

Occupational Exposures to Carcinogens in Italy:

An Update of CAREX Database

DARIO MIRABELLI, MD, TIMO KAUPPINEN, PHD

To update estimates of the prevalence of occupational exposures to carcinogens in Italy, the 85 CAREX agents were re-assessed. The original exposure estimates in the CAREX database were updated, taking into account changes in exposure patterns and in numbers of employees by industrial class. The 21.8 million employees in Italy, 19.4 in industry and services, 2.4 in agriculture, had 4.2 million exposures. Prevalences of exposures were highest for environmental (passive) tobacco smoke (800,000 exposures), solar radiation (700,000), diesel engine exhaust (500,000), wood dust (280,000), silica (250,000), lead and inorganic lead compounds (230,000), benzene (180,000), hexavalent chromium compounds (160,000), glass wool (140,000), and PAHs (120,000). Exposures to carcinogens at work are still an issue in Italy and do not appear to be controlled as strictly as they should be. *Key words:* carcinogens; occupational exposure; primary prevention; workers' protection.

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Knowledge of exposure to carcinogens at work is needed to set up effective prevention programs and strategies. The "Europe Against Cancer" program of the European Union (EU) prompted a project to estimate the burden of occupational cancer in Europe, which included a component on occupational exposure to carcinogens. An international group of experts provided documented estimates of the numbers of workers exposed to carcinogens in the EU, by country, agent, and industry.¹

An exposure information system, CAREX (carcinogen exposure) was developed and was used by the group of experts to estimate national exposure patterns in EU countries. The initial exposure assessment carried out with CAREX aimed at estimating exposures in the 1990-1993 period. CAREX has been extended to new EU member countries,² but not updated. We provide here an update to the 2000-2003 period for Italy.

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Address correspondence and reprint requests to: Davio Mirabelli, MD, Unit of Cancer Epidemiology, Centro per la Prevenzione Oncologica, Università di Torino, Via Santena 7, 10126 Torino, Italy.

MATERIALS AND METHODS

Overview of Exposure Assessment

The CAREX assessment procedure is fully described elsewhere.¹ Briefly, 1) agents, exposures, and industries were defined; 2) national labor-force data by industry were obtained; 3) reference exposure prevalences from Finland and the United States were computed; 4) default figures of exposed workers by country, agent, and (in most instances, see below) industry were produced; 5) national experts reviewed and corrected these figures; 6) correction factors for multiple exposures were estimated; 7) the overall number of workers exposed to carcinogens was computed.

Agents Covered and Exposure Definition

CAREX included all agents, groups of agents, and mixtures that 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, ionizing radiation was included, although not evaluated at that time by IARC. Some of the group 1 or 2A agents are 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 settings as complex mixtures, and exposure to a single PAH is impossible to disentangle. However, tobacco smoke (passive exposure at work) and diesel exhaust, while recognized also as complex mixtures containing PAHs, were assessed separately. Ultraviolet radiation A, B, and C were merged under the title artificial ultraviolet radiation, and assessed separately from solar radiation. Exposure to hepatitis B and C viruses was not assessed due to difficulties in defining the concept of exposure.

Most agents and groups of agents (85 items, including PAHs as a single item) were assessed according to a detailed procedure that provided 55 industry-specific estimates of the number of exposed workers in each country. Nine agents (including artificial ultraviolet

radiation and erionite) were assessed according to a country-specific procedure that provided only one overall estimate per country. Fifteen exposure circumstances carcinogenic according to IARC were only briefly described in CAREX. For eight carcinogens (including betel quid, salted fish, some viruses) exposure was considered primarily not occupational and the number of exposed workers was assumed to be zero.

This update includes only the agents that were assessed according to the industry-specific procedure. For the sake of comparison with our previous estimates, new IARC carcinogens (Volumes 64–83) have not been included.

The definition of occupational exposure (relevant route of exposure, level relative to non-occupational, background exposure) was the same as in the original assessment procedure.¹

Characterization of Industry and Labor Force

The numbers of exposures in CAREX were estimated mainly 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 levels. The number of industrial classes in CAREX was 55.

In this update the number of employed workers in each class was estimated according to the results³ of the 2001 Italian National Census of Industry and Services (INC-IS), which provided information about all employees, including salaried workers, self-employed workers, working family members, and part-time workers, except in agriculture and forestry. Only employees in “industrial activities” in agriculture and forestry are enumerated in INC-IS; the numbers of other agricultural and forestry workers, mainly self-employed workers, working family members, and part-time workers in enterprises officially classified as “agricultural” as opposed to “industrial,” were estimated according to the results³ of the 2001 Italian National Census of Agriculture (INC-A).

Exposure Measurements

Systematic estimation of the levels of exposure to CAREX agents was lacking¹ at the time of the original procedure and is not yet available in Italy.

Estimation Procedure

Default estimates, low-exposure-level estimates, and estimates of multiple exposures were provided by the CAREX database, thus reflecting the original choices and methods.¹ In CAREX default estimates had been computed for each country for a combination of 85 agents in 55 industry classes, by applying the default exposure prevalences from two reference countries,

Finland and the United States, to national industry-specific labor force figures. The main sources of Finnish data were: the SUTKEA project,⁴ a survey carried out by the Finnish Institute of Occupational Health (FIOH) in the late 1980s and early 1990s, the ASA register,⁵ the Finnish national register of workers exposed to carcinogens, and FINJEM,⁶ an exposure information system developed by FIOH. The United States data came from the National Institute for Occupational Safety and Health (NIOSH) NOES nationwide survey conducted in a sample of more than 4,000 plants in the early 1980s.⁷

Default estimates had been reviewed by the national experts, who could refine them, choosing among the following: 1) switch from the Finnish- to the USA-based estimate or vice versa; 2) average the two; 3) produce their own industry-specific exposure assessments. This was mostly accomplished by defining relevant subgroups of exposed workers within the CAREX industry classes, and assessing the number of workers belonging to each, the CAREX information system then providing appropriate sums at the industrial class level. Experts could also flag the subgroup estimates they considered either low-level (levels close to those of non-occupationally exposed groups) or low-confidence (exposures reported to occur in specific cases, whose relevance for the overall subgroup was judged unclear).

