per year.

As reported previously, the observed trend for dermatologist reported CD was very similar to that observed for total skin disease at an annual average decrease of 3.9%. Analysis of shorter-term trends (2006-2016) also suggested a very similar average, annual decrease in incidence of 4.1% with the annual plots continuing to suggest a relatively flat trend since 2013.

Although the overall trend is small but significant downward, and therefore favourable, even when taking 'reporter fatigue' into account, it may hide or be blunted by adverse i.e. increasing trends in incidence in specific contexts. Therefore, in addition to investigating CD trends overall, we have continued to apply the MLM methodology (or an adaptation of) to investigate change in incidence of CD related to specific agents or economic sectors[24-29]. In doing so we have shown that whilst the incidence of dermatologist reported CD may be falling overall, the extent to which it is falling may vary between workers and for certain groups with specific exposures, it may even be increasing. The most recent application of this methodology has been to investigate trends in incidence of allergic CD attributed to fragrances in different groups of potentially exposed workers (for example, healthcare, beauty, food and cleaners)[29]. Although the results of this study suggested there was no significant change in incidence of fragrance related allergic CD during the twenty-year study period, the observed trends were statistically significantly different to the overall (declining) trend for allergic CD. This effect was seen for industry overall and then for the health and social care sector and the food industry but not for the beauty industry.

Other examples whereby this methodology has been used to investigate the effectiveness of interventions aimed at reducing the incidence of work-related CD include CD in healthcare workers attributed to latex and in cement workers attributed to chromate, for both of which a reduction in incidence was shown in response to specific Government interventions aimed at reducing exposure to these agents)[24, 25]. Conversely, however, we have also shown an increase in irritant CD amongst healthcare workers attributed to increased handwashing as a result of interventions aimed at reducing healthcare associated infections[28]. Reports to EPIDERM have also suggested an increase in incidence of CD in nail technicians attributed to acrylates, and in healthcare workers attributed to isothiazolinoes[26-

[27]. Initial investigations are also underway to investigate the impact of the HSE's 'Bad Hand Day campaign' on CD incidence amongst hairdressers.

Importantly, it is anticipated that this methodology will be a useful tool in addressing the research priorities highlighted within the HSE Sector strategies[30]. It is proposed that the MLM (and other) methodology could be utilised to determine incidence, trends in incidence and to evaluate intervention strategies within these specific sectors. In general, rather than (or in addition to) COEH determining which topics are most important, HSE could identify specific campaigns, interventions of interest, and (if feasible) this methodology can be applied to help evaluate their effectiveness.

Analysis by type of CD, continue to suggest an overall larger decrease for allergic CD (compared to irritant and mixed allergic/irritant). However, the graphs showing the annual variation suggest that whilst the incidence of allergic CD has remained relatively unchanged since 2012, the incidence of irritant CD appears to have been declining over the same period. If taken at face value these findings may suggest that (besides the beneficial trends in allergic CD caused by the aforementioned Government interventions (UK/EU) aimed at reducing allergic CD attributed to specific agents as mentioned above) there are now favourable reductions in trends of irritant CD. However these findings warrant cautious interpretation as various biases could be at play. For instance if there is pressure on NHS referrals to our EPIDERM reporters and these are differentially restricted in favour of cases needing specialist patch testing. These and other possible explanations continue to be investigated further.

A statistically significant annual average decrease in incidence continues to be observed for dermatologist reported contact urticaria which is larger than that seen for CD at approximately 7% per year. As reported previously, markedly different trends were observed for 'core' and 'sample' reporters, with 'core' data suggesting a decrease in incidence and 'sample' data suggesting no change. Furthermore, if EPIDERM 'sample' reporters are experiencing greater fatigue than 'core' reporters (shown for total skin disease) then the disparity between the 'core' and 'sample' trend estimates may become even larger.

A disparity between 'core' and 'sample' trends for neoplasia was also observed with a decrease in incidence suggested by reports from 'core' reporters and an increase in incidence suggested by reports from 'sample' reporters. However, for neoplasia, the confidence intervals for the annual plots are wide and overlapping for both 'core' and 'sample' reporters, suggesting that EPIDERM in general may not be particularly capturing these cases.

There have been a number of discussions between COEH, key EPIDERM reporters and the

HSE regarding the effectiveness of EPIDERM as a data source for neoplasia. Most recently this was at the 2017 EPIDERM Academic Advisory Committee Meeting and subsequently at the August 2017 Steering Meeting between HSE and COEH. The main topic of discussion was whether there is a wish (specifically from HSE) to improve the ability of EPIDERM to capture this diagnosis through a targeted recruitment drive of dermatologists specialising in skin cancer and if so how would this be accomplished/supported. However, following feedback from HSE it has been decided not to pursue this specific recruitment of skin oncologists. One of the strengths of THOR is the associated information on causal agent, however neoplasia diagnoses are predominantly attributed to UV sunlight. A second issue is the difficulty of ascertaining work attribution. Additionally, HSE stated that they have a good source of information on work-related neoplasia in the work carried out by Lesley Rushton (based on the attributable fraction)[31]. However, to avoid the risk of losing reporters/impacting on the reporting of other diagnoses, for example CD, and to enable novel (non UV) causes of work-related neoplasia to continue to be captured, it was agreed that the option to report neoplasia to EPIDERM would remain.

Trends based on reports to EPIDERM have been compared with trends suggested by the Self-reported Work-related Illness (SWI) survey, conducted annually as part of the Labour Force Survey (LFS)[32]. Reports to the SWI also suggest a decline in incidence (of skin problems) over time from 33 per 100,000 (for the 3-year averaging period of 2006/7 to 2008/9) to 22 per 100,000 (2009/10 to 2011/12) to 20 per 100,000 (2013/14 to 2015/16)[33]. As previously reported, THOR derived CD trends have also been compared with trends for other European countries as part of the work undertaken by the Modernet group (an EU wide network for development of new techniques for discovering trends in WRI and tracing new and emerging risks)[34]. The results showed a similarity in CD trends across the different countries, with data for most countries suggesting a decline in incidence.

RESPIRATORY (SWORD): Similar to EPIDERM, reports from chest physicians to SWORD are the only current HSE funded source of THOR data on trends in incidence for work-related respiratory disease with approximately 13000 actual cases reported 1999-2016. Unlike dermatologists the addition of each successive year of data appears to have had more of an impact on the trend estimate (from an initial 1% annual decrease in the first report submitted to HSE in 2006[2] to the 3% currently observed). As discussed previously, this probably reflects the fact that compared to EPIDERM (where reports are predominantly of CD and neoplasia, and have been throughout the study period), case reports to SWORD encompass a wider diagnostic range with the proportion of the total cases attributed to each diagnosis exhibiting some variation throughout the study period.

Investigations of reporter 'fatigue' (manifesting as an increase in zero cases reports over membership time) suggests some evidence of this phenomenon amongst SWORD 'sample' reporters but not amongst SWORD ‘core’ reporters (probably reflecting the strong commitment of stalwart ‘core’ SWORD reporters). As seen for EPIDERM, SWORD ‘sample’ reporters contribute proportionally less data than their ‘core’ counterparts (21%) thus the impact of ‘fatigue’ on the trend estimate for total respiratory disease is relatively small (a reduction in the annual, average decrease from approximately -3.2% to -2.1%).

The estimated average, annual decrease in asthma incidence was just under 7% per year (it has generally been between 7-8% with the addition of each successive year of data since 2010). The annual plots also suggest much of the decrease occurred in the earlier part of the period with a relatively flat trend since approximately 2007. There is some evidence that incidence has increased slightly since 2014 but the confidence intervals for the individual estimates are overlapping so it is difficult to draw any firm conclusions at this stage.

As with work-related skin disease, it is important to view these ‘overall’ changes in incidence in conjunction with the results from other studies investigating changes in incidence of WRI related to specific agents, Government interventions etc. Previous observations include a decline in asthma attributed to isocyanates or paint spraying (but a non-significant decline amongst motor vehicle repair workers)[35,] and a significant reduction in reports of asthma attributed to agents with a work exposure limit (WEL) relative to those without a WEL[36]. Conversely, a significant increase in the incidence of asthma attributed to flour (relative to other agents) was observed[37]. As noted previously, this is disappointing to note especially in view of longstanding attempts at dissemination of knowledge of asthma risks associated with flour and other substances involved in baking. It is anticipated that future applications of the MLM methodology to SWORD data will primarily focus on addressing the HSE Sector Strategy research priorities[30].

The SWI also collects data on work-related respiratory disease although they do not disaggregate beyond ‘breathing or lung problems’. The 3-year average SWI derived incidence rate for this group suggest a decline in incidence from 54 per 100,000 employed (2006/7 to 2008/9) to 42 per 100,000 employed (2009/10 to 2011/12) and then a slight increase to 43 per 100, 000 employed (2013/14 to 2015/16)[33]. Trends in asthma were also investigated by the Modernet consortium with the results suggesting similarities across the participating EU countries, with an overall decline in the incidence of asthma[34].

