OCCUPATIONAL EXPOSURE TO CARCINOGENS IN GERMANY IN 1990-93: Preliminary results

Wolfgang Ahrens
Timo Kauppinen
Jouni Toikkanen
David Pedersen
Randy Young
Manolis Kogevinas

Finnish Institute of Occupational Health, Helsinki 1999
# Contents

Summary ................................................................. 3  
Introduction ........................................................... 4  
Material and methods .............................................. 6  
  Overview of the assessment method and data included .................................................. 6  
  Agents and occupational exposure .................................................................................. 7  
    Agents covered ........................................................................................................... 7  
    Definition of occupational exposure .......................................................................... 7  
  Industry specific estimation procedure ......................................................................... 8  
    Characterisation of industry and labour force ......................................................... 8  
    Estimation procedure ............................................................................................... 9  
    Estimates of multiple exposure ................................................................................ 9  
    Estimates of low confidence .................................................................................... 10  
    Estimates of low level of exposure ........................................................................ 10  
    Exposure measurements included ........................................................................... 10  
    Exposure by occupation and gender ....................................................................... 11  
    Reference countries ............................................................................................... 11  
Results ............................................................................. 15  
Discussion .......................................................................... 16  
References and appendices ......................................................................................... 18
Summary

CAREX is an international information system on occupational exposure to known and suspected carcinogens. The CAREX (CARcinogen EXposure) database, constructed with support from the Europe Against Cancer program of the European Union (EU), provides selected exposure data and documented estimates of the number of exposed workers by country, carcinogen, and industry. CAREX includes data on 139 agents evaluated by the International Agency for Research on Cancer (all agents in Groups 1 and 2A, and selected agents in Group 2B), displayed across the 55 industrial classes of the United Nations system (ISIC Revision 2). The 1990-93 occupational exposure to these carcinogens was estimated for the fifteen countries of the EU in two phases. First, estimates were generated automatically by the CAREX system on the basis of national workforce data and exposure prevalence estimates from two reference countries (the United States and Finland). These estimates are adjusted for the economic structure (workforce distribution) of each country individually, but do not take into account country-specific exposure patterns which may deviate from those of the reference countries. For selected countries, these estimates were then refined by national experts in view of similarity/dissimilarity to the perceived exposure patterns in their own countries. The results presented in this report are based solely on estimates generated by the CAREX system.

According to the preliminary estimates, there were over 8 million workers (24% of the employed) exposed to the agents covered by CAREX in Germany in 1990-93. The number of exposures was approx. 11 million. The most common exposures were solar radiation (2.4 million workers exposed at least 75% of working time), environmental tobacco smoke (2.0 million workers exposed at least 75% of working time), crystalline silica (1.0 million exposed), radon and its decay products (800 000), diesel engine exhaust (720 000), wood dust (680 000), benzene (470 000), lead and inorganic lead compounds (460 000), ethylene dibromide (440 000), chromium VI compounds (260 000), and glasswool (250 000).
Introduction

The 'Europe Against Cancer' program of the European Union (EU) prompted a project on the estimation of the burden of occupational cancer in Europe, which includes a component on occupational exposure to carcinogens. This substudy is aimed at estimating the number of workers exposed to major known and suspected carcinogens in the EU by specific carcinogen, country and industry.

The review of available literature, including the Monographs of the International Agency for Research on Cancer (IARC), indicated that direct estimates on numbers of exposed workers were usually not available. Therefore, it was obvious that most of the estimates would have to be derived indirectly by professional judgement, on the basis of available published and unpublished information on workers exposed to carcinogens.

An international group of experts on carcinogen exposure was summoned to a meeting to plan the estimation procedure. After the initial meeting, a first version of exposure information system called CAREX (from Carcinogen Exposure) was constructed by the Finnish Institute of Occupational Health (FIOH) to support the estimation process. CAREX was tested and further developed in another meeting of experts. Because knowledge on national exposures is essential in the estimation process, additional experts from different countries were identified and called to participate to the project. The following scientists have contributed significantly to the planning, system design, data collection or assessment of exposure in the CAREX system:

