
Contents

| | | |
|----------|---|----|
| 1 | Overview | 1 |
| 1.1 | Introduction | 1 |
| 1.2 | Asbestos and Health | 1 |
| 1.3 | History of Asbestos | 4 |
| 1.4 | Epidemiological Discovery | 5 |
| 1.5 | Johns-Manville Corporation | 6 |
| 1.6 | Manville Trust | 6 |
| 1.7 | Manville Trust Litigation | 7 |
| 1.8 | Project History | 9 |
| 1.9 | Results | 11 |
| 1.10 | Organization of Monograph | 14 |
| 2 | Epidemiology of Asbestos-Related Diseases | 17 |
| 2.1 | Introduction | 17 |
| 2.2 | Design Issues in Studying Occupational Exposure | 18 |
| 2.2.1 | Measures of Risk | 19 |
| 2.2.2 | Design Issues | 22 |
| 2.3 | Studies of Health Risks of Occupational Exposures | 24 |
| 2.3.1 | Health Risks of a Cohort of Insulation Workers Occupationally Exposed to Asbestos | 25 |
| 2.3.2 | A Case-Control Study of Asbestos Risks in the United States and Canada | 35 |
| 2.3.3 | Short-Term Amosite Exposure Among Factory Workers in New Jersey | 37 |
| 2.3.4 | Effects of Chrysotile Exposure Among Miners and Millers in Quebec | 38 |
| 2.3.5 | Mesothelioma Risks Among World War II Shipyard Workers | 40 |
| 2.3.6 | Effects of Asbestos Exposure Among a Cohort of Retired Factory Workers | 42 |

| | | |
|----------|--|-----------|
| 2.4 | Increases in Disease Risk Associated with Exposure to Asbestos | 44 |
| 2.5 | Effects of Fiber Type on Disease Risks | 52 |
| 2.6 | Simian Virus 40 and Mesothelioma | 57 |
| 3 | Forecasts Based on Direct Estimates of Exposure | 61 |
| 3.1 | Introduction | 61 |
| 3.2 | Selikoff's Study: General Description | 61 |
| 3.2.1 | Data | 61 |
| 3.2.2 | Model and Methods | 62 |
| 3.3 | Selikoff's Six Tasks | 62 |
| 3.3.1 | Task 1: Identify the Industries and Occupations Where Asbestos Exposure Took Place | 63 |
| 3.3.2 | Task 2: Estimate the Number, Timing, and Duration of Employment of Exposed Workers | 67 |
| 3.3.3 | Task 3: Estimate Risk Differentials Among Occupations and Industries | 71 |
| 3.3.4 | Task 4: Estimate Dose-Response Models for Cancer Risks | 74 |
| 3.3.5 | Task 5: Project Future Asbestos-Related Cancer Mortality | 76 |
| 3.3.6 | Task 6: Estimate and Project Deaths Due to Asbestosis | 76 |
| 3.4 | Sensitivity of Selikoff's Projections | 79 |
| 3.5 | Alternative Projections of Health Implications | 81 |
| 4 | Forecasts Based on Indirect Estimates of Exposure | 89 |
| 4.1 | Introduction | 89 |
| 4.2 | Background | 89 |
| 4.3 | Walker's Study: General Description | 93 |
| 4.3.1 | Data | 93 |
| 4.3.2 | Model and Methods | 94 |
| 4.4 | Walker's Five Tasks | 94 |
| 4.4.1 | Task 1: Determine the Effective Number of Past Asbestos Workers | 95 |
| 4.4.2 | Task 2: Project Mesothelioma Incidence | 112 |
| 4.4.3 | Task 3: Project Lung Cancer Incidence | 115 |
| 4.4.4 | Task 4: Estimate Current and Future Asbestosis Prevalence | 119 |
| 4.4.5 | Task 5: Estimate the Amount of Asbestos-Related Disease Likely to Occur in Women | 124 |
| 4.5 | Asbestos-Related Disease Projections by Other Authors | 125 |
| 4.6 | Conclusions | 127 |