The expert's judgment for Italy was based partly on his own experience and partly on evaluations received from a group of Italian industrial hygienists collaborating in a surveillance program of occupational hazards launched in 1996–97 by the Piedmont region. The same expert went now through the CAREX database and revised and updated his original exposure estimates, taking into account changes that occurred in Italy after 1990–93 as well as changes in the numbers of workers employed in the 55 industrial classes of CAREX, according to INC-IS and INC-A.

RESULTS

According to the 2001 Censuses of Industry, Services and Agriculture there were 21.8 million employees in Italy, 19.4 in industry and services, 2.4 in agriculture. These workers had altogether 4.2 million exposures not considered either low-level or low-confidence by the rater. Ignoring the problem of multiple exposures, this would correspond to 19% of all employees, or approximately 1 exposure to a CAREX carcinogen for every 5 workers.

The prevalences of exposures were highest for environmental (passive) tobacco smoke (800,000 exposures), solar radiation (700,000), diesel engine exhaust (500,000), wood dust (280,000), silica (250,000), lead and inorganic lead compounds (230,000), benzene (180,000), hexavalent chromium compounds (160,000), glass wool (140,000), and PAHs (120,000). The ten most

common exposures are the same as those already identified in CAREX,¹ with the relevant exception of asbestos. For a proper quantitative comparison of current and previous estimates it should be borne in mind that we present here only data referring to exposures not flagged as low-level or low-confidence, whereas the published CAREX report¹ included all exposures. Tabulations of exposures not flagged as low-level or low-confidence, however, are downloadable from the Center for Cancer Epidemiology and Prevention–CPO Piemonte Web site.⁸ For some agents, the inclusion of low-level/low-confidence exposures can strongly influence the overall figures: in previous CAREX estimates, relative to 1990–93, the prevalence of exposure to asbestos was 680,000 with, 350,000 without them. A similar effect was present for PAHs: 350,000 exposure, falling to 130,000 with exclusion of those considered low-level/low-confidence. A less strong but still important effect was present for lead and inorganic lead compounds: from 290,000 to 215,000. However, estimates of most of the other carcinogens, notably environmental tobacco smoke, solar radiation, diesel engine exhaust, wood dust, silica, benzene, hexavalent chromium compounds, and glass wool, were affected minimally, or not at all, and published data¹ may be used for comparison.

Overall, 5.6 million exposures had been estimated in 1990–93, 4.4 million of which were not considered low-level/low-confidence, compared with 4.2 million currently.

Exposure to environmental tobacco smoke increased only slightly; however, major changes occurred in its distribution. Exposure almost disappeared for employees in the public administration at large (ISIC economic activities 91 “Public Administration and Defence,” 931 “Education services,” 932 “Research and scientific institutes,” 933 “Medical, dental, other health and veterinary services,” 934 “Welfare institutions,” which in Italy are largely public), whereas the number of exposed persons increased according to the relevant rise in the number of employees in other non-industrial activities, such as ISIC 8 “Financing, insurance, real estate and business services,” or 935-9 “Business, professional and other organisations.”

Other major changes include the large increase in exposure to solar radiation, and the large drop in asbestos exposure. A comparison of the most prevalent exposures between former CAREX and the current updated estimate is given in Table 1. Complete reports of current estimates can be found in Appendices A and B.

DISCUSSION

The strengths and limitations of CAREX have been described elsewhere.¹ Briefly, it is a systematic assessment of exposures to carcinogens, applying consistently the same method to all EU member states, covering all economic activities and a wide range of carcinogens (a

TABLE 1 Most Prevalent Exposures: Comparison between Former CAREX and Current Estimates*

Carcinogen	Current	Former CAREX
Tobacco smoke (environmental)	806,550	770,468
Solar radiation	702,100	562,000
Diesel engine exhaust	521,162	552,495
Wood dust	279,747	309,464
Silica, crystalline	254,657	269,688
Lead and lead compounds, inorganic	227,820	215,325
Benzene	184,025	176,543
Chromium VI compounds	156,225	134,056
Glasswool	138,191	148,425
Polycyclic aromatic hydrocarbons (excl. environmental tobacco smoke)	121,716	127,315
Formaldehyde	113,384	74,508
Tetrachloroethylene	106,290	102,500
Nickel compounds	97,178	78,575
Asbestos	76,100	352,691
Strong-inorganic-acid mists containing sulfuric acid (occup. exp. to)	54,363	48,713
Methylene chloride	51,740	38,581
Cadmium and cadmium compounds	44,623	32,346
Styrene	36,861	30,532
Trichloroethylene	34,481	41,919
Arsenic and arsenic compounds	32,436	28,322

*Numbers of exposures across all 55 CAREX industries.

comprehensive list of IARC Group 1 and Group 2A agents in 1995, plus selected Group 2B, had been used). However, CAREX estimates were not the direct result of field surveys. The preliminary estimates were actually computed by applying exposure prevalences from Finnish data (ASA registry and others) or from U.S. data (NOES survey) to national work-force statistics; the refined estimates were produced by national experts, sometimes with the support of some country-specific data, but not in the case of Italy. Thus, the estimates for Italy reflected the personal experience and knowledge of the rater, and this fact can limit their validity. The same pros and cons apply to the current exercise of updating CAREX estimates for Italy.