- Dr Manolis Kogevinas, Greece, Spain, leader of the project, planning
- Dr Timo Kauppinen, Finland, coordinator, planning, assessment
- Mr Jouni Toikkanen, Finland, planning, system design
- Dr David Pedersen, USA, planning, US data, conversions
- Mr Randy Young, USA, US data, computing
- Ms Anja Savela, Finland, Finnish data, computing
- Dr Hans Kromhout, the Netherlands, planning, assessment
- Dr Jeronimo Maqueda Blasco, Spain, planning, assessment
- Dr Victoria de la Orden-Rivera, Spain, assessment
- Dr Wolfgang Ahrens, Germany, planning, assessment
- Dr Dario Mirabelli, Italy, planning, assessment
- Mr Raymond Vincent, France, planning, assessment
<table>
<thead>
<tr>
<th>Name</th>
<th>Country</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr Nils Plato</td>
<td>Sweden</td>
<td>planning, assessment</td>
</tr>
<tr>
<td>Mr Brian Pannett</td>
<td>United Kingdom</td>
<td>planning, assessment</td>
</tr>
<tr>
<td>Dr Johnni Hansen</td>
<td>Denmark</td>
<td>assessment</td>
</tr>
<tr>
<td>Dr Hendrik Veulemans</td>
<td>Belgium</td>
<td>assessment</td>
</tr>
<tr>
<td>Dr Paolo Boffetta</td>
<td>IARC</td>
<td>planning</td>
</tr>
</tbody>
</table>

Only a small part of the CAREX documentation (which includes definitions, subindustrial estimates, descriptive information, results of exposure measurements, labour force data, and bibliographic references) could be included in this report.

This project was partially financed by the EU from the ‘Europe Against Cancer’ program.
Material and methods

Overview of the assessment method and data included

The assessment procedure included several main phases:

- definition of agents and occupational exposure
- definition of industries and collection of labour force data
- collection of exposure measurement data and descriptive exposure data
- generation of default estimates of exposures by the CAREX system
- generation of final estimates of exposures by national experts
- estimation of multiple exposures

The majority of agents were assessed according to a detailed \textit{industry-specific ('long')} procedure which involves stratification by industry. The assessment of a few agents followed a \textit{country-specific ('short')} procedure which provides only one figure of the exposed workers per country. For example, some medical treatments were assessed according to this procedure. Carcinogenic '\textit{exposure circumstances}' evaluated by IARC were only briefly described. \textit{No assessment} was appropriate or feasible for some of the agents (betel quid, some viruses, salted fish, etc) exposure to which is not primarily occupational. They were included in the database but the number of occupationally exposed workers was assumed to be zero or unknown. Only results from the industry-specific estimations are presented in this report because data from other procedures was very incomplete.

To support the estimation and to document the basis for estimates, a CAREX exposure information system was designed and constructed. It is based on the Microsoft Access 2 database which can be run on personal computers.

Our preference was to use original national estimates on carcinogenic exposures, but their poor availability forced us to adopt an approach where most figures were derived indirectly on the basis of information from two reference countries with reasonably comprehensive data (Finland and the United States). The calculation of these first estimates started from direct exposure data retrieved from the Finnish SUTKEA (Anttila et al 1992), FINJEM (Kauppinen et al, in press) and ASA databases (Kauppinen et al 1990), and from US NOES database (Greife et al 1995, Seta et al 1988, Sieber 1990). After conversion of the Finnish and US industrial classifications to ISIC Rev 2 of UN (1968) format, the numbers of workers exposed to agents under study were listed by industry. The absolute figures were converted to exposure frequencies (prevalences) by dividing them by the employed labour force of the industry concerned. The prevalence considered to be most valid, which was often the mean of the US and Finnish...
prevalences, was then multiplied by the number of employed in the industry of the country to be assessed. The resulting estimates generated by the CAREX system were used as first (preliminary) estimates of the numbers of the exposed workers in Germany.

Knowledge on multiple exposure to agents covered by CAREX is needed when data are summed to obtain the total number of the exposed workers in an industry or in a country. Multiple exposure to the CAREX agents was estimated in Finland and the Finnish values were applied also to German data.

Agents and occupational exposure

Agents covered

The selection of agents was carried out by the project group in its first meeting in March 1995. CAREX includes all agents, groups of agents and mixtures which the International Agency for Research on Cancer (IARC) had classified to group 1 (carcinogenic to humans) and group 2A (probably carcinogenic to humans) as of February 1995. Selected agents from group 2B (possibly carcinogenic to humans) were also included. In addition, ionising radiation was included because, although not evaluated by IARC, there is sufficient evidence of its carcinogenicity to humans. Appendix 4 of this report lists major agents which were assessed according to the industry-specific procedure.

