OCCUPATIONAL EXPOSURE TO CARCINOGENS IN THE CZECH REPUBLIC IN 1997

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CAREX is an international information system on occupational exposure to known and suspected carcinogens. The CAREX (CARcinogen EXposure) database, constructed in the mid-1990s 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). 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.

In 1999-2000, CAREX approach was applied to Estonian, Latvian, Lithuanian and Czech exposure situation in 1997 as part of EU-INCO Copernicus project ‘Comparative analysis of occupational health system and practices as part of preventive health care systems in seven European countries (FIBELLC project)’. The first estimates generated by CAREX were checked and improved by national experts in Estonia, Latvia, Lithuania and the Czech Republic for asbestos, benzene and lead, which were agents of special interest for the project. The estimates for other CAREX agents were left as such. In addition, Estonian and Lithuanian exposure data were collected and included in the CAREX database.

According to the preliminary estimates, there were about 1 400 000 workers (28% of the employed) exposed to the agents covered by CAREX in the Czech Republic in 1997. The number of exposures was approx. 1 800 000. The most common exposures were solar radiation (370 000 workers exposed at least 75% of working time), environmental tobacco smoke (270 000 workers exposed at least 75% of working time), wood dust (180 000 exposed), crystalline silica (170 000), diesel engine exhaust (130 000), radon and its decay products (120 000), lead and inorganic lead compounds (71 000), benzene (67 200), asbestos (56 000), ethylene dibromide (50 000), and formaldehyde (44 000).

This report and its appendices are freely available also through the Internet (http://www.occuphealth.fi/list/data/CAREX).
Introduction

The 'Europe Against Cancer' program of the European Union (EU) prompted in the mid-1990s a project on the estimation of the burden of occupational cancer in Europe, which included a component on occupational exposure to carcinogens. This substudy 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 had 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 results were published in the project report (Kauppinen et al 1998), in 15 country reports, and in scientific literature (Kauppinen et al 2000). Basic data and essential parts of the reports are freely available also in the Internet (http://www.occuphealth.fi/list/data/CAREX). A more complete CAREX documentation, such as definitions, subindustrial estimates, descriptive information, results of exposure measurements, labour force data, and bibliographic references are included in the CAREX database maintained by FIOH.

In 1999-2000, CAREX approach was applied to Estonian, Latvian, Lithuanian and Czech exposure situation in 1997 as part of EU-INCO Copernicus project ‘Comparative analysis of occupational health system and practices as part of preventive health care systems in seven European countries (FIBELLC project)’. The first estimates generated by CAREX were checked and improved by national experts in Estonia, Latvia, Lithuania and the Czech Republic for asbestos, benzene and lead, which were agents of special interest for the project. The estimates for other CAREX agents were left as such. In addition, Estonian and Lithuanian exposure data were collected and included in CAREX database. The Czech results are reported in this document.

This work was partially financed by the EU-INCO Copernicus project no PL 973108.
Material and methods

Overview of the assessment method and data included in Carex

The assessment procedure of CAREX 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 was based on the Microsoft Access 2 database which could be run on personal computers. In 1999, CAREX was updated to Access 97 database and renamed as CAREX 2. Data from Estonia, Latvia, Lithuania and the Czech Republic were entered in this new version of CAREX.

The preference in the original CAREX project was to use original national estimates on carcinogenic exposures, but their poor availability forced 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, Toikkanen, Pukkala 1998) and ASA databases (Kauppinen et al 1992), 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.

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. The estimation of multiple exposure to the CAREX agents was carried out only in Finland due to limited resources available, and the Finnish values were applied to all other countries.

**Agents and industries**

**Agents covered**

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 3 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.

**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. As far as possible, we tried to include all employed persons in the industry covering salaried workers, self-employed, working family members and part-time workers.