The majority (70%) of the diagnoses reported by chest physicians to SWORD are the (primarily) asbestos related diseases, namely, mesothelioma, benign pleural plaques and pneumoconiosis. For mesothelioma, an overall downward trend in incidence continues to be observed (of 3.7% per year). However, the trend appears to have been relatively flat over the last 3 years. Previously we have discussed how these observed trends are in contrast to evidence from other data sources such as epidemiological studies by Peto *et al* and the mesothelioma death registers which suggests that mesothelioma incidence has been rising over the same period with a possible peak expected in 2016 (although data from the mesothelioma death register suggests the peak may have occurred in 2013 with no further increase (yet) observed since this point) [38, 39]. Possible explanations for the apparent decline in SWORD derived mesothelioma incidence have been discussed previously[12]. In brief, changes in clinical practice/referral procedures are likely to have diluted the reporting of such cases to SWORD. For example, long-latency respiratory disease diagnoses such as mesothelioma that were previously seen by SWORD reporters may increasingly be seen by chest physicians specialising in lung cancer, who may not participate in SWORD. As discussed at the SWORD Advisory Committee, one approach to address this would be to approach lung cancer specialists and/or possibly the non-specialist physicians who organise and run the rapid access systems and ask them to report to SWORD.

An overall decrease in incidence (of 1.8%) was also observed for benign pleural disease but again the graphs showing relative rates by year suggest a relatively flat trend over the last three years. As discussed previously, this probably reflects the fact that individuals presenting with this abnormality alone (in England and Wales) are no longer financially compensated[40] and therefore, referrals to chest physicians are less common. Consultation with key chest physicians also suggests that patients with pleural effusions are increasingly managed within acute or general care and are therefore much less likely to have an occupational history taken or to be seen by a chest physician.

For pneumoconiosis, an overall increase in incidence was observed at approximately 3% per year. The graphs showing relative rates by year suggest much of this increase has occurred since 2007 (with an annual average increase of approximately 8% per year if restricted to this period). However, reports for the last four years suggest a relatively flat trend (although confidence intervals are fairly wide). Approximately 22% of the pneumoconiosis diagnoses reported to SWORD are attributed to agents other than asbestos (for example, silica and coal). Analysis of trends by specific agents (other than asbestos) is not possible due to insufficient case numbers to obtain any meaningful results. However a comparison of asbestos versus non-asbestos pneumoconiosis (not reported here) suggested the increase was due to asbestosis rather than ‘other’ pneumoconiosis. Both the data sources on compensation claims to the IIDB and those of cause of death (death certificates) also support an increase in asbestosis incidence during the study period[41, 42]. However, as discussed previously, part of the observed increase in asbestosis incidence may be due to changes to the diagnostic criteria (resulting in asbestosis being more readily diagnosed)[43].

5. CONCLUSIONS

This is the latest report to provide an estimation of trends in incidence of work-related illness using THOR data. The report builds upon previous annual reports, each of which not only update the trends estimates (with a further year of data) but also describe any ongoing methodological developments. A number of peer reviewed publications have arisen from this body of work, the latest of which describes the impact of reporter fatigue on the trend estimates. Overall, the observed trends have remained relatively unchanged with the addition of each successive year of data and are in accordance with those expected as a result of Government initiatives (for example, the general decline in incidence of asthma and contact dermatitis). However, others continue to show more variation (for example, the asbestos related diseases). We have also shown that trends related to specific sectors or agents often appear discordant with the 'overall' trends by manifesting an increase (for example asthma and flour or CD and handwashing), thus showing the value of THOR in identifying real and significant adverse or desired trends in relation to specific exposures. The current focus is on applying this methodology to investigate trends in incidence and the impact of interventions to reduce incidence with specific reference to those industries highlighted by the HSE in their sector strategies.

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APPENDIX A SUMMARY OF REPORTER FATIGUE INVESTIGATIONS

1) **The probability of a zero return as a function of membership time:** the percentage increase, per year of membership, in the *odds* of a returned card having zero cases was estimated. These analyses were initially carried out for SWORD (1999-2004) and EPIDERM (1996-2004) and subsequently for THOR-GP (June 2005-2008). Separate analyses were carried out for 'core' and 'sample' reporters (except for THOR-GP, which was exclusively core reporting during this period). These analyses sought to separate the true trend with calendar time from a trend with membership time (used as a proxy for fatigue). Membership time was included as a covariate in the usual model which also included calendar time, season, and whether or not it was the first return. ***Results:*** Results were inconclusive due to wide confidence intervals caused by high collinearity between membership time and calendar time, especially for EPIDERM, SWORD and THOR-GP core reporters. There was some evidence for EPIDERM sample reporters that blank returns increased as a function of membership time (by 6% per year) but not for SWORD sample.

2) **Calendar time trends in incidence adjusted for membership time:** The results of the analyses described in 1) suggested it might be possible to separate out the effects of calendar time and membership time for sample reporters. Therefore, the percentage change in incidence of total cases (EPIDERM 1996-2004, SWORD 1999-2004), 'adjusted' for an independent effect of membership time on incidence was estimated. Variables included in the MLM were 'calendar time', 'membership time', season, and first report.
   Results: Results suggested evidence of fatigue for EPIDERM sample reporters but not for SWORD sample reporters. On including 'membership time' in the models, the estimated annual change in incidence of cases reported to EPIDERM became -0.4% (95% CIs: -6.5, 6.2) instead of -3.2% whilst for SWORD it showed little change from -7.3% (95% CIs: -11.8, -2.7) to 7.1% (95% CIs: -12.0, -2.0).

3) **Descriptive analysis using the FATCATS/CALCATS approach:** i.e. zero return rates broken down simultaneously by categories of membership time (2 year intervals) (FATCATS) and calendar time (2 year intervals) (CALCATS). This was initially undertaken for EPIDERM (1996-2006) and SWORD (1999-2006), and subsequently for THOR-GP (June 2005-2008).
   Results: EPIDERM and SWORD core: little evidence that for any given calendar period the proportion of zero returns increased with membership time or that for any given membership period the proportion of zero returns increased with calendar time. EPIDERM and SWORD sample: some evidence of the former but not of the latter phenomenon. THOR-GP core: little evidence of the former but some evidence of the latter phenomenon.

4) **GEE (generalised estimating equations) modelling on zero returns in relation to time: The GEE modelling approach is an alternative to the random effects (RE) approach. It was used as a sensitivity analysis – to see if consistent with the results from RE approach.** Zero return rates were modelled as a function of membership time, with adjustment for calendar time. Membership time was included in the model as either a continuous variable (years) or categorised (2 year intervals). Analyses were carried out on core and sample reporters combined (EPIDERM 1996-2006 and SWORD 1999-2006).

   Results: Results suggested an increase in zero cases of 4% and 2% per membership year (EPIDERM and SWORD, respectively) but these trends were not statistically significant (EPIDERM p=0.08, SWORD p=0.20). In models where membership time was categorised, the odds ratios for all membership categories were higher than 1 (the reference year was <2 years membership) and seemed to settle around 1.3% after 6 years membership for EPIDERM whilst for SWORD there was no suggestion of an increase with membership time.

5) **Estimation of calendar time trends in incidence rates with membership restrictions:** The percentage change in incidence of WRI was estimated 'as usual' using the methodology described under Section 2.4 but reporters were categorised by membership time (2 year intervals) and separate analyses were carried out for each group. Analyses were carried out for core and sample reporters combined (EPIDERM 1996-2006, SWORD 1999-2006).

   Results: The trends estimates suggested that there was some evidence that EPIDERM reporters, but not SWORD reporters, in the longer membership categories might be more influenced by fatigue (manifesting as an increase in zeros).

6) **Modelling of zeros and non-response with membership time:** Longitudinal logistic GEE and RE models were fitted to investigate the relationship between non-response and zero response with membership time i.e. whether the probability of either type of response changes as membership time increases, and whether one type of response is more likely than the other (and whether this changes with membership time).

   Results: EPIDERM sample: there was strong evidence that both non-returns and zero returns (given a return) increased with membership time; the estimated odds were 13% and 7%, respectively. The conditional probability of a zero (i.e., given a zero case or non-return) declined over time (by 9% per membership year); we would expect this to decline if non-response increased more rapidly than zero returns. For the other reporters/schemes the estimated odds of non-response, zero response, and the conditional probability of a zero were EPIDERM core: 31%, 7% and 21%, respectively; SWORD sample: 17%, 4% and 14%. SWORD core: 33%, 7% and 18%, respectively.

All these analyses were conducted on total cases for each scheme. The implicit assumption is that fatigue was a general phenomenon affecting the reports as a whole for a given reporter and is not specific to a diagnostic group.

Table A1 Evidence of fatigue as exhibited by an increase in zero returns over time

Analyses	EPIDERM		SWORD		THOR-GP	
	Core	**Sample**	**Core**	**Sample**	**Core**	**Sample**
1*	/	Yes	/	No	/	/
2	/	Yes	/	No	/	/
3	No	Yes?	No	Yes?	Yes?	/
4**	Yes?		No		/	/
5	Yes?		No		/	/
6	Yes?	Yes	Yes?	Yes?	/	/

*It was not possible to separate out the effect of calendar time and membership time due to high collinearity between the two variables

**Analyses for SWORD and EPIDERM were on all reporters combined. This analysis was not repeated for THOR-GP

6 Analysis of zero-inflated count data using a zero-inflated negative binomial model (ZINB)

The most recent (and we believe improved) approach to investigate reporter fatigue (manifesting as an excess of zeros) has been the application of a zero-inflated negative binomial (ZINB) model. These analyses have now been published in the literature with an overview provided below.