Some of the group 1 or 2A agents are chemically polycyclic aromatic hydrocarbons (PAHs) or their mixtures, and they were merged under that title. PAHs include coal-tar pitches, coal-tars, untreated and mildly-treated mineral oils, shale-oils, soots and creosotes, as well as benzo(a)pyrene and other probably carcinogenic PAH-compounds. The reason for this regrouping is that PAHs almost always occur in occupational setting as complex mixtures and exposure to a single PAH is impossible to distinguish. However, tobacco smoke (passive exposure at work) and diesel exhaust, while recognised also as complex mixtures containing PAHs, were assessed separately.

Definition of occupational exposure

The definition of exposure in the documentation of CAREX provides the relevant routes of exposure (inhalatory, dermal or both of them) and the nonoccupational background level, which was used as the minimum criterion of occupational exposure. If the background level was assumed to be negligible, it was not reported numerically. If a CAREX agent was a group or otherwise unspecific, the definition listed the most common agents included. In some cases the definition also noted inclusions or exclusions of 'borderline' exposures and national deviations from the general definition.
Industry specific estimation procedure

Characterisation of industry and labour force

The numbers of exposures in CAREX were estimated for industrial classes (CAREX industries) at the 3-digit level of United Nations ISIC Revision 2 (1968). For some non-manufacturing sectors, 1- or 2-digit levels were used as the assessment level. The industrial classes with the labour force data are presented in Appendix 1.

Labour force information was necessary for the estimation of exposed workers. The number of employed persons used in the calculation was the mean number of employed in 1990-93. As far as possible, we tried to include all employed in the industry covering salaried workers, self-employed, working family members and part-time workers. However, labour force information in the EU countries was heterogeneous and incomplete.

The major source of labour force data was Organisation for Economic Co-operation and Development (OECD) which has collected industrial structure and workforce statistics uniformly according to the ISIC Rev 2 classification since the late 1960s. The manufacturing industry and mining are divided up into 76 sectors at the 3-digit level. Selected industries data are also at the 4-digit level, if available. Non-manufacturing sectors are reported only at the 1-digit level in the OECD statistics which was not accurate enough for the CAREX purposes. Therefore, workforce data by Nomenclature Général des Activités Economiques dans les Communautés Européennes (NACE) Revision 1 (1993) of EUROSTAT, which are available at the 2-digit level (60 classes) and available national statistics were also used to derive the 1- or 2-digit level workforce figures needed for the non-industrial ISIC-sectors of CAREX.

OECD data for the manufacturing sector were only available for West-Germany. They are almost identical with the German ‘Beschäftigtenstatistik’ that is published according to the ‘Systematik für das produzierende Gewerbe (SYPRO)’ by the Federal Statistical Office (Staatliches Bundesamt, StaBuA) for both, East- and West-Germany in a more detailed categorization than the 3-digit ISIC. These data were used for the whole manufacturing sector (ISIC major group 3) and the mining sector (ISIC major group 2). The corresponding figures for East-Germany were only available for 1992 and partly for 1993. The employment figures of the year 1991 were not reported for East-Germany. The numbers for 1990 had to be estimated from a special evaluation of available statistics as of Nov 30, 1990 (‘Berufstätigenenerhebung in den Neuen Ländern und Berlin-Ost,’ Fachserie 1, Reihe 4.S.1, Statistisches Bundesamt. Metzler-Poeschel, Stuttgart 1993). The missing numbers for 1991 were estimated by interpolation of the preceding and the following year.

Employment data for some specific sectors are not reported by the Federal Statistical Office for less than 2 enterprises, they are declared to be ‘secret’. This lead to some underestimation, particularly in 1993 where numbers for some specific subgroups were missing. These numbers were extrapolated by insertion of the corresponding number of the previous year. The employment figures are published for East- and West-Germany since 1992 as ‘Beschäftigtenstatistik’ Fachserie 18, Reihe 1.3; Statistisches Bundesamt. Metzler-Poeschel, Stuttgart.

Data from the ‘Beschäftigtenstatistik’ were not available in the desired detail and completeness for the non-manufacturing sector. Therefore these numbers were estimated on the basis of the yearly Micro Census that covers 1% of the total population. These data are categorized according to a standard
classification of industries called ‘Systematik der Wirtschaftszweige (WZ 79)’. Because this classification entails some conversion problems when converted to ISIC and because of the statistical variability of the 1% sample the corresponding numbers have to be considered as approximation of the true employment figures.