Recently some European countries implemented national information systems on occupational exposures: for instance, ATABAS and PROBAS in Denmark, FINJEM in Finland, COLCHIC in France, GESTIS in Germany, WAUNC in The Netherlands, and the National Exposure Database in United Kingdom. No comparable database currently exists in Italy.

In the absence of both industrial hygiene data and descriptive information about exposure occurrences, it would appear reasonable to consider the prevalences of exposures to carcinogens at work to be equivalent to those used in the previous CAREX estimates, unless the knowledge of specific, relevant, circumstances suggest otherwise.

A 1992 law, coming into effect in 1993, banned the use of asbestos in the production of any kind of goods in Italy, as well as its import and export.⁹ Two years were allowed to sell all stocks of asbestos materials. A further important feature of the law was the introduction of strict control on asbestos removal, which must be reported to the inspection bodies of local health authorities and has to be carried out according to specific and high technical standards.

In 1994 a law¹⁰ applied in Italy for the first time a series of EU directives on health and safety at work, among others Directives 89/391/CEE¹¹ and 90/394/CEE.¹² Modified in 1996,¹³ the law included two new legal obligations for Italian employers: 1) to switch from a carcinogen to a safer agent, if feasible, and 2) to register exposures to carcinogens. All other provisions of the EU directives were already mandatory in Italy.

Last, it must be mentioned that smoking in public offices and buildings, such as schools and hospitals, had been forbidden a long time ago, but this legislation has only recently been enforced.¹⁴ The actual implementation of new regulations is never a straightforward process. It takes a long time and considerable enforcement efforts before becoming satisfactory; this is even more true when the regulation is technically complex, and leads to increasing industrial costs, as in the case of the EU directives on carcinogens. However, these new regulations called for an update of previous estimates of exposure to carcinogens. Major changes had occurred in the Italian economy during the whole span of the 1990s, with shrinkage of employment in industry, particularly in traditional mechanical industry, and a steady and constant increase in the number of workers in services; this was another reason for updating the CAREX estimates.

Exposure prevalences were assumed to have remained approximately constant, due to the inertia of complex developed economies such as that of Italy, but the asbestos regulation and that on smoking in public places have been considered capable to have produced important changes. On the other hand, the regulation on carcinogens at work in general has not yet produced, in our view, a comparable impact on actual exposures of workers, for many reasons. First, this regulation is often applied only to carcinogens intentionally introduced at work as raw or auxiliary materials, identified by their packaging and labeling according to the specific EU regulation¹⁵; however, most of the exposure circumstances relevant for many common carcinogens at work are due to their formation as byproducts, combustion products, etc., during the production processes. Second, even the carcinogens that are present in raw materials, such as PAHs in aromatic extracts used as extender oils in the rubber industry, are not easily identified: their concentrations may be variable and at least sometimes low enough to offer producers a justification to avoid their labeling as carcinogen-containing mixtures, as well as the corresponding warnings on material

data sheets. In other words, there are, in our opinion, cultural difficulties in hazard identification when carcinogens are at issue. Further consequences of such difficulties are: 1) no field survey of exposures to carcinogens at work has yet been conducted either by industrial organizations or by the public bodies in charge of law enforcement; 2) registration of exposed workers, even if mandatory by law according to the EU directives on carcinogens at work, has not been implemented. In accordance with the above considerations:

- Estimates of exposures to asbestos have been thoroughly revised. Many previously relevant exposures have been now considered low-level/low-confidence, if they have not completely disappeared; thus they do not contribute to the current estimates. They include passive exposure of workers in heat-intensive processes, as in the chemical and petrochemical industries, in oil refineries, in certain food-processing industries, in steel mills and rolling stock mills, etc. Exposure in the construction industry has been judged considerably reduced, but has not completely disappeared: a prevalence about 5% of employees has been assumed, yielding an estimate of 70,000 exposed workers. Other small groups of exposed workers have been identified among maintenance workers of transport systems and equipment, and of water pipings.
- Estimates of exposures to environmental tobacco smoke (ETS) have been revised systematically. There is anecdotal evidence of a major reduction in smoking at the workplace among employees in public offices and buildings. Accordingly, all previous CAREX estimates in the economic activities of public administration, or where public administration is dominant in Italy, such as health services, have been revised, and prevalence of exposure to ETS has been considered marginal. In private industries and premises smoking is not forbidden, and since the overall prevalence of tobacco smokers in adults is still around 24% for both sexes combined,¹⁶ the prevalence of workers exposed to ETS among office workers has been considered not to have changed. No exposure of workers in production (blue-collar workers and plant technicians) has been considered, as in CAREX, since in many workplaces smoking is not allowed for safety reasons.
- Exposure prevalences for other carcinogens have been considered, on average, the same as in CAREX, but new denominators (i.e., number of employees by industry class) have been used to compute the expected numbers of exposures.

We did not take into account new agents classified as carcinogens by IARC since 1995 (Voll 64–83). Among Group 1 agents, we thus excluded postmenopausal estrogen replacement therapy (ERT), tamoxifen, 2,3,7,8-tetrachlorodibenzo-p-dioxin, viruses such as

HIV-1, EBV, HPV-16 and -18, HTLV-I, and among Group 2 A agents alpha-chlorinated toluenes, etoposide, glycidol, teniposide, o-toluidine. Among group 2 B we did not consider carbon blacks, ethylbenzene, magnetic fields at extremely low frequencies, naphthalene, nitrilotriacetic acid, postmenopausal estrogen-progestogen therapy, paligorskite, or refractory ceramic fibers. Ionizing radiations and certain radionuclides had been already considered in CAREX, as well as environmental tobacco smoke, and the upgrading of crystalline silica from group 2 A to 1 does not imply in itself any change in the CAREX estimate of exposure prevalence. At the same time, we continued to include glass wool, which IARC in Vol 81 downgraded to Group 3, along with glass filament, and rock and slag wool.