To account for the presence of excess zero cases within the reported data, the reported monthly number of cases was fitted using a Zero-Inflated Negative Binomial Model (ZINB) with multi-level random effects. This model has two parts; the first supposes that, on occasion, a reporter might send back a zero report regardless of the actual number of cases seen i.e. an excess zero. This part of the model supposes a binary decision: send back an excess zero regardless or send back the true count zero or otherwise. The second part is the usual negative binomial model for true cases, including true zero cases, each month. The model allows for two sets of predictors in the two portions of the model. These were mean centred membership year (first part of model) and calendar time (second part of model). Thus the complete model allows for the possibility of excess zeros in the data; it can estimate their frequency and can estimate the true trend after allowing for this phenomenon.

The covariate thought to influence zero case reports and therefore included in the first part of the model was peak holiday season. Covariates thought to influence the incidence of work-related illness, and therefore included in the second part of the model, were first month as a reporter and months of the year containing a bank holiday. All modelling was repeated for 'core' reporters only, 'sample' reporters only, and both 'core' and 'sample' reporters.

Using this approach, data for EPIDERM (1996-2012) and SWORD (1999-2012). The impact of adjusting for excess zeros on the annual average percentage change in incidence of total work-related skin disease (EPIDERM) and total work-related respiratory disease (SWORD) is shown in Table A2.

Results:

EPIDERM The results suggest that both core and sample dermatologists reporting to EPIDERM are exhibiting reporter fatigue. Overall core reporters were less likely to report an excess zero than sample, yet both experienced an increase in excess zero returns with increasing membership time. Thus, adjusting for reporter fatigue as implied by 'excess zeros' would have a greater impact on the trend estimates for sample reporters compared to core. However, because sample reporters contribute less data, the impact on the overall estimate (core and sample) is less pronounced.

SWORD There is little evidence that SWORD core reporters are exhibiting reporter fatigue as would be shown by an increase in excess zero returns with increasing membership time. The evidence of reporting fatigue for SWORD sample reporters appears to be less strong than for EPIDERM sample reporters but there does appear to be fatigue manifesting in this way for this group. For SWORD, sample reporters contribute more data than core reporters and therefore fatigue in this group may have more impact on the overall estimate (compared to core).

Table A2 Influence of excess zeros on the average annual percentage change in reported incidence in work-related illness

		Core	Sample	Core + sample
EPIDERM	Member year[a]	1.14 (1.06, 1.22)*	1.09 (1.05, 1.12)*	1.08 (1.05, 1.12)*
(Total skin disease)	Negative binomial[b]	-2.8	-1.8	-2.6
	ZINB[c]	-2.4	0.0	-2.3
	% change[d]	14%	100%	12%
	Vuong p-value[e]	<0.001	0.003	<0.001
SWORD	Member year	1.04 (0.94, 1.14)	1.05 (1.02, 1.08)*	1.04 (1.02, 1.07)*
(Total respiratory disease)	Negative binomial	-2.7	-2.4	-2.5
	ZINB	-2.8	-0.5	-2.1
	% change	4%	79%	16%
	Vuong p-value	0.406	0.053	0.012

*****Statistically significant at the 5% level or below

[a]Excess zero odds ratio: This denotes whether the proportion of excess zeros is (significantly) increasing with membership time. For example, for EPIDERM core reporters, excess zeros increase by 14% per year of membership and this increase is statistically significant

[b]Annual average percentage change in incidence from negative binomial model (i.e. not adjusted for excess zeros)

[c]Annual average percentage change in incidence from zero-inflated negative binomial model (i.e. adjusted for excess zeros)

[d]Percentage difference between negative binomial model and zero-inflated negative binomial model

[e]Vuong test comparing whether the zero-inflated negative binomial model is a statistically better fit to the data than the negative binomial model

APPENDIX B DESCRIPTIVE ANALYSES

Table B1 Reporting activity of reporters in EPIDERM, 1996-2016

	CORE	SAMPLE
Total reporters ever in 1996-2016	59	404
Total active[a] reporters in 1996-2016	57	370
Response rate**	84%	74%
% of returns that are blank	18%	62%
Number of reporters who responded at least once but never returned a case	1	117
Number of reporters who have never responded	2	34

[a] Active reporter is someone who returns a card
[b] Response rate = cards returned/cards sent out

Figure B1 Number of reporters in EPIDERM by year and reporter type, 1996-2016

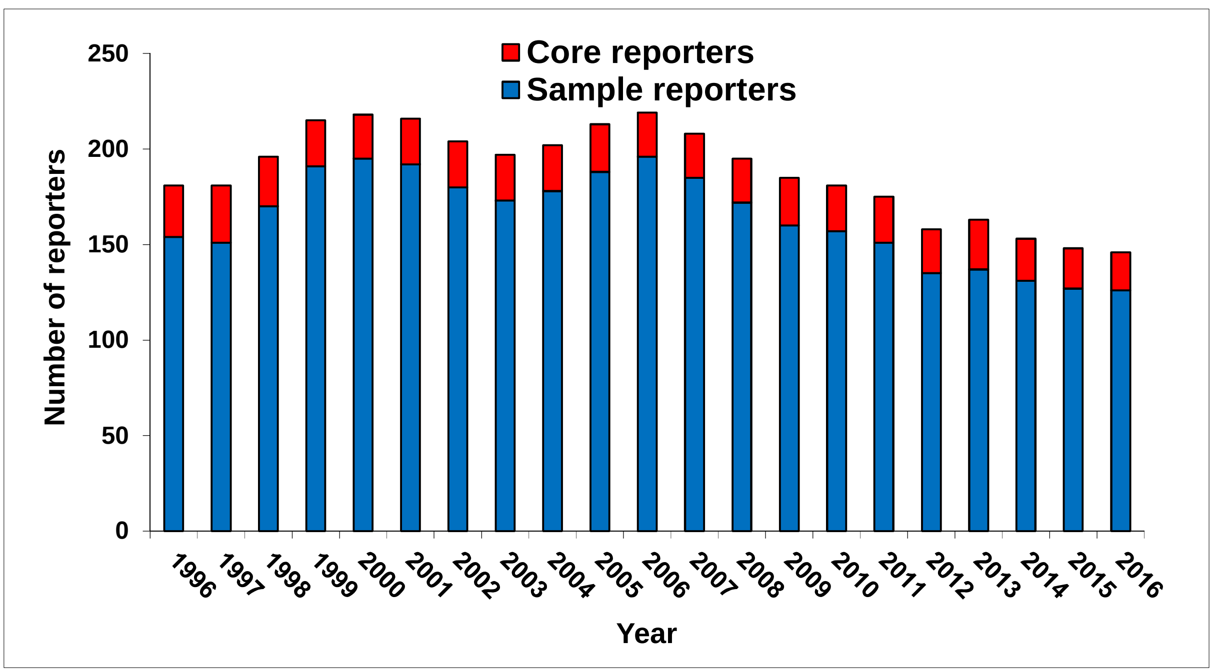
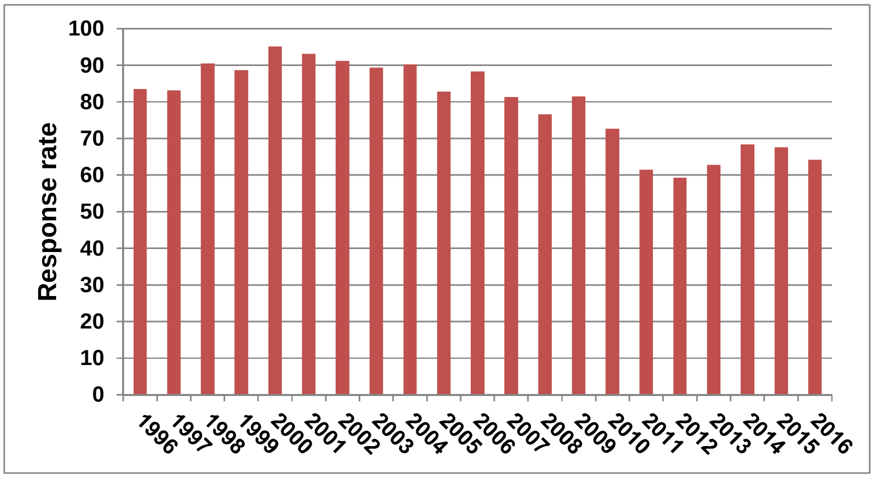
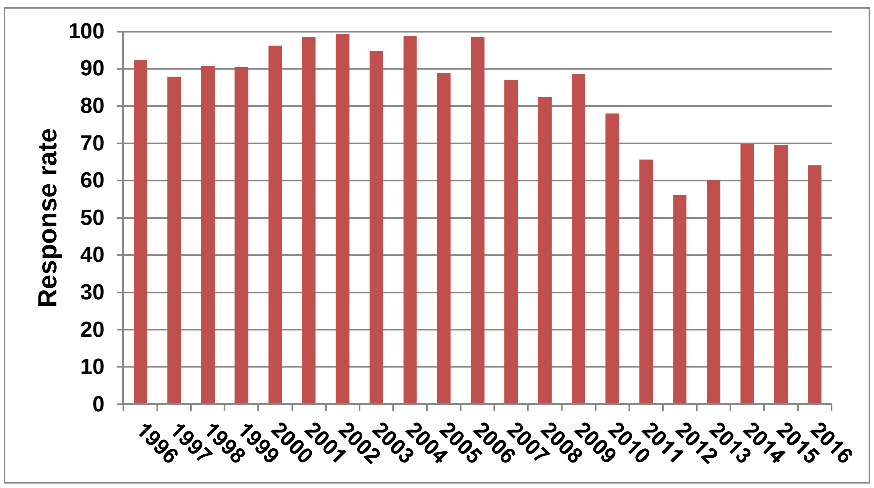