**Estimation procedure**

CAREX includes internal routines which calculated some guiding figures on the basis of the labour force structure of the country and exposure prevalences in the reference countries:

1) a figure based on exposure prevalence in Finland (FIN)
2) a figure based on exposure prevalence in the United States (USA)
3) a figure based on the mean prevalence of Finland and the United States (AVERAGE)
4) own national estimate (OWN), designated by the national assessor
5) the number of exposed is zero (ZERO)

One of the values was set as DEFAULT VALUE. The logic in the selection of default value was that the AVERAGE value was preferred. If either the Finnish or the US value was flagged with a warning (indicating low validity), the other was proposed as the default value. Because the US NOES Survey did not cover all agents included in CAREX, the Finnish value was proposed if the US value was missing. If both Finnish and US values were flagged, the AVERAGE value was used as the default value because most often the US prevalence was suspected to be too high and the Finnish value too low. The following table summarises the default values in CAREX:

<table>
<thead>
<tr>
<th>FINNISH VALUE</th>
<th>no flag</th>
<th>flagged</th>
<th>zero</th>
</tr>
</thead>
<tbody>
<tr>
<td>US VALUE</td>
<td>no flag</td>
<td>AVE</td>
<td>USA</td>
</tr>
<tr>
<td></td>
<td>flagged</td>
<td>FIN</td>
<td>AVE</td>
</tr>
<tr>
<td></td>
<td>missing</td>
<td>FIN</td>
<td>OWN</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AVE</td>
<td>ZERO</td>
</tr>
</tbody>
</table>

**Estimates of multiple exposure**

If one worker is exposed to two agents, the number of exposed workers is one, but the number of exposures is two. The concept 'exposure' does not refer to the number of exposure events (e.g., 5 times/year) but to the qualitative occurrence of exposure of a worker.

The reason for distinguishing between exposure and exposed worker relates to the calculation of exposed workers in a CAREX-industry, or in a country. If we add up all exposures within an industry, we may be counting the same workers several times (in cases of multiple exposure) and end up with an overestimate. The CAREX estimation procedure addresses exposures (number of workers exposed to a specified agent). The number of exposures and that of the exposed workers is the same if there is only one carcinogenic exposure/worker within the CAREX-industry. The estimation of exposed workers in multiple exposure situation required the development of industry-specific factors (multipliers),
which convert the numbers of exposures to those of the exposed workers. These 'multiple exposure factor' were derived in CAREX for the Finnish data only. They are based on the assessment of additivity of exposed subgroups. The US NOES data did not allow us to derive multiple exposure factors by CAREX industry.

**Estimates of low confidence**

The confidence of many estimates in the reference countries was considered low. In Finland, the following criteria to flag estimates of low confidence were used (intuitively):

1) The order of magnitude of the estimate may be wrong. This concerns mainly low figures.

2) The absolute error may exceed 0.1% of the national workforce (about 2000 exposed workers in Finland). This concerns mainly high figures.

The premises for the US low confidence flags were different. By general survey/statistical design, NOES was intended to produce 'defensible estimates' of the number of workers exposed to specific agents at the 2-digit US SIC level. According to the Standard Error Tables, any NOES estimate of less than 8000 exposed workers is associated with a standard error of 25% or more. Therefore all such subindustrial estimates were marked as 'low confidence'. This resulted in earmarking a majority of US subindustrial estimates in CAREX which included exposure information at the 4-digit SIC level.

**Estimates of low level of exposure**

If the level of exposure was considered to be close to background, the estimate was marked as such. In Finland, the nonoccupational annual dose was used as a guideline. However, the background exposure may vary quite a lot and is often subjective. Many low exposures in Finnish data involved handling of small amounts of carcinogens in laboratories, pharmacies or hospitals. Volatility, dustiness and, in some cases, skin contact were used as criteria to make the decision of existence or lack of occupational exposure.

The premises for the US low level flags were different. NOES did not classify exposures by level and therefore 'low exposures' could not be systematically identified. The Finnish estimates which were judged to be close to the background level were used as one basis to mark NOES estimates. However, no NOES data were discarded on this basis which resulted in tagging of some exposures in laboratories as 'low level' in the USA when similar exposures were not considered to entail exposure (exceeding the background level) in Finland. Similarly, exposure to many impurities in polymeric materials and metal alloys were considered as 'low exposure' in the USA and as being below the minimum criterion of exposure in Finland. Another criterion to assign a 'low exposure' flag to NOES data was discrepancy with the Finnish data without an evident reason. For example, if there were over 10 000 exposed workers in a CAREX industry in NOES and none in Finland, it was assumed that most of the US exposures were of low level. In addition, some very small figures were considered to reflect low exposure.