| | | |
|----------|--|-----|
| 5 | Uncertainty in Forecasts Based on Indirect Estimates | 129 |
| 5.1 | Introduction | 129 |
| 5.2 | Qualitative Sources of Uncertainty in Walker's Projections | 129 |
| 5.2.1 | Uncertainties in Either Direction | 130 |
| 5.2.2 | Why Walker's Projections May Be Too Low | 132 |
| 5.2.3 | Why Walker's Projections May Be Too High | 133 |
| 5.3 | Sensitivity Analysis of Walker's Projections | 134 |
| 5.3.1 | Results for Single Parameters | 138 |
| 5.3.2 | Results for All Variables Jointly | 139 |
| 5.3.3 | Summary of Uncertainty Results | 142 |
| 5.4 | Further Sensitivity Analysis of Walker's Mesothelioma Projections | 143 |
| 5.4.1 | Projection Methodology | 145 |
| 5.4.2 | Alternative Scenarios | 147 |
| 5.4.3 | Results | 149 |
| 5.5 | Conclusions | 152 |
| 6 | Updated Forecasts Based on Indirect Estimates of Exposure | 155 |
| 6.1 | Introduction | 155 |
| 6.2 | Factors Considered | 155 |
| 6.3 | Assumptions | 160 |
| 6.4 | First-Stage Calibration: Overview | 165 |
| 6.5 | Data Preparation | 169 |
| 6.5.1 | Step 1: Nonmesothelioma Mortality Rates | 169 |
| 6.5.2 | Step 2: National Estimates of Mesothelioma Incidence Counts | 172 |
| 6.5.3 | Step 3: Distribution of Age and Date at Start of Asbestos Exposure for Mesothelioma Incidence Among Manville Trust Claimants | 174 |
| 6.5.4 | Step 4: Normalization of Exposure | 189 |
| 6.5.5 | Step 5: Intensity of Exposure | 190 |
| 6.6 | Model Estimation | 191 |
| 6.6.1 | Step 6: Stratification of National Estimates of Mesothelioma Incidence Counts, by Level of Asbestos Exposure | 191 |
| 6.6.2 | Step 7: Estimation of the IWE Population Exposed to Asbestos Prior to 1975 by Level of Asbestos Exposure | 192 |
| 6.6.3 | Step 8: Adjustments to Exposure During 1955-1974, by Level of Asbestos Exposure | 198 |
| 6.6.4 | Step 9: Adjustments to Reflect Improvements in the Workplace During 1960-1974, by Level of Asbestos Exposure | 198 |

| | | |
|----------|---|------------|
| 6.6.5 | Step 10: Renormalization by Level of Asbestos Exposure | 199 |
| 6.7 | Model Projection | 200 |
| 6.7.1 | Step 11: Forward Projection of the At-Risk IWE Population by Level of Asbestos Exposure | 202 |
| 6.7.2 | Step 12: Forward Projection of Mesothelioma Incidence by Level of Asbestos Exposure | 202 |
| 6.8 | Nonparametric Hazard Modeling of Claim Filing Rates: CHR Model | 208 |
| 6.8.1 | Step 1: Distribution of 1990-1994 Claims by Attained Age, TSFE, and Disease/Injury | 208 |
| 6.8.2 | Step 2: Estimation of Claim Hazard Rates by Attained Age, TSFE, and Disease/Injury | 209 |
| 6.8.3 | Step 3: Claim Projections | 213 |
| 7 | Uncertainty in Updated Forecasts | 217 |
| 7.1 | Introduction | 217 |
| 7.2 | Analysis S1: Constant Age-Specific Claim Runoff | 222 |
| 7.3 | Analysis S2: Ratio Estimation of Nine Asbestos-Related Diseases – PTS Model | 223 |
| 7.4 | Analysis S3: Parametric Claim Hazard Rate Model | 224 |
| 7.5 | Analysis S4: Mesothelioma Incidence Function | 229 |
| 7.5.1 | Sensitivity to the <i>b</i> Parameter..... | 232 |
| 7.5.2 | Sensitivity to the <i>k</i> Parameter | 233 |
| 7.6 | Analysis S5: Adjustments to the IWE Exposed Population | 235 |
| 7.7 | Analysis S6: National Mesothelioma Incidence Counts | 236 |
| 7.8 | Analysis S7: Nonmesothelioma Mortality Rates | 237 |
| 7.9 | Analysis S8: Excess Mortality Among Insulation Workers | 239 |
| 7.10 | Analysis S9: Decline in Claim Filing Rates | 240 |
| 7.11 | Overall Sensitivity: Analyses S1-S9 | 241 |
| 7.12 | Analysis S10: Manville Trust Calibrations | 247 |
| 7.13 | Conclusions | 249 |
| 8 | Forecasts Based on a Hybrid Model | 251 |
| 8.1 | Introduction | 251 |
| 8.2 | Model Overview | 252 |
| 8.2.1 | First Stage | 252 |
| 8.2.2 | Second Stage | 254 |
| 8.3 | Data Preparation | 255 |
| 8.3.1 | Step 1: Nonmesothelioma Mortality Rates | 255 |
| 8.3.2 | Step 2: Occupation Groups with Significant Asbestos Exposure | 256 |
| 8.3.3 | Step 3: Distribution of Mesothelioma Claim Counts 1990-1994 by Attained Age at the Time of Claim and TSFE | 257 |