Figure B2 Response rates (cards returned/cards sent out) per year

a) All reporters



b) Core reporters



c) Sample reporters

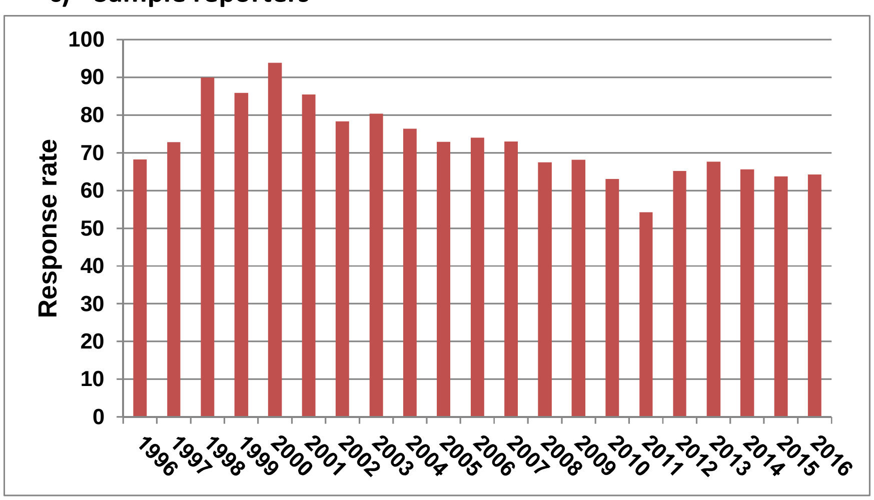


Figure B3 Number of active reporters per month – EPIDERM, 1996-2016

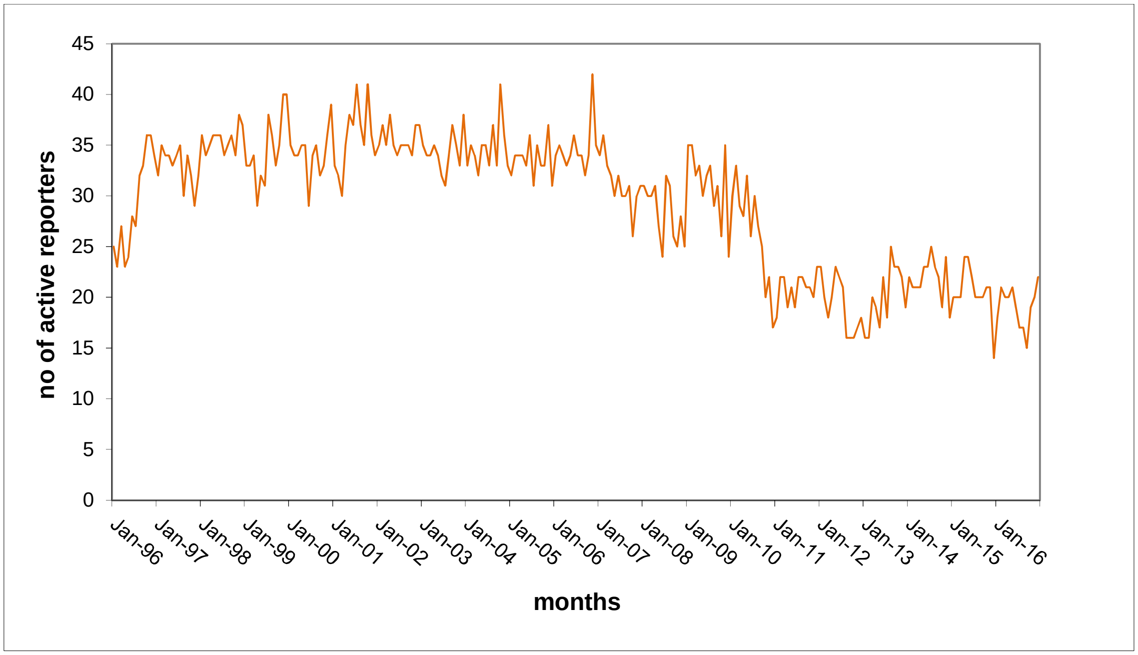
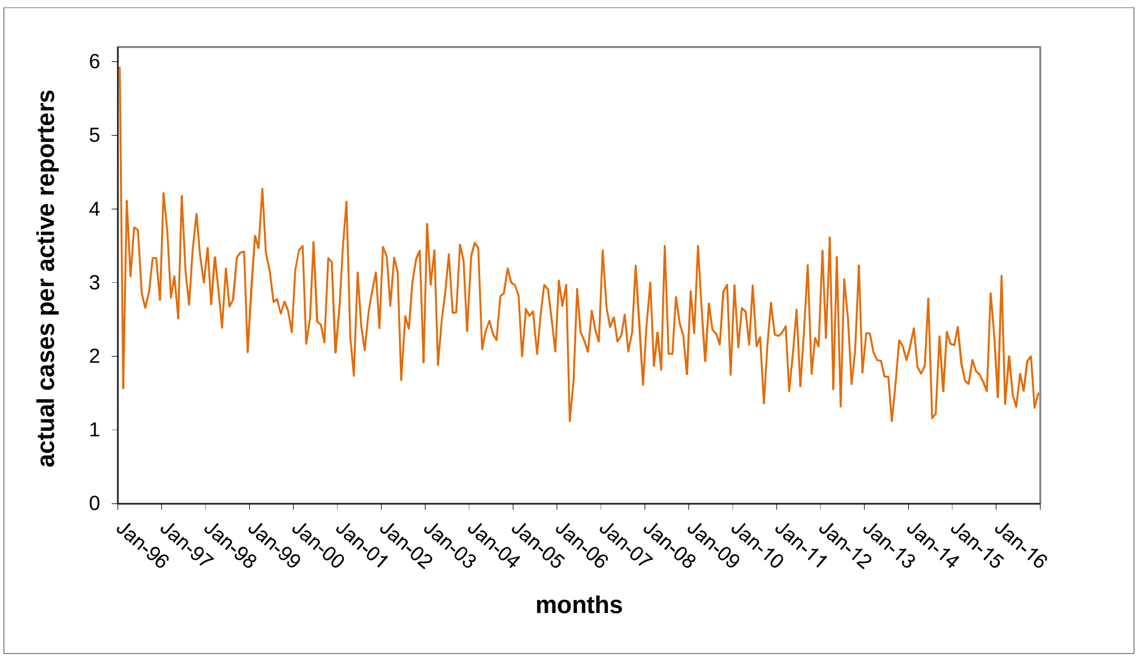
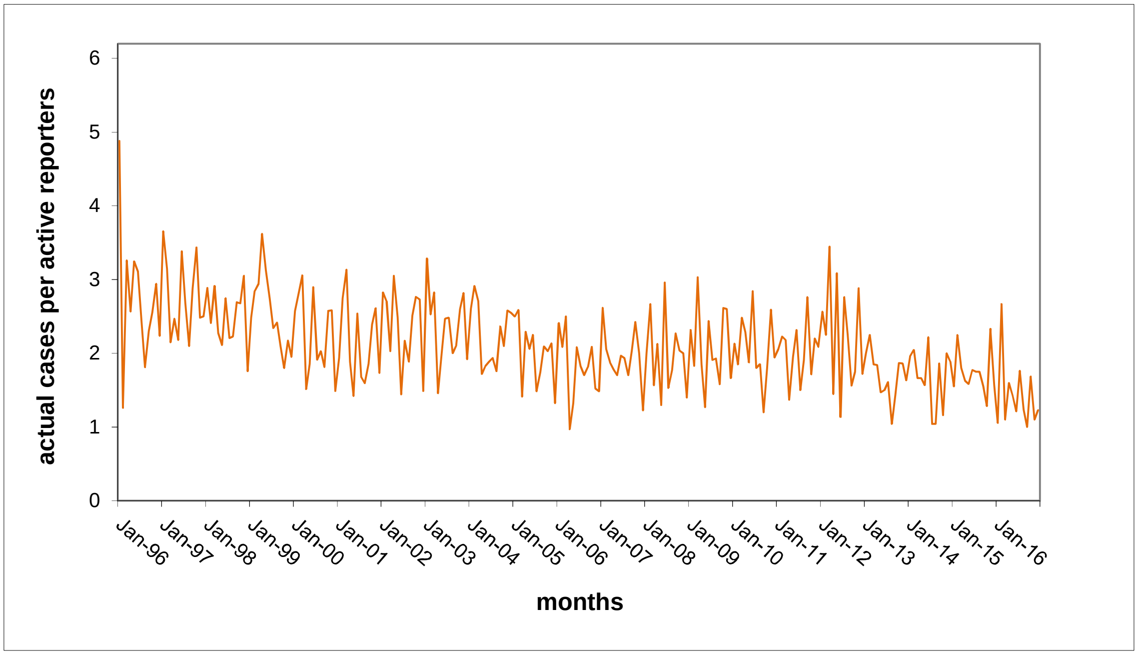


