

5. Occupational exposure

5.1. *Estimation of the number of occupationally exposed workers*

5.1.1. Introduction

Few attempts have been made to establish comprehensive estimates of occupational exposure to carcinogens. IARC has been publishing *IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans* on individual carcinogens, groups of carcinogens, carcinogenic mixtures, and industries linked with elevated incidence of cancer since 1972. Over the decades, IARC has assembled an impressive and highly respected overview of exposure to carcinogens in the workplace. International Programme on Chemical Safety (IPCS) is another useful source of information and has been publishing Environmental Health Criteria (EHCs) since 1976. EHCs have a broader scope than IARC and tend to focus on environmental issues, but occupational exposure is also included.

Although the IARC and IPCS reports are of high quality with extensive input from senior scientists and take considerable effort to prepare, the older issues would not have information about recent exposures. Industrial processes have changed over the years and steps have been put in place to protect workers' health. The older data probably do not reflect current situations and likely overestimate recent occupational exposures. In addition, both IARC and IPCS reports contain exposure information for specific occupations gathered from different sources. The methodologies used to gather the data and the data structure may not always be comparable, making it very difficult to compare exposures between different industrial sectors.

At one time, the Ontario Ministry of Labour (MOL) used to systematically collect exposure information on chemical and physical agents in the workplace, but that is not currently being done. The older data are being transferred into a new database and until this database is operational, the occupational exposure data are not available (McCloskey, 2001). Although some data may be available from MOL and from some other organisations in the future, a comprehensive database containing exposure information to occupational carcinogens is currently not available. It is noteworthy that Cancer Care Ontario has identified the collection of occupational exposure information as a top priority.

In principle, there are three possible general approaches to building an occupational exposure database. First, it is possible to integrate and standardise the existing occupational exposure data for Toronto workers from different sources. Such an approach would be labour-intensive and one would likely accomplish only partial success in data standardization. It is expected that such a database would have numerous gaps, which would need to be filled.

A second alternative would be to sponsor a major monitoring/survey study involving many industrial sectors to create a standardised database, perhaps similar to the environmental emission inventories [e.g. National Pollutant Release Inventory (NPRI - see <http://www.ec.gc.ca/pdb/npri/>), Toxics Release Inventory (TRI –

see <http://www.epa.gov/tri/>). This approach too is resource-intensive and time-consuming, but one, which over time promises the best quality results.

The third approach is relatively quick and inexpensive, using the CAREX database (<http://www.occuphealth.fi/list/data/CAREX/>). CAREX is a database created by the Finnish Institute of Occupational Health in collaboration with IARC. It contains estimates of the number of workers occupationally exposed to carcinogens by different industry sectors in 15 countries of the European Union (EU) in 1990-93 and in four non-EU countries including the United States in 1997. CAREX includes occupational data on 139 carcinogens evaluated by the (IARC).

The third approach is based on the assumption that the proportion of exposed workers in a given industry sector in Toronto is roughly comparable to the proportion of the exposed workers in the same industry in Europe as presented in CAREX database. Thus the number of workers exposed to carcinogens in Toronto can be estimated if the proportion of workers in a particular industry exposed to a given carcinogen in Europe (from CAREX) and the total number of workers in the same industry in Toronto are known. The database derived using this CAREX-like approach can later be compared to and supplemented by monitored/surveyed data. This approach is similar to the one used by the designers of CAREX. The main weakness is the requirement to assume that Toronto's occupational exposures are comparable to those in the USA between 1981 and 1983 and in Finland from 1980's to early 1990's.

The third approach is used in this report. Details of the methodology are described below.

5.1.2. Method

Method conceptual overview

CAREX contains estimates of the number of workers occupationally exposed to above ambient levels of carcinogens. Table 5.1.2.1 summarizes the occupational levels, which CAREX defined as *background*. The results are grouped by industrial sectors and by individual carcinogens. The database also lists the total number of workers in a given industrial sector. The proportion of workers exposed to a given carcinogen can be estimated from these numbers on an industry sector-by-sector basis. Knowing the number of workers employed in an industrial sector in Toronto, the number of exposed workers in the sector can be estimated using the following equation.

$$E_T = N_T \times (E_E / N_E)$$

E_T represents the number of Toronto workers exposed to a given contaminant in a given industrial sector. N_T represents the number of Torontonians employed in a given sector and E_E and N_E are analogous measures for European workers.