Extending our estimates to these agents would have largely increased them, particularly when considering 2,3,7,8-tetrachlorodibenzo-p-dioxin, carbon blacks, ethylbenzene, magnetic fields at extremely low frequencies, and naphthalene. However, comparability between current and previous CAREX estimates would have been impaired.

CONCLUSIONS

Work entails exposure to carcinogens for almost one employee out of five, and exposure prevalence has not changed much in the last ten years or so. The frequent habit of relying on material data sheets and/or labels on packages of raw materials limits the ability of employers to identify occupational carcinogenic hazards, which may have nothing to do with labels and packages (e.g., diesel engine exhaust). Even when carcinogens are chemicals classified according to the EU regulations, often they are not bought on the market, but are present as trace contaminants of other substances or mixtures, or they arise during an industrial process.

Exposure to carcinogens at work is still a relevant issue in public health in Italy and it does not appear to be controlled as strictly as it should be.

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APPENDIX A

Exposures by Economic Activity, Excluding Low-level, Low-probability Exposures

Agent	Estimate Type	Exposures	Agent	Estimate Type	Exposures
11 Agriculture and hunting			313 Beverage industries		
Captafol	specific	12000	Chromium VI compounds	specific	150
Radon and its decay products	specific	5000	Diesel engine exhaust	US	3582
Solar radiation	specific	390000	Tobacco smoke (environmental)	specific	300
Wood dust	specific	10000	Nickel compounds	specific	150
Total		417000	Tetrachloroethylene	US	298
12 Forestry and logging			Radon and its decay products	specific	9000
Solar radiation	specific	2400	Trichloroethylene	US	79
Wood dust	specific	10000	Total		13559
Total		12400	314 Tobacco manufacture		
13 Fishing			Diesel engine exhaust	US	18
Diesel engine exhaust	specific	5600	Tobacco smoke (environmental)	specific	100
Tobacco smoke (environmental)	specific	8400	Polycyclic aromatic hydrocarbons (excl.)	US	161
Solar radiation	specific	3200	Tetrachloroethylene	US	37
Total		17200	Trichloroethylene	US	62
21 Coal mining			Total		378
Tobacco smoke (environmental)	specific	50	321 Manufacture of textiles		
Total		50	Cadmium and cadmium compounds	US	693
22 Crude Petroleum and Natural Gas Production			Chromium VI compounds	US	4074
Strong-inorganic-acid mists containing sulfuric acid	US	140	Diesel engine exhaust	US	1252
Chromium VI compounds	US	117	Dimethyl sulfate	US	110
Diesel engine exhaust	US	737	Tobacco smoke (environmental)	specific	2500
Tobacco smoke (environmental)	specific	200	Formaldehyde	Finnish	5864
Nickel compounds	specific	110	Glass wool	US	1623
Polycyclic aromatic hydrocarbons (excl.)	US	87	Nickel compounds	specific	1000
Silica, crystalline	US	164	Total		17116
Total		1555	322 Manufacture of wearing apparel, except footwear		
23 Metal Ore Mining			Cadmium and cadmium compounds	US	28
Diesel engine exhaust	Finnish	171	Chromium VI compounds	specific	4000
Polycyclic aromatic hydrocarbons (excl.)	Finnish	27	Diesel engine exhaust	US	2258
Radon and its decay products	specific	100	Tobacco smoke (environmental)	specific	4000
Silica, crystalline	specific	300	Formaldehyde	specific	5000
Total		598	Nickel compounds	specific	4000
29 Other Mining			Total		19286
Diesel engine exhaust	Finnish	15412	323 Manufacture of leather and products of leather or of its substitutes		
Tobacco smoke (environmental)	specific	1000	Strong-inorganic-acid mists containing sulfuric acid	average	3077
Polycyclic aromatic hydrocarbons (excl.)	Finnish	237	Chromium VI compounds	average	2241
Silica, crystalline	specific	15000	Diesel engine exhaust	specific	300
Solar radiation	specific	55000	Tobacco smoke (environmental)	specific	700
Total		86649	Methylene chloride	specific	7000
311-2 Food manufacturing			Nickel compounds	specific	300
Cobalt and its compounds	Finnish	478	Lead and lead compounds, inorganic	specific	300
Chromium VI compounds	specific	4000	Tetrachloroethylene	specific	7000
Diesel engine exhaust	US	6447	Trichloroethylene	specific	7000
Tobacco smoke (environmental)	specific	4000	Total		27918
Nickel compounds	specific	4000	324 Manufacture of footwear		
Polycyclic aromatic hydrocarbons (excl.)	Finnish	954	Cadmium and cadmium compounds	US	133
Radon and its decay products	specific	2000	Chromium VI compounds	specific	3000
Total		21879	Diesel engine exhaust	specific	550
			Tobacco smoke (environmental)	specific	1500
			Methylene chloride	specific	12000
			Nickel compounds	specific	3000
			Tetrachloroethylene	specific	12000
			Trichloroethylene	specific	12000
			Total		44183