Figure B4 Cases per active reporter per month – EPIDERM, 1996-2016

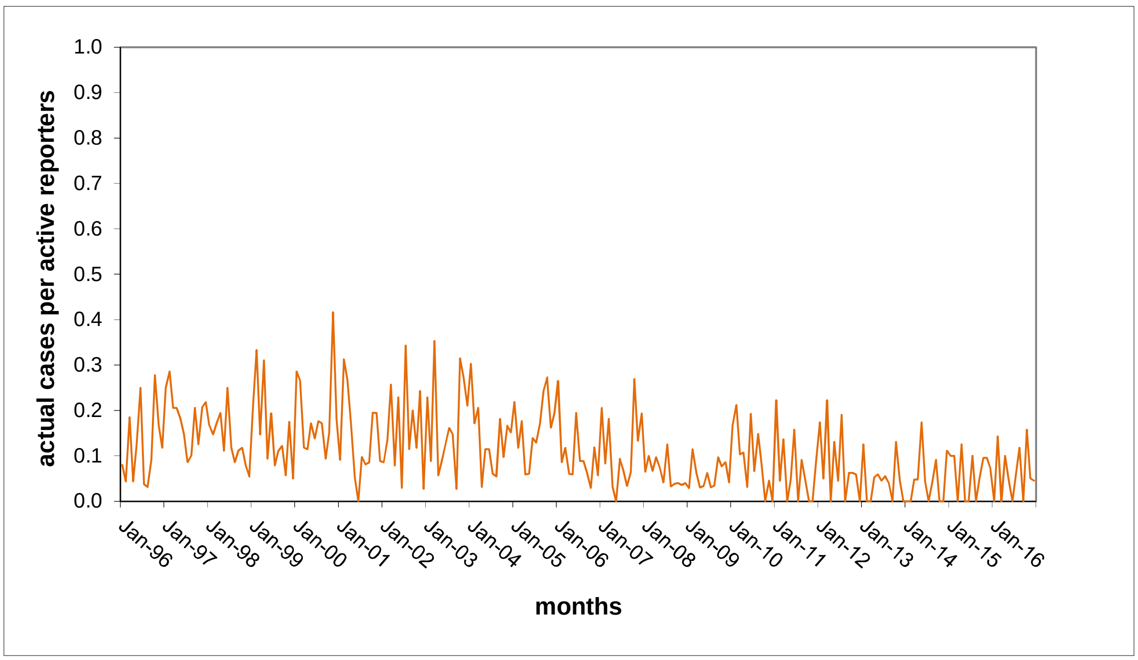
a) **Total cases**



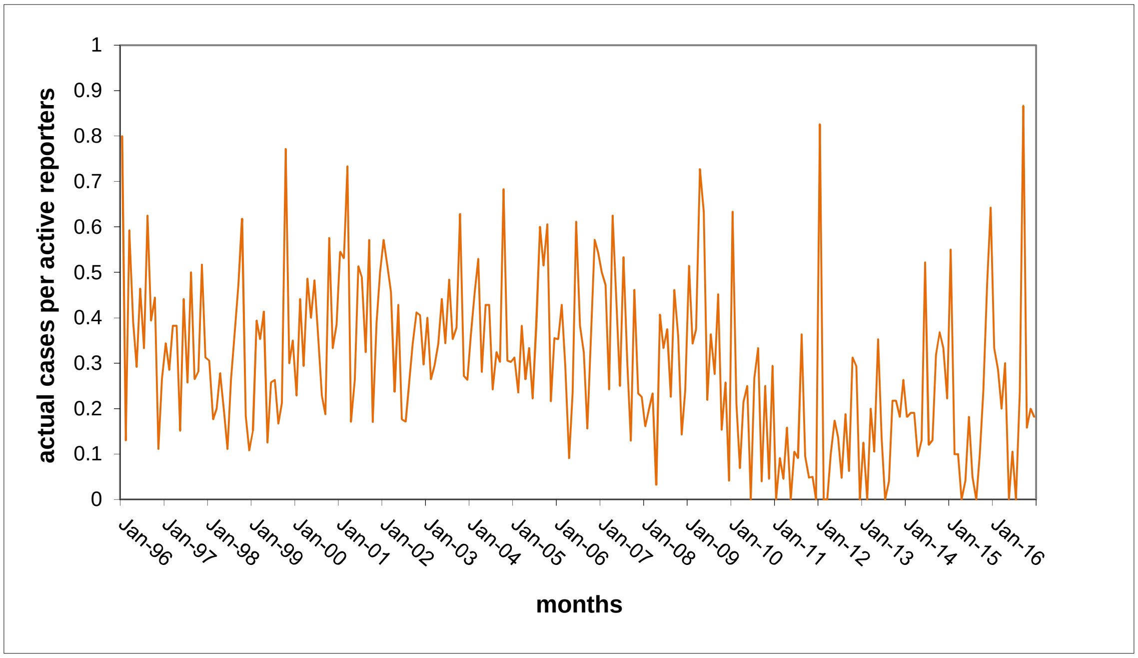
b) Contact dermatitis



c) Contact urticaria (note scale change)



d) Neoplasia



e) Other skin (other than contact dermatitis) (note scale change)

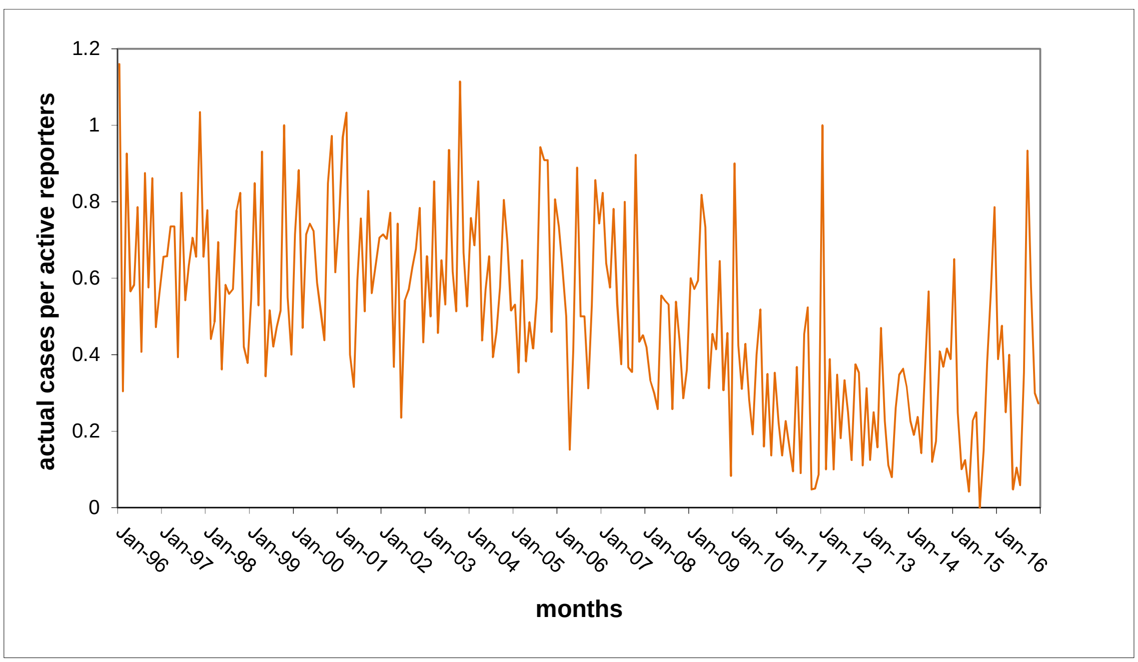


Table B2 Cases reported per month by disease category and type of reporter, EPIDERM, 1996-2016

		All Reporters				Core reporters				Sample reporters			
	Statistic		**Min**	**Max**	**SD**		**Min**	**Max**	**SD**		**Min**	**Max**	**SD**
	Total active reporters ever in 1996-2016	402				57				370			
	Mean no. of active[a] reporters per month	29.23	14	42	6.74	19.12	9.00	26.00	4.37	10.14	3.00	20.00	3.23
Disease group													
All cases	Total cases	19330				16932				2388			
	Mean cases per month	76.71	25.00	148.00	30.35	67.19	14.00	147.00	28.59	9.59	0.00	33.00	6.52
	Mean cases per active reporter per month	2.56	1.12	5.92	0.70	3.40	1.39	7.74	1.01	0.97	0.00	4.50	0.68
Contact dermatitis (CD)	Total cases	15886				14237				1640			
	Mean cases per month	63.04	15.00	122.00	24.46	56.50	12.00	121.00	23.15	6.59	0.00	23.00	4.75
	Mean cases per active reporter per month	2.12	0.97	4.88	0.59	2.89	1.20	6.37	0.83	0.67	0.00	3.00	0.50
Allergic CD	Total cases	5892				5188				696			
	Mean cases per month	23.38	3.00	58.00	11.26	20.59	3.00	54.00	10.30	2.80	0.00	12.00	2.65
	Mean cases per active reporter per month	0.78	0.21	1.66	0.28	1.04	0.23	2.44	0.40	0.27	0.00	2.00	0.27
Irritant CD	Total cases	7036				6422				610			
	Mean cases per month	27.92	4.00	58.00	11.51	25.48	3.00	58.00	11.22	2.45	0.00	13.00	2.30
	Mean cases per active reporter per month	0.94	0.27	2.32	0.32	1.30	0.33	3.05	0.46	0.25	0.00	1.86	0.25
Mixed CD	Total cases	2568				2337				231			
	Mean cases per month	10.19	1.00	27.00	5.02	9.27	0.00	25.00	4.91	0.93	0.00	5.00	1.16
	Mean cases per active reporter per month	0.35	0.05	0.92	0.15	0.48	0.00	1.21	0.22	0.10	0.00	0.75	0.14
Other[b] cases	Total cases	3905				3121				783			