Industry specific estimation procedure

Estimation procedure of Carex

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

1) an estimate based on exposure prevalence in Finland (FIN)
2) an estimate based on exposure prevalence in the United States (USA)
3) an estimate based on the mean prevalence of Finland and the United States (AVERAGE)
4) own national estimate (OWN) provided by the national assessor
5) an opportunity to set the number of exposed to 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 often the US prevalence was presumed to be too high and the Finnish value too low. The following table summarises the rationale of the default values in CAREX:

<table>
<thead>
<tr>
<th>US VALUE</th>
<th>FINNISH VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flagged</td>
<td>FIN AVE ZERO</td>
</tr>
<tr>
<td>Missing</td>
<td>FIN OWN ZERO</td>
</tr>
<tr>
<td>Zero</td>
<td>AVE ZERO ZERO</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FINNISH VALUE</th>
<th>Flagged</th>
<th>Zero</th>
</tr>
</thead>
<tbody>
<tr>
<td>No flag</td>
<td>AVE US</td>
<td>AVE</td>
</tr>
<tr>
<td>Flagged</td>
<td>FIN AVE</td>
<td>ZERO</td>
</tr>
<tr>
<td>Missing</td>
<td>FIN OWN</td>
<td>ZERO</td>
</tr>
<tr>
<td>Zero</td>
<td>AVE ZERO</td>
<td>ZERO</td>
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</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' in CAREX does not refer to the number of exposure events (eg 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 were 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.

**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 were available for many agents but their representativeness and generalisation across countries were debatable. It was considered too laborious and uncertain to estimate exposures by level in each of the countries with the limited resources available. However, measurement data were collected and included in the CAREX to enable the user of the database to make his/her own estimations and conclusions on the levels.

The industrial hygienic measurement sets in CAREX were 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 was 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, methylene chloride, nickel compounds, PAHs, lead, perchloroethylene, silica, styrene and wood dust. Most of the measurements were from Finland but also the IARC Monographs were used as sources of information.

**Estimation procedure in 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 can not 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 (eg, 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 (e.g., 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).

### Estimation procedure in the Czech Republic

An estimate of the prevalence of exposure to asbestos, benzene and lead among working population in the Czech Republic in 1997 relies mostly on records of the Czech Hygienic Service and district authorities. With permission of the Major Hygienic Officer, the National Institute of Public Health at Prague asked for collaboration with the Regional Hygienic Officers. With an exception of two regions all of them participated in the project. So, via District Hygienic Officers and some other district authorities the data on approximately 80% of the Czech working population were summarized at the regional level and forwarded to the National Institute of Public Health. The final estimates are based on the assumption that the structure of the labour force in the missing parts of the Czech Republic is similar to the those parts of the country which provided exposure data.
Results

According to the preliminary estimates, there were about 1,400,000 workers (28% of the employed) exposed to the agents covered by CAREX in the Czech Republic in 1997 \( (\text{Appendix 1}) \). The number of exposures was approximately 1,800,000. 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 (e.g., research laboratory chemicals, certain pharmaceutical drugs) are used only in one or a few industries whereas some others (e.g., 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 the Czech Republic.

The total numbers of exposed workers by agent are presented in Appendix 3. The most common exposures in the Czech Republic (Appendix 4) were solar radiation (370,000 workers exposed at least 75% of working time), environmental tobacco smoke (270,000 workers exposed at least 75% of working time), wood dust (180,000 exposed), crystalline silica (170,000), diesel engine exhaust (130,000), radon and its decay products (120,000), lead and inorganic lead compounds (71,000), benzene (67,200), asbestos (56,000), ethylene dibromide (50,000), and formaldehyde (44,000).
The Czech estimates with the exception of asbestos, benzene and lead, 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 2000). 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, differences in national estimation procedures, 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 in the Czech Republic was over 750 000 out of 1 800 000 exposures.
References and appendices

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APPENDICES

APPENDIX 1. Employed, exposures and exposed workers by industry in the Czech Republic in 1997

APPENDIX 2. Exposures (exposed workers) by industry and agent in the Czech Republic in 1997

APPENDIX 3. Exposures (exposed workers) by agent in the Czech Republic in 1997

APPENDIX 4. Most common occupational exposures to IARC agents
in the Czech Republic in 1997