Agent	Estimate Type	Exposures
331 Manufacture of wood and wood and cork products, except furniture		
Arsenic and arsenic compounds	specific	18000
Cadmium and cadmium compounds	US	77
Chromium VI compounds	specific	4500
Diesel engine exhaust	US	8402
Tobacco smoke (environmental)	specific	1500
Formaldehyde	average	16767
Methylene chloride	specific	2000
Nickel compounds	specific	4500
Styrene	average	129
Wood dust	specific	68000
Total		123875
332 Manufacture of furnitures and fixtures, except primary of metal		
Arsenic and arsenic compounds	specific	9000
Chromium VI compounds	specific	5000
Diesel engine exhaust	US	673
Tobacco smoke (environmental)	specific	2000
Formaldehyde	average	53082
Glass wool	specific	3000
Methylene chloride	specific	20000
Nickel compounds	specific	5000
Tetrachloroethylene	specific	10000
Styrene	average	2282
Trichloroethylene	specific	10000
Wood dust	specific	55000
Total		175037
341 Manufacture of paper and paper products		
Strong-inorganic-acid mists containing sulfuric acid	US	4032
Chromium VI compounds	Finnish	1736
Diesel engine exhaust	US	698
Tobacco smoke (environmental)	specific	800
Nickel compounds	specific	400
Styrene	average	228
Wood dust	average	3047
Total		10941
342 Printing, publishing and allied industries		
Benzene	specific	2000
Cadmium and cadmium compounds	US	746
Chromium VI compounds	US	3393
Diesel engine exhaust	US	290
Tobacco smoke (environmental)	specific	2000
Nickel compounds	specific	900
Tetrachloroethylene	US	2246
Total		11575
351 Manufacture of industrial chemicals		
Acrylamide	Finnish	447
Strong-inorganic-acid mists containing sulfuric acid	US	3847
Acrylonitrile	US	656
Benzene	specific	800
Cadmium and cadmium compounds	US	499
Cobalt and its compounds	US	668
Chromium VI compounds	Finnish	1609
Diesel engine exhaust	US	1231
Dimethyl sulfate	US	138
Epichlorohydrin	Finnish	134
Tobacco smoke (environmental)	specific	600
Methylene chloride	US	1990
Nickel compounds	specific	300

Agent	Estimate Type	Exposures
Lead and lead compounds, inorganic	US	1336
Styrene	US	1183
Vinyl chloride	US	774
Total		16212
352 Manufacture of other chemical products		
Acrylamide	US	371
Strong-inorganic-acid mists containing sulfuric acid	US	8670
Acrylonitrile	US	498
Cadmium and cadmium compounds	US	23
Cisplatin	specific	10
Chromium VI compounds	US	2450
Diesel engine exhaust	US	1176
Dimethyl sulfate	US	1344
Epichlorohydrin	Finnish	458
Tobacco smoke (environmental)	specific	1500
Ionizing radiation	specific	100
1-(2-Chloroethyl)-3-(4-methylcyclohexyl)-1-nitroso	specific	10
Methylene chloride	US	7671
Nickel compounds	specific	250
Oral contraceptives, combined	Finnish	762
Oral contraceptives, sequential	Finnish	762
Oestrogens, steroidal	Finnish	762
Lead and lead compounds, inorganic	US	3527
Styrene	US	3168
Vinyl chloride	US	2351
Total		35863
353 Petroleum refineries		
1,3-Butadiene	US	185
Benzene	Finnish	462
Cadmium and cadmium compounds	US	145
Chromium VI compounds	specific	700
Diesel engine exhaust	US	649
Tobacco smoke (environmental)	specific	150
Nickel compounds	specific	700
Polycyclic aromatic hydrocarbons (excl.)	US	704
Tetrachloroethylene	US	6
Vinyl chloride	US	121
Total		3822
354 Manufacture of miscellaneous products of petroleum and coal		
Diesel engine exhaust	US	354
Tobacco smoke (environmental)	specific	100
Glass wool	specific	500
Polycyclic aromatic hydrocarbons (excl.)	US	1508
Lead and lead compounds, inorganic	US	801
Total		3263
355 Manufacture of rubber products		
Cadmium and cadmium compounds	US	634
Cobalt and its compounds	specific	300
Chromium VI compounds	US	2073
Diesel engine exhaust	specific	300
Tobacco smoke (environmental)	specific	700
N-Nitrosodiethylamine	specific	7700
N-Nitrosodimethylamine	specific	7700
Nickel compounds	specific	700
Polycyclic aromatic hydrocarbons (excl.)	specific	7700
Styrene	US	681
Total		28488

Agent	Estimate Type	Exposures
356 Manufacture of plastic products not elsewhere classified		
Cadmium and cadmium compounds	US	6901
Chromium VI compounds	US	6384
Diesel engine exhaust	US	360
Epichlorohydrin	Finnish	497
Tobacco smoke (environmental)	specific	1500
4,4'-Methylene bis(2-chloroaniline) (MOCA)	Finnish	247
Nickel compounds	specific	1000
Lead and lead compounds, inorganic	US	6226
Silica, crystalline	average	2149
Styrene	average	10849
Total		36113
361 Manufacture of pottery, china and earthenware		
Strong-inorganic-acid mists containing sulfuric acid	US	11
Cadmium and cadmium compounds	Finnish	410
Ceramic fibers	Finnish	1026
Cobalt and its compounds	Finnish	410
Chromium VI compounds	specific	750
Diesel engine exhaust	specific	150
Tobacco smoke (environmental)	specific	250
Methylene chloride	US	205
Nickel compounds	specific	750
Polycyclic aromatic hydrocarbons (excl.)	average	590
Lead and lead compounds, inorganic	Finnish	4102
Silica, crystalline	average	9431
Total		18085
362 Manufacture of glass and glass products		
Arsenic and arsenic compounds	average	1378
Beryllium and beryllium compounds	specific	200
Cadmium and cadmium compounds	Finnish	787
Ceramic fibers	Finnish	472
Cobalt and its compounds	average	548
Chromium VI compounds	specific	750
Diesel engine exhaust	US	225
Tobacco smoke (environmental)	specific	500
Formaldehyde	US	280
Glass wool	average	3542
Nickel compounds	specific	750
Polycyclic aromatic hydrocarbons (excl.)	average	876
Lead and lead compounds, inorganic	US	2739
Tetrachloroethylene	US	494
Silica, crystalline	average	7437
Trichloroethylene	US	278
Total		21256
369 Manufacture of other non-metallic mineral products		
Cadmium and cadmium compounds	US	2718
Ceramic fibers	Finnish	2729
Chromium VI compounds	US	876
Diesel engine exhaust	US	30112
Tobacco smoke (environmental)	specific	700
Glass wool	US	2639
Polycyclic aromatic hydrocarbons (excl.)	average	5377
Lead and lead compounds, inorganic	US	9166
Silica, crystalline	average	63279
Trichloroethylene	US	261
Total		117857