			All Reporters				Core reporters				Sample reporters		
	Statistic		Min	Max	SD		Min	Max	SD		Min	Max	SD
	Mean cases per month	15.50	0.00	39.00	9.03	12.38	0.00	33.00	8.06	3.14	0.00	20.00	3.44
	Mean cases per active reporter per month	0.50	0.00	1.16	0.25	0.60	0.00	1.78	0.35	0.32	0.00	2.33	0.37
Contact urticaria	Total cases	883				831				52			
	Mean cases per month	3.50	0.00	15.00	2.88	3.30	0.00	14.00	2.80	0.21	0.00	3.00	0.50
	Mean cases per active reporter per month	0.11	0.00	0.42	0.08	0.16	0.00	0.78	0.13	0.02	0.00	0.33	0.05
Neoplasia	Total cases	2321				1731				590			
	Mean cases per month	9.21	0.00	28.00	6.02	6.87	0.00	20.00	5.00	2.37	0.00	19.00	3.15
	Mean cases per active reporter per month	0.30	0.00	0.87	0.18	0.33	0.00	1.05	0.22	0.24	0.00	2.17	0.34

[a]Active reporter is someone who returns a card
[b]other than contact dermatitis

Table B3 Reporting activity of reporters in SWORD, 1999-2016

	CORE	SAMPLE
Total reporters ever in 1999-2016	51	850
Total active[a] reporters in 1999-2016	47	795
Response rate[b]	81%	71%
% of returns that are zero returns (i.e. no cases to report)	28%	73%
Number of reporters who responded at least once but never returned a case	1	266
Number of reporters who have never responded	4	55

[a] Active reporter is someone who returns a card
[b]Response rate = cards returned/cards sent out

