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

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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 8
  Estimates of multiple exposure 9
  Estimation procedure in Sweden 9
Results 10
Discussion 11
References and appendices 13
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 mainly on estimates generated by the CAREX system.

According to the preliminary estimates, there were ca. 800 000 workers (20% of the employed) exposed to the agents covered by CAREX in Sweden in 1990-93. The number of exposures was ca. 1.1 million. The most common exposures were solar radiation (240 000 workers exposed at least 75% of working time), environmental tobacco smoke (210 000 workers exposed at least 75% of working time), radon and its decay products (100 000), crystalline silica (86 000), wood dust (84 000), diesel engine exhaust (81 000), lead and inorganic lead compounds (35 000), benzene (34 000), ethylene dibromide (31 000), chromium VI compounds (21 000), glasswool (20 000) and PAHs (18 000).

In addition to estimates generated by the CAREX system, a set of alternative estimates was collected from a Swedish national report on exposure to carcinogens. These estimates differed sometimes significantly from CAREX estimates. Because the validity of the CAREX estimates is unknown, there is a need to continue discussion on methodological issues and assessment work to provide reliable estimates at the national level.
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
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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.

A diskette copy of CAREX is available from FIOH upon request (Dr Timo Kauppinen, Finnish Institute of Occupational Health, Topeliuksenkatu 41aA, FIN-00250 Helsinki, FINLAND, FAX 358-9-2414634). It is planned to make the CAREX data available also on the Internet.

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 industry-specific ('long') procedure which involves stratification by industry. The assessment of a few agents followed a 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 'exposure circumstances' evaluated by IARC were only briefly described. 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 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 Great Britain.

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 Swedish data.

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**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 Économiques 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.

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:
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.

Estimation procedure in Sweden

Two alternative approaches were used in Sweden. First, preliminary estimates were generated by the CAREX system. These estimates are adjusted for the economic structure/workforce distribution of Sweden, but they do not take into account country-specific exposure patterns, which may deviate in Sweden from those in the reference countries.

Second approach based on the data published in the Swedish national working environmental report (Plato, Nise, Lundberg 1995). The numbers of exposed workers were estimated for selected carcinogens by job title. Swedish labour force statistics classified by Swedish occupational codes at 5-digit level were used to identify the numbers of employed workers. The prevalence of exposure was estimated for each occupational group potentially exposed to the carcinogens under study. The numbers of exposed workers were calculated from the estimates prevalence and labour force figures. In order to produce figures comparable with the CAREX figures, occupation-based data were converted to the industrial classification of CAREX by using labour force figures on the distribution of occupations within industries. Because this estimation procedures differs from that used by the CAREX system, also results are presented separately.
Results

The main results are presented in appendices of this report. Appendix 1 shows the labour force structures in Sweden and the EU. Metal ore mining, welfare institutions, forestry and logging, water transport, paper industry, medical etc services, manufacture of petroleum and coal products, research and scientific institutes, and recreational and cultural services employed in Sweden proportionally at least 50% more workers than in the EU on average. On the other hand, coal mining, production of crude petroleum and natural gas, footwear industry, wearing apparel industry, international organisations, leather industry, pottery/china industry, textile industry, other manufacturing, fishing, water works, beverage industry, tobacco industry, agriculture/hunting, furniture industry, plastics industry, glass industry, petroleum refining, other mining, and rubber industry employed only 50% or less of the mean in the EU.

According to the preliminary estimates (Appendix 2), there were ca. 800 000 workers (24% of the employed) exposed to the agents covered by CAREX in Sweden in 1990-93. The number of exposures was ca. 1.1 million. These figures are rounded from calculatory estimates presented in Appendix 2. 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 3. 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 3 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 Sweden.

The total numbers of exposed workers by agent are presented in Appendix 4. The most common exposures in Sweden (Appendix 5) were solar radiation (240 000 workers exposed at least 75% of working time), environmental tobacco smoke (210 000 workers exposed at least 75% of working time), radon and its decay products (100 000), crystalline silica (86 000), wood dust (84 000), diesel engine exhaust (81 000), lead and inorganic lead compounds (35 000), benzene (34 000), ethylene dibromide (31 000), chromium VI compounds (21 000), glasswool (20 000) and PAHs (18 000).

The alternative estimates produced on the basis of the Swedish national report on exposure to carcinogens (Plato, Nise, Lundberg 1995) are presented in appendix 6.
Discussion

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.

The alternative estimates produced on the basis of the Swedish national report on exposure to carcinogens differ sometimes significantly from those generated by the CAREX system. The alternative estimates incorporate some misclassification that underestimate the workforce and the numbers of exposed as compared to the CAREX model. Another source of difference is the definition of agent-specific exposure, and the estimation of low levels of exposure. Generally, the alternative exposure prevalences are lower than those in the CAREX. For example, CAREX is able to take crudely into account also exposures of bystanders employed in workshops where stainless steel welding is being carried out. This is an appropriate and feasible approach when one bases the calculations on industry codes but very difficult when assessment is carried out by occupations.

The differences in method to estimate the labour force and exposures ends up in a systematic underestimation in the alternative Swedish numbers. The CAREX figures are often about 3-4 times higher than the previous Swedish figures. Two illustrative examples are described below:

**Example 1:** Exposure to chromium (VI) in welding of stainless steel

Total number of welders in Sweden was 27 145 males and 1 003 females (occupation code 756.12 in any industry). The Swedish welding association estimated that 7% of welders work (regularly?) with stainless steel which equals with 1 970 welders exposed to chromium VI. When industry code 381 (metal products) is linked with occupational code 756.12, there would be 9 356 welders and 655 welders exposed to chromium VI.

The comparative CAREX estimates extrapolated to Sweden are 7 397 welders exposed to chromium VI, out of which 2 751 are employed in industry 381 (metal products). The Swedish alternative figures are only 27% and 24% of the respective CAREX estimates. One important reason for the discrepancy is that CAREX estimates 20% of welders as regularly or temporarily exposed, and that also an equivalent number bystanders are considered exposed in some industries.
Example 2: Exposure to wood dust and formaldehyde

For exposure to wood dust and formaldehyde in the furniture industry, the Swedish occupation-based estimates are 2235 (of 3179 employed in potentially exposing jobs) and 956 (of 3864), respectively. The CAREX estimates are 6502 and 2746, respectively, both from the total labour force of 8120.

The occupation-based method identified 2 314 wood shop teachers and 19 019 carpenters exposed to wood dust. The CAREX system estimated 446 exposed teachers (SIC 931 education services) and 30062 exposed carpenters (SIC 5 construction) in Sweden. In addition, CAREX earmarks carpenters as having 'low level of exposure'.

Because the validity of the estimates generated by the CAREX system is unknown, and the occupation-based Swedish estimates may underestimate the numbers of the exposed workers, there is a need to continue discussion on methodological issues and assessment work to provide reliable estimates 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, Helsinki 1992


APPENDIX 1. Employed by industry in Sweden and EU in 1990-93
APPENDIX 2. Employed, exposures and exposed workers by industry in Sweden Britain in 1990-1993
APPENDIX 3. Exposures (exposed workers) by industry and agent in Sweden in 1990-1993
APPENDIX 4. Exposures (exposed workers) by agent in Sweden in 1990-93
APPENDIX 5. Most common occupational exposures to IARC agents in Sweden in 1990-1993
APPENDIX 6. Alternative Swedish estimates