In the CAREX database, the number of employed workers and the number of exposed workers are defined using the United Nations (UN) industry classification system. On the other hand, the Toronto Business Directory 2000, which is used to estimate the number of workers in each industry sector, classifies the industries using Standard Industry Classification (SIC). As a result, the UN classifications had to be converted into SIC codes.

The accuracy of the estimated number of workers exposed in Toronto depends on how the data was selected for the Toronto Business Directory. For example, defining the Toronto boundaries too narrowly or selectively listing businesses may skew the estimation of the population at risk.

Table 5.1.2.1. Contaminant levels assumed to be background by CAREX

Contaminant	Levels treated by CAREX as <i>background</i>
1,3-Butadiene	Inhalation exposure at work to 1,3-butadiene likely to exceed significantly the non-occupational background level in urban air (usually below 0.01 parts per million of agent in cubic meter of air)
Asbestos	Inhalation exposure at work to any form of asbestos (e.g., chrysotile, crocidolite, tremolite, anthophyllite, actinolite, amosite) likely to exceed significantly the non-occupational background level in dwellings or urban air (usually below 0.001f/cm ³) (length >5 µm, diameter <3 µm, aspect ratio at least 3:1)
Benzene	Inhalation or dermal exposure at work to benzene likely to exceed significantly the non-occupational exposure due to inhaling urban air or due to filling in gasoline stations (long-term exposure usually below 0.01 parts per million of agent in cubic meter of air)
Cadmium	Inhalation exposure at work to cadmium, cadmium alloys or cadmium compounds (cadmium oxide, cadmium chromate and other cadmium pigments) likely to exceed significantly the non-occupational background level due to air pollution (usually below 0.1 µg/m ³).
Chromium (VI)	Inhalation exposure at work to chromium (VI) compounds (e.g. chromium trioxide, chromic acid, chromates and dichromates) likely to exceed significantly the non-occupational background level due to air pollution (usually <0.1 µg/m ³).
Dioxins	Not in CAREX
Formaldehyde	Inhalation exposure at work to formaldehyde gas, formalin mist, paraformaldehyde dust or dust containing fresh formalin-based glue exceeding the level in urban air and dwellings (usually <0.1 parts per million of agent in cubic meter of air)
PAHs (B[a]P)	Inhalation exposure at work to PAHs with at least four aromatic rings (e.g. benzo(a)pyrene, benz(a)anthracene, dibenz[a,h]anthracene) likely to exceed significantly the non-occupational levels in urban air (usually <0.005 µg/m ³ of benzo(a)pyrene). Includes coal tar pitch, coal tars, soots, creosotes, shale oils, and untreated/mildly treated mineral oils. Excludes environmental tobacco smoke and bus/truck/van/taxi drivers exposed to engine exhaust.
Tetrachloroethylene	Inhalation or dermal exposure at work to tetrachloroethylene (perchloroethylene) probably exceeding non-occupational exposure (assumed to be nil for this agent).
Trichloroethylene	Inhalation or dermal exposure at work to trichloroethylene exceeding significantly the levels in urban air (usually <0.01 parts per million of agent in cubic meter of air)

Coverage of Toronto Business Directory 2000 (TBD)

TBD on CD-ROM is an electronic database with search capability published by the City of Toronto. It provides the names and addresses of establishments. In the TBD, an "establishment" is defined as an entity, which has a physical location and at least one employee. The database also includes 4-digit and 8-digit 1987 US Industrial Standard Industry Classification Code, and the 4-digit 1987 Standard Industry Classification Code developed by Statistics Canada. Most of the classifications used in this report are based on the US 4-digit code.

The TBD database covers the following sectors.

- All public and private sector employers in the City of Toronto (the boundaries of the City fall within the "M" postal code area). The database does include establishments in the Greater Toronto Area (GTA), which fall outside of this postal code boundary. Accordingly, the term "Toronto" refers to the City of Toronto.
- All locations of franchise and chain operators, such as McDonald's or the LCBO
- All schools, churches, hospitals and other institutional employers
- Government agencies which maintain their own locations
- Non-profit agencies of all kinds
- Commercial and public residential units (coops, apartment complexes, condominiums) may be listed, but will often be found under the names of their owners, not necessarily at their physical locations.
- Home-based businesses are not included in the file.