Agent	Estimate Type	Exposures
371 Iron and steel basic industries		
Strong-inorganic-acid mists containing sulfuric acid	US	2876
Arsenic and arsenic compounds	Finnish	1185
Cadmium and cadmium compounds	specific	1000
Ceramic fibers	Finnish	790
Chromium VI compounds	specific	1000
Diesel engine exhaust	US	3146
Tobacco smoke (environmental)	specific	1000
Formaldehyde	US	3279
Glass wool	US	1054
Ionizing radiation	specific	1000
Nickel compounds	specific	1000
Polycyclic aromatic hydrocarbons (excl.)	average	9493
Lead and lead compounds, inorganic	Finnish	13422
Polychlorinated biphenyls (PCB)	specific	300
Silica, crystalline	US	10151
Wood dust	specific	700
Total		51396
372 Non-ferrous metal basic industries		
Strong-inorganic-acid mists containing sulfuric acid	US	1703
Ceramic fibers	Finnish	542
Cobalt and its compounds	US	183
Chromium VI compounds	specific	600
Diesel engine exhaust	US	1530
Tobacco smoke (environmental)	specific	500
Glass wool	US	159
Nickel compounds	specific	200
Polycyclic aromatic hydrocarbons (excl.)	average	938
Lead and lead compounds, inorganic	US	1736
Silica, crystalline	US	609
Total		8700
381 Manufacture of fabricated metal products, except machinery & equipment		
Strong-inorganic-acid mists containing sulfuric acid	average	13512
Beryllium and beryllium compounds	average	1439
Cadmium and cadmium compounds	US	10470
Cobalt and its compounds	average	15514
Chromium VI compounds	average	51666
Diesel engine exhaust	US	17151
Tobacco smoke (environmental)	specific	7000
Formaldehyde	average	13658
Glass wool	US	12509
Nickel compounds	average	35932
Polycyclic aromatic hydrocarbons (excl.)	average	15001
Lead and lead compounds, inorganic	average	33038
Tetrachloroethylene	US	26857
Silica, crystalline	average	19652
Total		273399
382 Manufacture of machinery except electrical		
Strong-inorganic-acid mists containing sulfuric acid	US	6446
Beryllium and beryllium compounds	US	7288
Cadmium and cadmium compounds	US	3884
Cobalt and its compounds	US	4737
Chromium VI compounds	average	20351
Diesel engine exhaust	US	3599
Tobacco smoke (environmental)	specific	6000