**Exposure measurements included**

In order to identify worker groups at high risk, information on the level of exposure is important. A valid estimation of the level would require that the levels (eg, high and low) are accurately defined and enough knowledge on exposure circumstances from different countries are available. Industrial hygienic data are
available for many agents but their representativeness and generalisation across countries are debatable. It was considered too laborious and uncertain to estimate exposures by level in each of the countries. However, CAREX includes agent- and industry-specific measurement data to enable the user of the database to make his/her own estimations and conclusions on the levels. The descriptions of measurements also show illustrative examples of work tasks and operations where exposure may occur.

The industrial hygienic measurement sets are characterised by:

- country where measurements were carried out
- year(s) of measurements
- range of concentrations in standard units
- mean concentrations in standard units
- number of measurements on which the mean is based
- bibliographic reference
- brief description of the measurement site, process, representativeness etc

The measurement data was limited to data easily available from published or unpublished sources. In Finland, over 1,000 measurement sets were entered. Data were available for arsenic, asbestos, benzene, cadmium, chromium VI, diesel engine exhaust (measured as nitrogen dioxide), formaldehyde, glasswool, methylenechloride, nickel compounds, PAHs, lead, perchloroethylene, silica, styrene and wood dust. Most of the measurements are from Finland but also the IARC Monographs were used as sources of information.

In Germany a huge database of industrial hygiene measurements is documented by the BIA (Berufsgenossenschaftliches Institut für Arbeitssicherheit, St. Augustin). This database called MEGA is unpublished and under normal circumstances not available for use by researchers outside BIA. Unfortunately, it was not possible to include measurement data from MEGA in the CAREX system.

**Exposure by occupation and gender**

CAREX includes some information about carcinogenic exposures by occupation and gender at the national level. The countries of the European Union have adopted the ISCO 88 (COM) classification of occupations. The workforce data are available at the 3-digit level, but EUROSTAT has emphasised that comparability of figures across countries is poor because of non uniform definitions and data collection practises. Therefore, occupation was not used as a basic variable in CAREX. Instead, descriptive information of the distribution of exposures by occupation was provided for the reference countries (Finland and the United States). These data do not allow systematic calculation of exposure prevalences by occupation, but help to identify the occupations at potential risk.

Detailed workforce statistics of OECD were not separately available for men and women (except for some countries). Gender could therefore not be used as a basic variable in CAREX. The reference countries had some exposure information available for men and women separately and descriptive information was included in CAREX.

**Reference countries**

Finland
Finnish estimates were generated and documented as accurately as possible at subindustrial level. The major source of Finnish data were the reports of a comprehensive estimation survey (SUTKEA project) carried out by industrial hygienists of the Finnish Institute of Occupational Health (FIOH) in the late 1980s and early 1990s. SUTKEA summarised the exposure data and experience of FIOH on the situation in Finland. It was not a systematic field survey but was based on industrial hygienic data collected for separate research projects, or for compliance testing. Much of the exposure data collected for SUTKEA is included in CAREX as background data to indicate crudely the level of exposure in different work tasks. Because the measurements were partially carried out for compliance testing purposes, they cannot be generalised directly to all exposed workers in addressed industries. The numbers of exposed workers are estimates generated by individual Finnish experts responsible for the SUTKEA reports.

Another basic source of information was the national register of workers exposed to carcinogens (ASA Register) kept by FIOH since 1979. ASA data are based on employers' annual notifications on exposed workers and use of carcinogens. The ASA notifications are obligatory and they cover all salaried workers in Finland. However, the coverage of ASA is incomplete for many carcinogenic exposures, because occasional low level exposures are often not reported, and there are also employers who are not aware of exposures or who neglect the notification duty. ASA estimates, subjectively adjusted for incompleteness, were used in CAREX when SUTKEA did not provide an estimate of exposed workers. If neither SUTKEA nor ASA provided estimates, other available sources were used as the basis of estimation.