Figure B5 Number of reporters in SWORD by year and reporter type

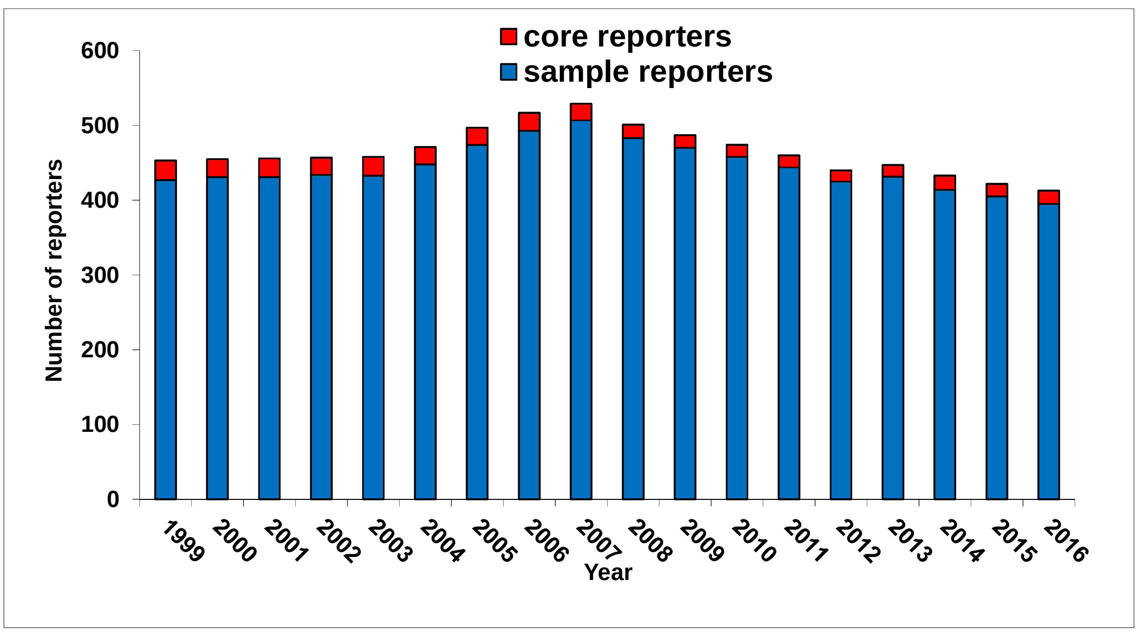


Figure B6 Response rates (cards returned/cards sent out) per year

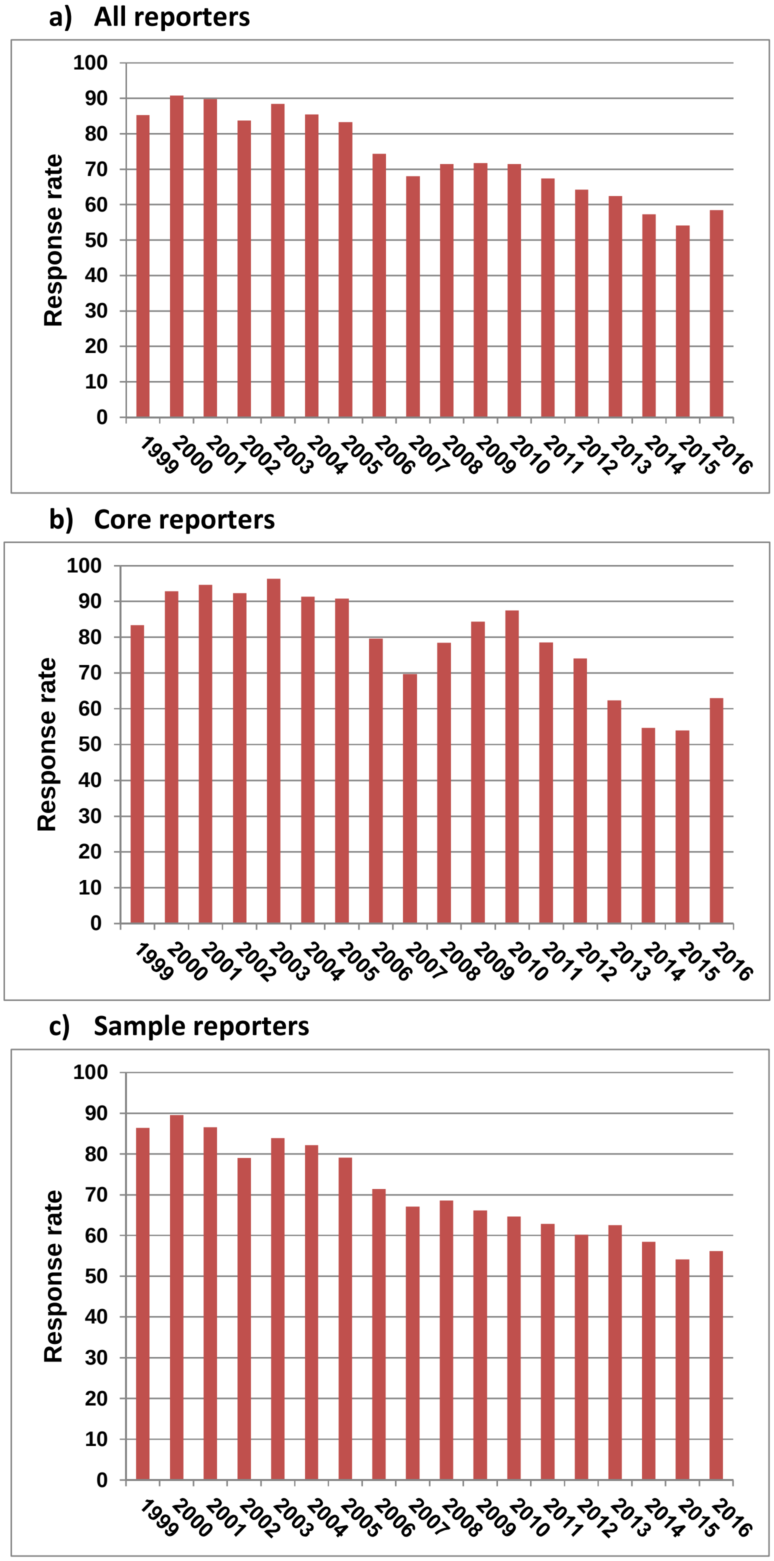


Figure B7 Number of active reporters per month – SWORD

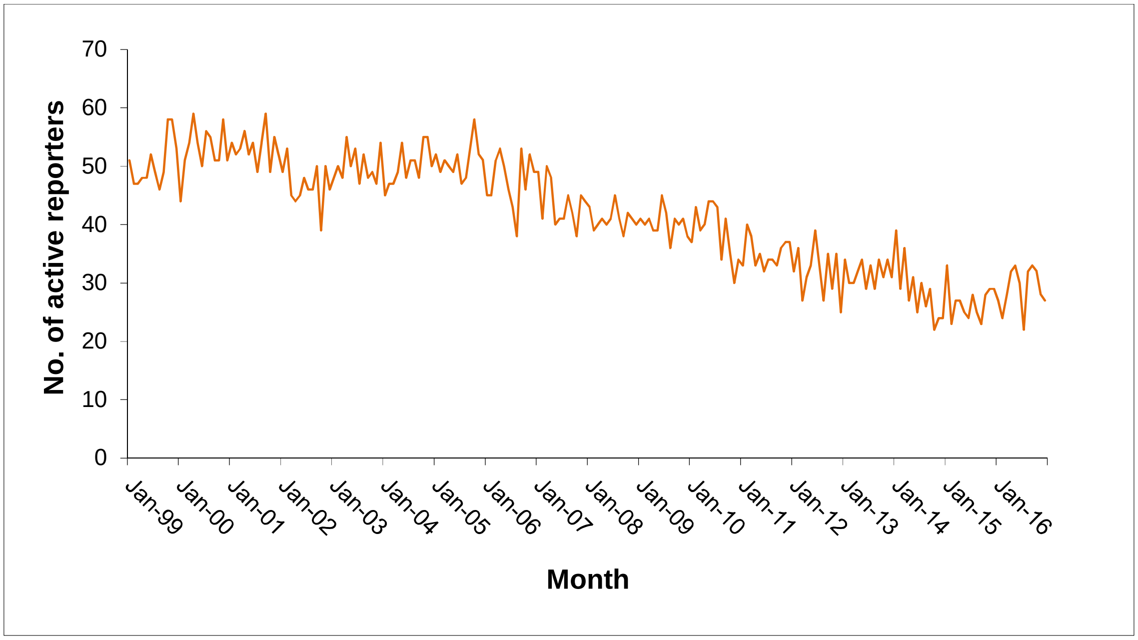
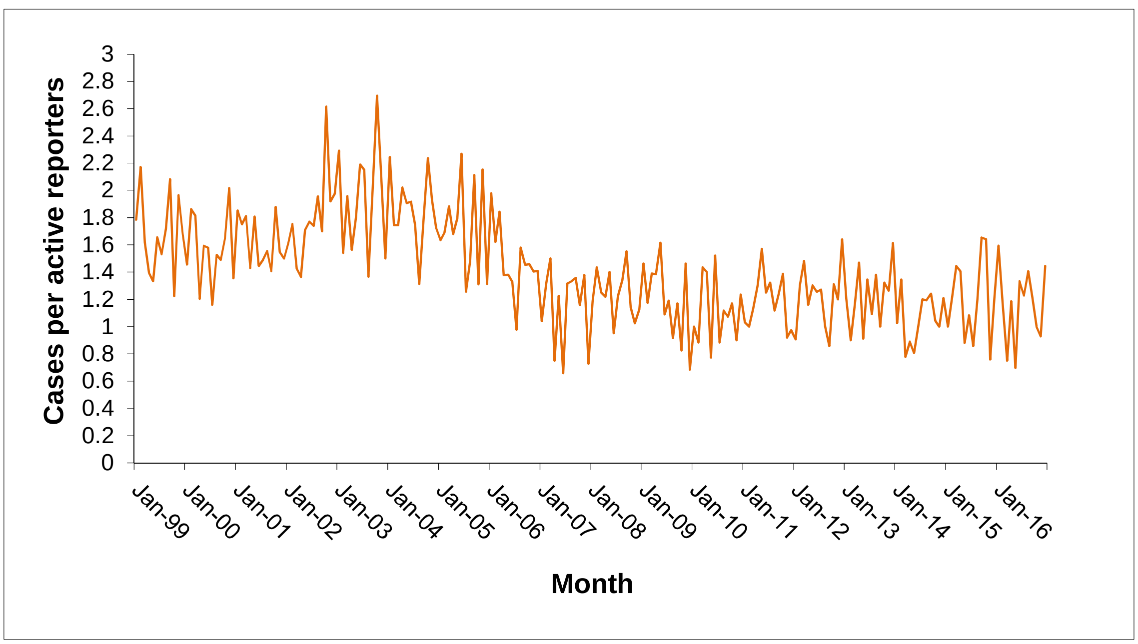
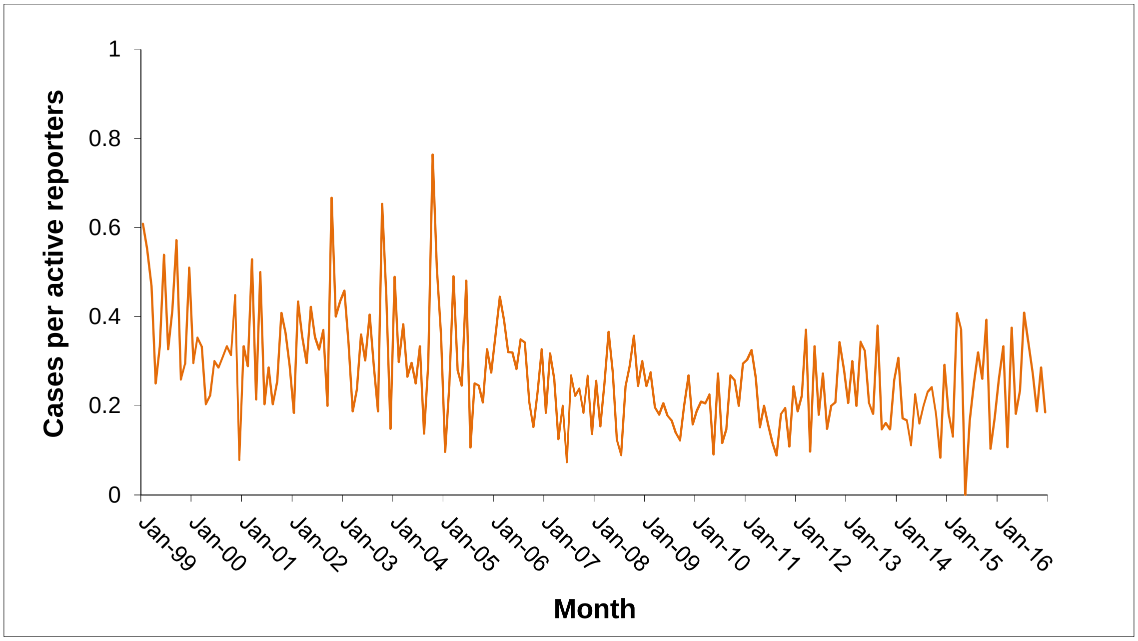