Matching UN's ISIC Revision 2 from CAREX database to SIC codes from Toronto Business Directory

Table 5.1.1-2 describes how the UN's ISIC code was mapped to the US SIC codes. (For further details on SIC code, please refer to <http://www.osha.gov/cgi-bin/sic/sicser5>. ISIC revision 2 is available at <http://esa.un.org/unsd/cr/registry/regcst2.asp?Cl=8&Lg=1>). Several sector categories were not rated, based on the assumption that Toronto hosts only head offices of enterprises within these sectors. For example, Toronto does not have coal mining operations and the employees located in Toronto are likely white-collar workers only. Other categories were excluded, because it was assumed that most of these workers would be exposed to normal office conditions with no major *occupational source* of exposure. Several sectors with UN codes within 8 and 9xx range belong to the latter categories (see table 5.1.2.2).

Table 5.1.2.2. Matching UN's ISIC Revision 2 codes to SIC codes

UN Codes	Industry	Matching SIC Codes
11	Agriculture and hunting	Excluded
12	Forestry and logging	Excluded
13	Fishing	Excluded
21	Coal mining	Excluded
22	Crude Petroleum and Natural Gas Production	Excluded
23	Metal Ore Mining	Excluded
29	Other Mining	Excluded
311-2	Food manufacturing	2011-2079, 2091-2099
313	Beverage industries	2082-2087
314	Tobacco manufacture	2111-2141
321	Manufacture of textiles	2211-2299
322	Manufacture of wearing apparel, except footwear	2311-2399
323	Manufacture of leather and products of leather	3111, 3151-3199
324	Manufacture of footwear	3131-3149, 3021, 3842
331	Manufacture of wood and wood and cork products,	2421-2499
332	Manufacture of furniture and fixtures	2511-2599
341	Manufacture of paper and paper products	2611-2679
342	Printing, publishing and allied industries	2711-2796
351	Manufacture of industrial chemicals	2812-2819, 2861-2869
352	Manufacture of other chemical products	2821-2851, 2873-2899
353	Petroleum refineries	Excluded
354	Manufacture of miscellaneous products of petroleum	2992-2999
355	Manufacture of rubber products	3011-3069
356	Manufacture of plastic products not elsewhere classified	3081-3089 (only 3089 found)
361	Manufacture of pottery, china and earthenware	3261-3269
362	Manufacture of glass and glass products	3211-3231
369	Manufacture of other non-metallic mineral products	3241-3259, 3271-3299
371	Iron and steel basic industries	3312-3325
372	Non-ferrous metal basic industries	3331-3399
381	Manufacture of fabricated metal products	3411-3499
382	Manufacture of machinery except electrical	3511-3536, 3541-3569, 3581-3599
383	Manufacture of electrical machinery, apparatus,	3571-3579, 3612-3699
384	Manufacture of transport equipment	3537, 3711-3799
385	Manufacture of instruments, photographic and optical	3812-3873
39	Other manufacturing industries	3911-3999

UN Codes	Industry	Matching SIC Codes
41	Electricity, gas and steam	4911-4939
42	Water works and supply	4941
5	Construction	1521-1799
6	Wholesale and retail trade and restaurants and hotels	5012- 5999, 7011-7041
711	Land transport	4011-4311
712	Water transport	4432,4449, 4482, 4489
713	Air transport	4512-4581
719	Services allied to transport	Excluded
72	Communication	Excluded
8	Financing, insurance, real estate and business services	Excluded
91	Public Administration and Defense	Excluded
92	Sanitary and similar services	4952-4959
931	Education services	Excluded
932	Research and scientific institutes	Excluded
933	Medical, dental, other health and veterinary services	8011-8099
934	Welfare institutions	Excluded
935-9	Business, professional and other organisation	Excluded
94	Recreational and cultural services	Excluded
95	Personal and household services	7211-7299
96	International organisations	Excluded

Excluded – not rated

X - an integer between 0 and 9

Estimating the number of employees in each industry in Toronto

The number of employees in each industry was obtained by selecting the appropriate SIC codes and applying the *Establishment Size* filter. With the filter on, it is possible to estimate the number of establishments with 1 to 4 employees, 5-9 employees etc. The results are presented in table 5.1.2.3. To estimate the total number of employees, it was assumed that the establishments with the number of employees within a certain range (such as 5 to 9) employ an average of that range (7 for a range of 5 to 9). For businesses with 1000 or more employees, it was assumed that they employ 1000 employees.