CONCEPT OF EXPOSURE: The basic criterion for assigning occupational exposure in Finland was that the annual exposure dose at work exceeded the nonoccupational dose. This was also the proposed criterion used to assess exposure in other countries in CAREX. If the dose due to occupational exposure was close to the background level and it was unclear if exposure was compatible with the definition of exposure, decisions on inclusion and exclusion were made. These decisions were documented in the CAREX system.

WARNING FLAGS: One weakness of Finnish estimation procedure was that it was not based on a systematic survey and it may have discarded many small groups of exposed workers, especially when exposure was infrequent or at a low level. If omission of small groups was suspected, a warning flag (red question mark in the CAREX application) was attached to all estimates proposed by CAREX for other countries. On the other hand, this estimation procedure is able to pick up some exposures which may have been missed by a sample-based field survey. A warning flag was used also to indicate that exposure may occur in other countries although it does not exist in Finland because there is no such industry (e.g., coal mining, oil drilling) or activity (manufacture of carcinogen X) at all in Finland. The person responsible for the Finnish data and estimates was Dr Timo Kauppinen (FIOH, Helsinki) who collaborated with many Finnish industrial hygienists and other experts.

The United States

The National Occupational Exposure Survey (NOES) conducted by the US National Institute for Occupational Safety and Health (NIOSH) was a nationwide observational survey conducted in a sample of 4,490 establishments from 1981-83. The goal of the NOES was to compile data on the kinds of exposure agents found in the workplace, and the kinds of safety and health programs which had been implemented at the plant level. The sample of establishments included in the survey was designed to represent those segments of industry covered under the Occupational Safety and Health Act of 1970. The target population was defined as employees working in establishments or job sites in the US employing eight or
more workers in a defined list of Standard Industrial Classifications. Generally, these classifications emphasized coverage of construction (USSIC1972 classes 15-17), manufacturing (20-39), transportation (40-47), private and business service (72-76), and hospital industries (80). The NOES had little or no sampling activity in agriculture, mining, wholesale/retail trade, finance/real estate, or government operations. The NOES sample was designed to maximize the reliability of estimates of the number of workers with defined characteristics, and utilized a two-stage sampling strategy which considered industrial activity, facility employment size, and geographical location. National estimates of the numbers of workers were obtained through the use of weighting factors assigned to sampled establishments, based on the probability of their selection from the national universe. The inverse of the sampling probability was then used as a weighting factor for facility-level observations, the results were subjected to ratio estimation to improve estimate precision, and then summed across sampled facilities nationally and by industry classification for final estimates.

The computerized NOES data file of approximately 10,000 chemical, physical, and biological agents was searched for the CAREX agents. Where the designated agent was not a single unique agent (eg, cadmium compounds) the appropriate IARC Monograph was searched for listings of individual agents by CAS number, and these CAS numbers were used to identify agents in the NOES data base for an 'aggregate estimate'. In the case of unique agents, an estimate of the number of US workers potentially exposed to the agent in question was produced for the US as a whole, and for all industry classifications at the 2-, 3-, and 4-digit US Standard Industrial Classification (SIC) levels in the NOES sample frame. In the case of an aggregate estimate, special computer processing allowed the production of estimates of the number of workers estimated to be potentially exposed to one or more of the agents in a nonunique or 'aggregated' list, again for the US as a whole, and for those industries at the 2-, 3-, and 4-digit SIC levels in the NOES sample frame.

NOES potential exposure data displayed in the CAREX system is limited to those industries which were sampled and surveyed in the NOES. The NOES did not provide for a sample in facilities employing less than 8 workers, or for activity in agriculture, mining, large portions of wholesale/retail trade, finance/real estate, or government operations. In order to utilize the NOES data in the CAREX system, it was necessary to convert the US 1987 SIC codes to the ISIC Rev2 system common outside the US. To accomplish this, a conversion table was established and used to convert from one coding system to the other so that data on the number of workers by industry estimated to be potentially exposed to carcinogens could be expressed in US SIC 1987, ISIC Rev2 notation, or ISIC Rev3 code, as desired. NOES data did not include environmental level measurements, with the exception of noise level readings.

MISSING NOES DATA: Because the NOES Survey did not cover all agents and industries in CAREX, first estimates based on NOES data could not be generated for uncovered CAREX agents or for uncovered or incompletely covered industries. If NOES covered a CAREX industry only partially, the number of exposed persons in the covered part of that industry was presented in the database (in Subgroup Exposure fields) but prevalence was not calculated because it was potentially invalid.