Figure B8 Cases per active reporter per month – SWORD

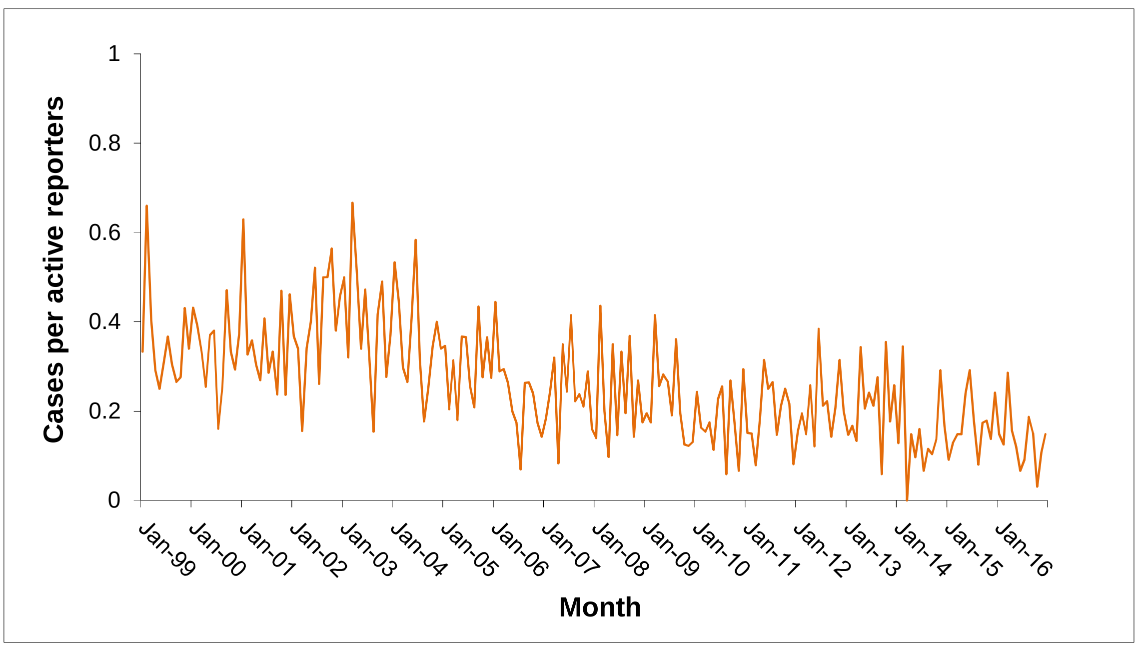
a) Total cases



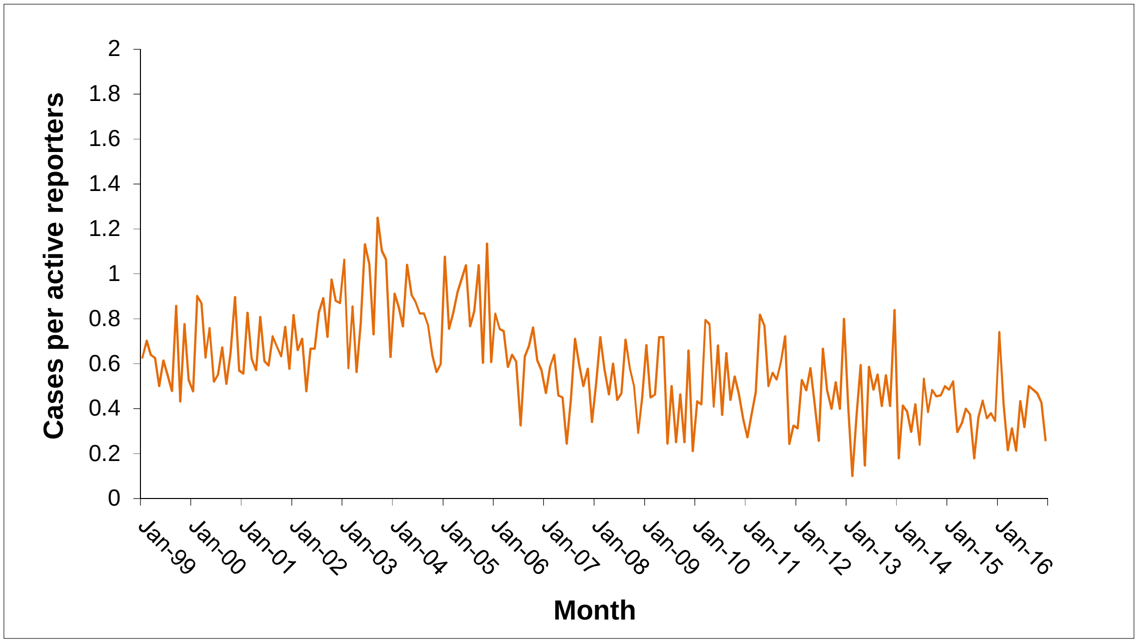
b) Asthma (note scale change)



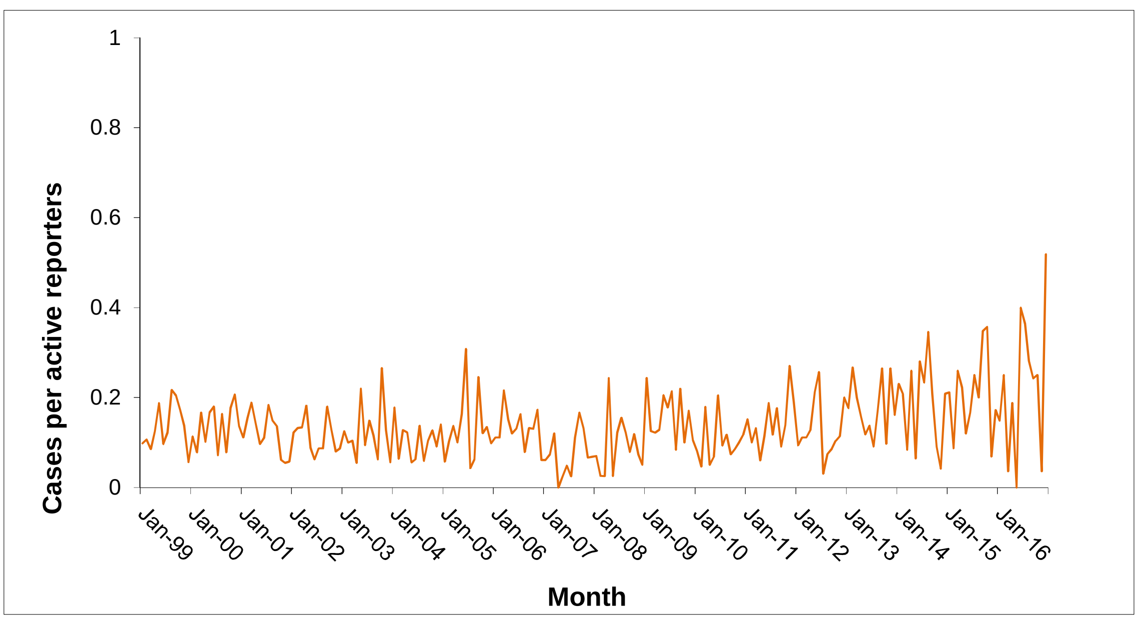
c) Mesothelioma



d) Non-malignant pleural disease (note scale change)



e) Pneumoconiosis (note scale change)



f) Other (than those specified above) respiratory disease

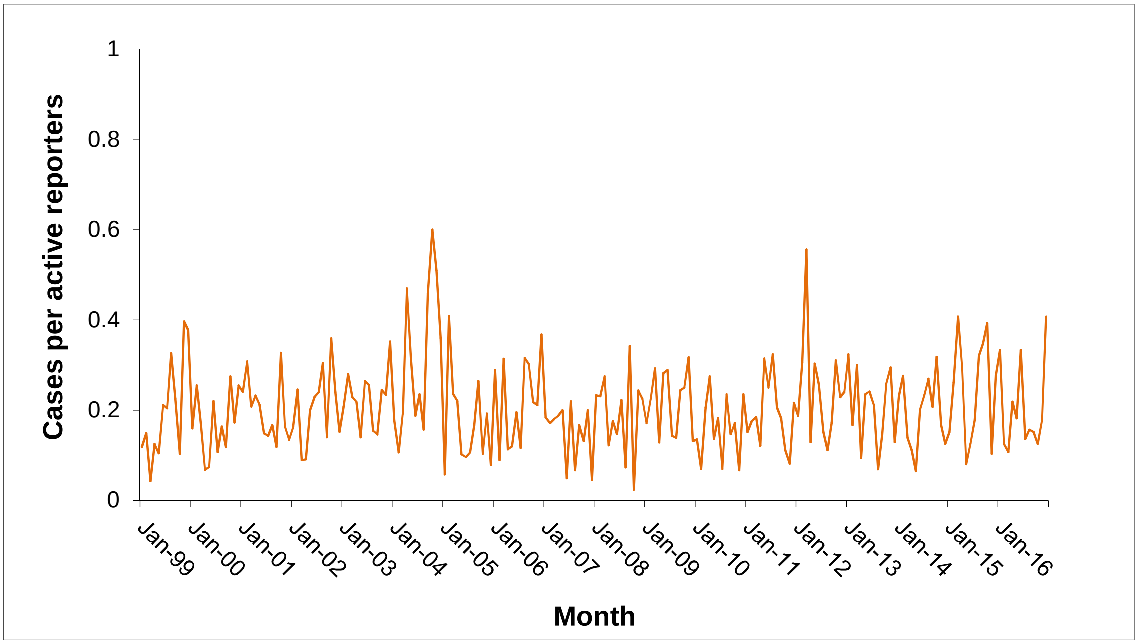


Table B4 Cases reported per month by disease category and type of reporter, SWORD, 1999-2016

	Statistic	All Reporters				Core reporters				Sample reporters			
			Min	Max	SD		Min	Max	SD		Min	Max	SD
	Total active reporters ever in 1999-2016	822				47				795			
	Mean no. of active[a] reporters per month	41.58	22.00	59.00	9.56	15.22	7.00	24.00	4.64	26.36	11.00	38.00	5.61
Disease group													
All cases	Total cases	13083				10360				2723			
	Mean cases per month	60.57	21.00	132.00	26.08	47.96	9.00	112.00	23.88	12.61	0.00	35.00	6.34
	Mean cases per active reporter per month	1.41	0.66	2.69	0.38	3.04	1.29	5.78	0.89	0.47	0.00	1.06	0.21
Asthma	Total cases	2527				2261				266			
	Mean cases per month	11.70	0.00	42.00	6.60	10.47	0.00	42.00	5.96	1.23	0.00	9.00	1.41
	Mean cases per active reporter per month	0.27	0.00	0.76	0.12	0.68	0.00	2.33	0.29	0.04	0.00	0.28	0.05
Mesothelioma	Total cases	2485				1601				884			
	Mean cases per month	11.50	0.00	34.00	6.94	7.41	0.00	27.00	5.81	4.09	0.00	11.00	2.65
	Mean cases per active reporter per month	0.26	0.00	0.67	0.13	0.44	0.00	1.69	0.28	0.15	0.00	0.45	0.09
Non-malignant pleural plaques	Total cases	5520				4492				1028			
	Mean cases per month	25.56	3.00	60.00	13.06	20.80	2.00	59.00	12.45	4.76	0.00	17.00	3.41
	Mean cases per active reporter per month	0.59	0.10	1.25	0.22	1.28	0.20	2.84	0.52	0.18	0.00	0.71	0.12
Pneumoconiosis	Total cases	1195				972				223			
	Mean cases per month	5.53	0.00	16.00	2.78	4.50	0.00	14.00	2.48	1.03	0.00	5.00	1.17

		All Reporters				Core reporters				Sample reporters			
	Statistic		Min	Max	SD		Min	Max	SD		Min	Max	SD
	Mean cases per active reporter per month	0.14	0.00	0.52	0.08	0.32	0.00	1.27	0.20	0.04	0.00	0.21	0.05
Other cases[b]	Total cases	1848				1475				373			
	Mean cases per month	8.56	1.00	33.00	4.66	6.83	1.00	28.00	4.20	1.73	0.00	13.00	1.78
	Mean cases per active reporter per month	0.21	0.02	0.60	0.10	0.32	0.00	1.27	0.20	0.07	0.00	0.45	0.06

[a]Active reporter is someone who returns a card

[b]Other than those specified above i.e SWORD categories: inhalation accidents, allergic alveolitis, bronchitis/emphysema, infectious disease, lung cancer and 'other' (the latter includes rhinitis). NOTE: A case may have more than one diagnosis