Agent	Estimate		Agent	Estimate	
	Type	Exposures		Type	Exposures
Formaldehyde	average	10927	Glass wool	average	1857
Glass wool	US	11595	Nickel compounds	US	752
Nickel compounds	Finnish	22403	Silica, crystalline	US	1376
Polycyclic aromatic hydrocarbons (excl.)	average	26139	Total		9490
Lead and lead compounds, inorganic	average	21469	41 Electricity, gas and steam		
Tetrachloroethylene	US	13939	Asbestos	specific	1000
Silica, crystalline	average	14512	Beryllium and beryllium compounds	Finnish	96
Total		173289	Ceramic fibers	Finnish	48
383 Manufacture of electrical machinery, apparatus, appliances & supplies			Chromium VI compounds	average	517
Strong-inorganic-acid mists			Diesel engine exhaust	US	2972
containing sulfuric acid	US	5800	Tobacco smoke (environmental)	specific	1000
Arsenic and arsenic compounds	Finnish	1873	Ionizing radiation	specific	500
Beryllium and beryllium compounds	US	468	Nickel compounds	Finnish	477
Cadmium and cadmium compounds	US	1025	Polycyclic aromatic hydrocarbons (excl.)	US	5441
Chromium VI compounds	US	3669	Lead and lead compounds, inorganic	US	3490
Diesel engine exhaust	US	902	Radon and its decay products	specific	100
Tobacco smoke (environmental)	specific	3000	Styrene	US	127
Glass wool	US	2234	Total		15768
Nickel compounds	US	671	42 Water works and supply		
Lead and lead compounds, inorganic	average	16608	Diesel engine exhaust	US	2169
Polychlorinated biphenyls (PCB)	specific	500	Tobacco smoke (environmental)	specific	250
Total		36750	Lead and lead compounds, inorganic	US	2030
384 Manufacture of transport equipment			Tetrachloroethylene	US	352
Strong-inorganic-acid mists			Total		4801
containing sulfuric acid	US	3659	5 Construction		
Asbestos	specific	2600	Asbestos	specific	70000
Beryllium and beryllium compounds	specific	1000	Cadmium and cadmium compounds	US	5328
Cadmium and cadmium compounds	US	562	Ceramic fibers	Finnish	1969
Ceramic fibers	Finnish	111	Chromium VI compounds	average	3723
Cobalt and its compounds	US	2201	Diesel engine exhaust	US	159659
Chromium VI compounds	average	8911	Tobacco smoke (environmental)	specific	15000
Diesel engine exhaust	US	2065	Glass wool	average	88626
Tobacco smoke (environmental)	specific	3000	Nickel compounds	specific	1000
Glass wool	US	7638	Radon and its decay products	specific	10000
Nickel compounds	average	4399	Silica, crystalline	US	104309
Polycyclic aromatic hydrocarbons (excl.)	average	5718	Solar radiation	specific	250000
Lead and lead compounds, inorganic	average	9282	Wood dust	specific	105000
Styrene	average	13162	Total		814614
Trichloroethylene	US	1424	6 Wholesale and retail trade and restaurants and hotels		
Wood dust	specific	18000	Benzene	Finnish	43216
Total		83732	Diesel engine exhaust	Finnish	11285
385 Manufacture of instruments, photographic and optical goods			Tobacco smoke (environmental)	specific	375000
Beryllium and beryllium compounds	US	344	Polycyclic aromatic hydrocarbons (excl.)	Finnish	4061
Cadmium and cadmium compounds	US	3173	Lead and lead compounds, inorganic	Finnish	8125
Cobalt and its compounds	average	1494	Total		441687
Chromium VI compounds	US	2413	711 Land transport		
Diesel engine exhaust	US	224	Asbestos	specific	2000
Tobacco smoke (environmental)	specific	1300	Benzene	Finnish	6210
Glass wool	US	1215	Chromium VI compounds	average	1213
Nickel compounds	US	1534	Diesel engine exhaust	average	125782
Silica, crystalline	US	2224	Tobacco smoke (environmental)	specific	55000
Total		13921	Polycyclic aromatic hydrocarbons (excl.)	US	12983
39 Other manufacturing industries			Lead and lead compounds, inorganic	average	1451
Cadmium and cadmium compounds	US	2309	Polychlorinated biphenyls (PCB)	specific	200
Cobalt and its compounds	US	727	Silica, crystalline	average	4064
Chromium VI compounds	US	963	Styrene	US	1536
Diesel engine exhaust	US	506	Total		210439
Tobacco smoke (environmental)	specific	1000			

Agent	Estimate		Agent	Estimate	
	Type	Exposures		Type	Exposures
712 Water transport			Polycyclic aromatic hydrocarbons		
Asbestos	specific	500	(excl.)	average	3398
Benzene	Finnish	175	Lead and lead compounds, inorganic	specific	21000
Chromium VI compounds	US	307	Polychlorinated biphenyls (PCB)	specific	1000
Diesel engine exhaust	average	3887	Trichloroethylene	US	84
Tobacco smoke (environmental)	specific	4200	Total		50546
Polycyclic aromatic hydrocarbons (excl.)	US	102	931 Education services		
Lead and lead compounds, inorganic	average	551	Acrylamide	Finnish	1705
Tetrachloroethylene	US	102	Acrylonitrile	Finnish	122
Solar radiation	specific	1500	Aflatoxins	Finnish	122
Styrene	US	517	1,3-Butadiene	Finnish	122
Vinyl chloride	average	162	Benzene	Finnish	1217
Total		12003	Benzidine	Finnish	609
713 Air transport			Carbon tetrachloride	Finnish	1827
Strong-inorganic-acid mists containing sulfuric acid	US	590	Diethyl sulfate	Finnish	122
Beryllium and beryllium compounds	US	58	Dimethyl sulfate	Finnish	243
Cadmium and cadmium compounds	US	207	Ethylene dibromide	Finnish	122
Chromium VI compounds	US	1129	Epichlorohydrin	Finnish	365
Diesel engine exhaust	US	1767	Ethylene oxide	Finnish	122
Tobacco smoke (environmental)	specific	250	Tobacco smoke (environmental)	specific	1500
Ionizing radiation	Finnish	4100	Formaldehyde	Finnish	243
Total		8101	Ionizing radiation	Finnish	609
719 Services allied to transport			Methylene chloride	Finnish	609
Diesel engine exhaust	average	26636	Mustard gas (Sulfur mustard)	Finnish	122
Tobacco smoke (environmental)	specific	3000	N-Nitrosodimethylamine	Finnish	61
Polycyclic aromatic hydrocarbons (excl.)	specific	4500	Polychlorinated biphenyls (PCB)	Finnish	122
Lead and lead compounds, inorganic	specific	5000	para-Chloro-ortho-toluidine and its strong acid salts	average	31
Tetrachloroethylene	US	1171	Pentachlorophenol	Finnish	122
Styrene	US	1898	Tetrachloroethylene	Finnish	122
Vinyl chloride	average	323	Styrene	Finnish	609
Total		42528	1,2,3-Trichloropropane	Finnish	61
72 Communication			Trichloroethylene	Finnish	122
Diesel engine exhaust	US	3955	Vinyl chloride	Finnish	243
Tobacco smoke (environmental)	specific	3000	Total		11274
Lead and lead compounds, inorganic	average	5360	932 Research and scientific institutes		
Tetrachloroethylene	US	429	Acrylamide	Finnish	212
Styrene	US	227	Acrylonitrile	Finnish	106
Total		12971	Aflatoxins	Finnish	53
8 Financing, insurance, real estate and business services			1,3-Butadiene	Finnish	53
Tobacco smoke (environmental)	specific	200000	Benzene	Finnish	265
Total		200000	Benzidine	Finnish	212
91 Public Administration and Defence			Carbon tetrachloride	Finnish	792
Diesel engine exhaust	specific	12000	Diethyl sulfate	Finnish	53
Tobacco smoke (environmental)	specific	9000	Dimethyl sulfate	Finnish	53
Polycyclic aromatic hydrocarbons (excl.)	specific	2000	Ethylene dibromide	Finnish	53
Lead and lead compounds, inorganic	specific	12000	Epichlorohydrin	Finnish	159
Wood dust	specific	5000	Ethylene oxide	Finnish	53
Total		40000	Tobacco smoke (environmental)	specific	500
92 Sanitary and similar services			Formaldehyde	Finnish	106
Arsenic and arsenic compounds	specific	1000	Ionizing radiation	Finnish	265
Benzene	Finnish	266	Methylene chloride	Finnish	265
Cadmium and cadmium compounds	specific	1000	Mustard gas (Sulfur mustard)	Finnish	26
Chlorambucil	Finnish	266	N-Nitrosodimethylamine	Finnish	26
Chromium VI compounds	Finnish	266	Polychlorinated biphenyls (PCB)	Finnish	212
Diesel engine exhaust	specific	20000	para-Chloro-ortho-toluidine and its strong acid salts	average	12
Epichlorohydrin	Finnish	266	Pentachlorophenol	Finnish	53
Tobacco smoke (environmental)	specific	1000	Tetrachloroethylene	Finnish	53
Nickel compounds	specific	1000	Styrene	Finnish	265
			Tris(2,3-dibromopropyl)phosphate	Finnish	53
			1,2,3-Trichloropropane	Finnish	26
			Trichloroethylene	Finnish	53
			Vinyl chloride	Finnish	53
			Total		4032