CONCEPT OF EXPOSURE: NOES addressed recordable potential exposure. A potential exposure had to meet two criteria to be recorded: (1) A chemical, physical or biological agent or a tradename product had to be observed in sufficient proximity to an employee such that one or more physical phases of that agent or product were likely to enter or contact the body of the employee, and (2) The duration of the potential exposure had to meet the minimum duration guidelines (at least 30 minutes/week on an annual average, or at least once per week for 90% of the weeks of the work year).
The following types of potential exposure were encountered: (1) Observed potential exposure: any potential exposure to chemical, physical, or biological agents observed directly by the surveyor. (2) Inferred potential exposure: If there is an observable dust accumulation or other physical evidence in the workplace which indicates that an agent is present in the workplace and if there are persons working in the immediate area of the agent and the minimum duration guidelines were met, or secondly, if the process is not functioning at the time of the surveyor’s observation, the surveyor must, through questioning, identify and record any potential exposures which in his/her judgement, are associated with the functioning process. For tradename products, the potential exposure was assigned to all components of the product. Approximately 80% of the exposures in NOES are due to the presence of agents in the tradename formulations, and about 80% of all NOES exposures are part-time in duration.

WARNING FLAGS: Because NOES data addressed potential (including very small) exposures, from 1981 to 1983, and did not cover all industries and agents in CAREX, it was considered reasonable to warn the users about applying US prevalence figures too directly to other countries. These flags are readable under the red question marks in the CAREX application. Selected Finnish estimates were also flagged with similar warnings. The NOES survey included data about part-time (or occasional) exposures and small groups of potentially exposed workers which were often discarded in Finnish estimates (resulting in a warning flag to some Finnish estimates). The NOES estimates were provided for the CAREX system by Dr David Pedersen and Mr Randy Young (NIOSH, Cincinnati, OH).
Results

Coal mining, metal ore mining, manufacture of industrial chemicals, manufacture of iron and steel, manufacture of electrical machinery, business/professional organisations, services allied to transport and international organisations employed in Germany proportionally at least 50% more workers than in the EU on average. On the other hand, fishing, production of crude petroleum and natural gas, footwear industry, wearing apparel industry and production of petroleum and coal products employed only 50% or less of the mean in the EU.

According to the preliminary estimates, there were over 8 million workers (24% of the employed) exposed to the agents covered by CAREX in Germany in 1990-93 (Appendix 1). The number of exposures was about 11 million. These figures are rounded from calculatory estimates presented in Appendix 1. Because of uncertainty of the estimates, it is reasonable to round all figures in the following appendices to a precision of one or two integers only.

Occurrence of exposure to specific agents in different industries is described in Appendix 2. Some agents (eg, research laboratory chemicals, certain pharmaceutical drugs) are used only in one or a few industries whereas some others (eg, environmental tobacco smoke, solar radiation, silica dust, lead chromium VI, diesel exhaust, PAH and radon) are widely distributed across industries. Appendix 2 does not provide any estimates for such industry-agent combinations where both Finnish and U.S. prevalences were considered inappropriate for the estimation of exposure in Germany.

The total numbers of exposed workers by agent are presented in Appendix 3. The most common exposures in Germany (Appendix 4) were solar radiation (2.4 million workers exposed at least 75% of working time), environmental tobacco smoke (2.0 million workers exposed at least 75% of working time), crystalline silica (1.0 million exposed), radon and its decay products (800 000), diesel engine exhaust (720 000), wood dust (680 000), benzene (470 000), lead and inorganic lead compounds (460 000), ethylene dibromide (440 000), chromium VI compounds (260 000), and glasswool (250 000).
Discussion

The German estimates are preliminary default estimates generated by the CAREX system. The methodological strengths and weaknesses of the CAREX system have been discussed elsewhere (Kauppinen et al 1998). Briefly, the strengths of CAREX are its systematic nature, good coverage and ease of use. Although several means to improve validity and to facilitate the estimation process were adopted, validity of the estimates is still of concern. Possible sources of error include the omission of country-specific exposure patterns, varying validity of the reference data used, and conversion difficulties of industrial classifications.

Substantial part of all exposures originated from natural sources (ultraviolet radiation from the sun, radon from the ground) or from activities not related to work as such (environmental tobacco smoke at work). The contribution of these environmental factors was over 5 million exposures out of 11 million exposures.