| | | |
|-------------------------|--|------------|
| 8.3.4 | Step 4: Distribution of Mesothelioma Claim Counts by Age at Start of Exposure and Date of First Exposure | 270 |
| 8.3.5 | Step 5: Normalization of Exposure..... | 273 |
| 8.4 | Model Estimation | 273 |
| 8.4.1 | Step 6: Estimation of the OSHA Model for Mesothelioma | 273 |
| 8.4.2 | Step 7: Estimation of the Population Exposed to Asbestos Prior to 1975 | 284 |
| 8.5 | Model Projection | 288 |
| 8.5.1 | Step 8: First-Stage Calibration | 288 |
| 8.5.2 | Step 9: Forward Projection of Mesothelioma Mortality .. | 288 |
| 8.6 | Second Stage: CHR Forecasting Model | 290 |
| 8.6.1 | Step 1: Distribution of Disease-Specific Claim Counts for 1990-1994 by Attained Age and TSFE | 290 |
| 8.6.2 | Step 2: Second-Stage Calibration | 290 |
| 8.6.3 | Step 3: At-Risk Population Projections..... | 294 |
| 8.6.4 | Step 4: Claim Projections | 298 |
| 8.7 | Conclusions..... | 308 |
| 9 | Uncertainty in Forecasts Based on a Hybrid Model | 311 |
| 9.1 | Introduction | 311 |
| 9.2 | Impact of Claim Filing Rules | 313 |
| 9.3 | Baseline Model: SDIS Criterion | 314 |
| 9.4 | Analysis S1: Validated Disease | 315 |
| 9.5 | Analysis S2: Multiple Diseases | 320 |
| 9.6 | Analysis S3: CHR Smoothing | 325 |
| 9.7 | Analysis S4: Exposure Smoothing | 327 |
| 9.8 | Analysis S5: Weibull k Parameter | 328 |
| 9.9 | Analysis S6: Relative Risks of Mesothelioma | 330 |
| 9.10 | Analysis S7: Duration of Exposure..... | 332 |
| 9.11 | Overall Sensitivity: Analyses S1-S7 | 334 |
| 9.12 | Conclusions..... | 336 |
| 10 | Conclusions and Implications | 345 |
| 10.1 | Introduction | 345 |
| 10.2 | Data..... | 347 |
| 10.3 | Comparisons of Original and Updated Data..... | 350 |
| 10.4 | Comparisons of Actual and Projected Numbers of Claims..... | 354 |
| 10.5 | Health and Vital Statistics Data, 1990-1999 | 359 |
| 10.6 | Conclusions | 374 |
| References | 377 | |
| Index | 389 | |