Agent	Estimate		Agent	Estimate	
	Type	Exposures		Type	Exposures
933 Medical, dental, other health and veterinary services			935-9 Business, professional and other organization		
Acrylonitrile	Finnish	72	Tobacco smoke (environmental)	specific	10000
Adriamycin	specific	4800	Total		10000
Azathioprine	specific	200	94 Recreational and cultural services		
Bischloroethyl nitrosourea (BCNU)	Finnish	363	Tobacco smoke (environmental)	specific	24000
1,3-Butadiene	US	21	Total		24000
Chlorambucil	average	1079	95 Personal and household services		
Ciclosporin	Finnish	363	Benzene	Finnish	129414
Cisplatin	average	3459	Cadmium and cadmium compounds	Finnish	1871
Cobalt and its compounds	average	1355	Chromium VI compounds	Finnish	11694
Cyclophosphamide	average	4269	Diesel engine exhaust	Finnish	38980
Diesel engine exhaust	specific	2000	Tobacco smoke (environmental)	specific	40000
Dimethyl sulfate	US	271	Formaldehyde	specific	2000
Tobacco smoke (environmental)	specific	1000	Polycyclic aromatic hydrocarbons (excl.	Finnish	13721
Formaldehyde	Finnish	2178	Lead and lead compounds, inorganic	Finnish	45061
Ionizing radiation	Finnish	5372	Tetrachloroethylene	Finnish	31184
Melphalan	average	954	Trichloroethylene	Finnish	3118
Mustard gas (Sulfur mustard)	Finnish	36	Wood dust	specific	5000
para-Chloro-ortho-toluidine and its strong acid salts	average	23	Total		322043
Total		27815	96 International organisations		
934 Welfare institutions			Tobacco smoke (environmental)	specific	1000
Tobacco smoke (environmental)	specific	4000	Total		1000
Total		4000			

APPENDIX 2

Exposures by Agents, Excluding Low-level, Low-probability Exposures

Agent	Exposures	Agent	Exposures
1,2,3-Trichloropropane	87	Ethylene oxide	175
1,3-Butadiene	381	Formaldehyde	113384
1-(2-Chloroethyl)-3-(4-methylcyclohexyl)-1-nitrosourea	10	Glass wool	138191
4,4'-Methylene bis(2-chloroaniline) (MOCA)	247	Ionizing radiation	11946
Acrylamide	2735	Lead and lead compounds, inorganic	227820
Acrylonitrile	1454	Melphalan	954
Adriamycin	4800	Methylene chloride	51740
Aflatoxins	175	Mustard gas (Sulfur mustard)	184
Arsenic and arsenic compounds	32436	N-Nitrosodiethylamine	7700
Asbestos	76100	N-Nitrosodimethylamine	7787
Azathioprine	200	Nickel compounds	97178
Benzene	184025	Oestrogens, steroidal	762
Benzidine	821	Oral contraceptives, combined	762
Beryllium and beryllium compounds	10893	Oral contraceptives, sequential	762
Bischloroethyl nitrosourea (BCNU)	363	para-Chloro-ortho-toluidine and its strong acid salts	66
Cadmium and cadmium compounds	44623	Pentachlorophenol	175
Captafol	12000	Polychlorinated biphenyls (PCB)	2334
Carbon tetrachloride	2619	Polycyclic aromatic hydrocarbons (excl. environmental)	121716
Ceramic fibers	7687	Radon and its decay products	26200
Chlorambucil	1345	Silica, crystalline	254657
Chromium VI compounds	156225	Solar radiation	702100
Ciclosporin	363	Strong-inorganic-acid mists containing sulfuric acid	54363
Cisplatin	3469	Styrene	36861
Cobalt and its compounds	28615	Tetrachloroethylene	106290
Cyclophosphamide	4269	Tobacco smoke (environmental)	806550
Diesel engine exhaust	521162	Trichloroethylene	34481
Diethyl sulfate	175	Tris(2,3-dibromopropyl)phosphate	53
Dimethyl sulfate	2159	Vinyl chloride	4027
Epichlorohydrin	1879	Wood dust	????
Ethylene dibromide	175		