It is notable that the concept of exposure used in the reference countries differ. The Finnish protocol required in most cases that the nonoccupational exposure measured as annual dose had to be exceeded whereas the US protocol addressed potential exposure. The Finnish approach sets the minimum limit generally higher than the US approach and results in lower estimates of exposed workers. The CAREX system compromises between these two concepts and usually applies the average of the US and Finnish prevalences to calculate preliminary estimates for other countries. This means that the concept of exposure in CAREX becomes unclear and is between potential exposure (as in the USA) and exposure exceeding nonoccupational background (as in Finland). In practice CAREX thus partially addresses exposures which are lower than the background.

Another significant difference is that the US data is based on an observational field survey and the Finnish data on professional judgement. Both methods have their advantages and disadvantages. A field survey is sensitive in identifying typical and untypical exposures whereas professional judgement may neglect small exposed groups and atypical exposures. However, sometimes professional judgement may identify exposures which are missed in a comprehensive field survey. For example, the NOES sample did not include any nickel refineries and did not therefore identify nickel exposure in ISIC 372 (manufacture of other metals). The Finnish professional judgement identified nickel refineries and provided a more reliable estimate in this case. The US procedure provided empirical values for many rare agents but was unable to address all CAREX agents. Professional judgement in Finland was extended to cover all CAREX agents. The NOES procedure was based on direct observations and inferences at work places. The effect of subjective opinions on the results was probably rather small. However, inclusion or exclusion of very low or infrequent exposures may depend on the observer. The Finnish procedure based more on experience of the experts on occurrence and level of exposure in different industries, although industrial hygiene data and labour force data were also used to the extent possible.
Another kind of procedural difference arose when the CAREX estimates were compared with alternative estimates from a Swedish national report. The alternative estimates differed significantly from those generated by the CAREX system. Major source of difference was the definition of agent-specific exposure, and the estimation of low levels of exposure. Generally, the alternative exposure prevalences were lower than those in the CAREX. For example, CAREX was able to take crudely into account exposures of bystanders employed in workshops where stainless steel was welded. This is an appropriate and feasible approach when one bases the calculations on industry codes (as in CAREX) but very difficult when assessment is carried out by occupations (as in the Swedish method). Therefore bystander exposures were neglected in the estimation of alternative Swedish figures.

The reference data from the United States comes from 1981-83. Exposure patterns may have changed after that in the United States and elsewhere. For example, the production or use of some agents may have been forbidden or strongly restricted since then. Although CAREX does not use clearly outdated US figures as default values, there probably are a number of them which could not be identified as outdated during the CAREX project. Therefore some of the resulting CAREX estimates may be biased by the US situation in the early 1980s when occupational exposure to carcinogens may have been more frequent than in 1990-93. The Finnish estimates are for the same period (1990-93) as those of other EU countries.

Conversions between different industrial coding systems were used in the processing of labour force statistics and US (NOES) exposure data. Major part of labour force statistics came from OECD directly in the UN ISIC Revision 2 coding system. However, the OECD data are not coded originally according to UN ISIC but according to national classifications which are then converted to UN ISIC. Conversions, different definitions of the employed populations included, and estimations of missing values caused some inaccuracy and incomparability to the labour force statistics used in CAREX. Also the US workforce figures and exposure data were converted from US SIC 1987 through UN ISIC Rev 3 to UN ISIC Rev 2. The concersion was carried out at maximal level of specificity to minimise conversion errors. In spite of conversion problems, the order of magnitude of the labour force figures is probably correct and not a major source of error.

No previous estimates of numbers of workers exposed to carcinogens have to our knowledge been published for Germany. These data are preliminary and should therefore be interpreted with caution. The figures are standardised by the labour force structure of Germany but the exposure patterns specific to Germany, which may differ from those in the reference countries, have not appropriately been taken into account. Because of unknown validity of the estimates generated by the CAREX system, there is a need to continue this work at the national level.
Anttila A, Jaakkola J, Tossavainen A, Vainio H. Occupational exposure to chemical agents in Finland (In Finnish), Altisteet työssä 34, Työterveyslaitos ja työsuojelurahasto, Helsinki1992


APPENDIX 1. Employed, exposures and exposed workers by industry in Germany in 1990-1993

APPENDIX 2. Exposures (exposed workers) by industry and agent in Germany in 1990-1993

APPENDIX 3. Exposures (exposed workers) by agent in Germany in 1990-93

APPENDIX 4. Most common occupational exposures to IARC agents in Germany in 1990-1993