The number of employees within a sector was calculated as the sum of employees from all establishments within that sector. Some establishments did not report the number of employees; these establishments were assigned the average number of employees in the sector. This assumption introduces a degree of uncertainty as it is possible that there is a relationship between the establishment size and the availability of information on its size in the directory.

Table 5.1.2.3. Number of employees in different industrial sectors in Toronto

Ranges of #s of employees/ establishment	Not reported	1 to 4	5 to 9	10 to 24	25 to 49	50 to 74	75 to 99	100 to 299	300 to 499	500 to 999	over 1000	Total estab.	Total employees
Food manufacturing	4	146	59	90	48	25	9	40	6	11	4	442	29067
Beverage industries	3	28	9	2	8	3	1	7	0	1	3	65	5886
Tobacco manufacture	0	8	1	0	1	0	1	2	0	0	0	13	551
Manufacture of textiles	1	59	23	33	23	12	2	12	2	0	0	167	5838
Manufacture of wearing apparel, except footwear	3	208	129	102	85	32	18	31	5	1	0	614	18802
Manufacture of leather and products of leather	0	29	4	3	4	2	1	3	0	0	0	46	1110
Manufacture of footwear	0	35	10	9	3	5	3	4	1	0	0	70	2192
Manufacture of wood and wood and cork products,	3	99	57	51	20	11	1	5	0	0	0	247	4022
Manufacture of furniture and fixtures	2	113	65	91	49	20	11	28	4	4	1	388	17494
Manufacture of paper and paper products	1	50	25	29	26	22	4	26	2	1	1	187	11217
Printing, publishing and allied industries	22	674	324	219	78	37	17	37	9	9	3	1429	35085
Manufacture of industrial chemicals	1	16	4	14	10	5	3	7	4	2	0	66	5747
Manufacture of other chemical products	17	92	35	70	34	18	5	24	7	6	2	310	18574
Manufacture of miscellaneous products of petroleum	1	3	1	1	3	3	0	0	0	0	0	12	328
Manufacture of rubber products	0	4	1	1	0	2	0	3	0	0	0	11	758
Manufacture of plastic products not elsewhere classified	4	51	43	44	28	14	8	34	2	2	0	230	12876
Manufacture of pottery, china and earthenware	1	5	2	0	1	2	1	0	0	0	0	12	274
Manufacture of glass and glass products	0	21	8	13	4	4	0	0	0	0	0	50	725
Manufacture of other non-metallic mineral products	2	30	12	19	14	8	2	4	0	1	1	93	4220
Iron and steel basic industries	1	12	10	17	6	4	0	3	1	0	1	55	2859
Non-ferrous metal basic industries	1	22	11	13	6	4	2	7	0	2	1	69	4897
Manufacture of fabricated metal products	5	93	48	71	39	19	5	10	4	0	0	294	8431
Manufacture of machinery except electrical	6	187	116	124	66	29	9	17	2	3	0	559	14860



Ten Carcinogens in Toronto

Ranges of #s of employees/ establishment	Not reported	1 to 4	5 to 9	10 to 24	25 to 49	50 to 74	75 to 99	100 to 299	300 to 499	500 to 999	over 1000	Total estab.	Total employees
Manufacture of electrical machinery, apparatus,	7	149	91	100	42	25	13	35	8	6	3	479	24644
Manufacture of transport equipment	1	35	20	29	14	3	3	12	1	2	3	123	8985
Manufacture of instruments, photographic and optical	5	115	37	42	14	13	4	10	3	1	2	246	8882
Other manufacturing industries	3	360	101	67	42	23	2	9	2	4	0	613	11500
Electricity, gas and steam	1	12	6	6	2	4	2	1	2	3	3	42	6920
Water works and supply	0	4	3	1	0	0	0	1	0	0	0	9	248
Construction	97	2743	733	599	142	72	9	32	4	2	4	4437	46172
Wholesale and retail trade and restaurants and hotels	461	14724	4673	3123	968	468	113	318	57	28	209	25142	513675
Land transport	43	366	119	146	61	27	6	29	4	4	1	806	20083
Water transport	0	6	1	0	1	0	0	0	1	0	0	9	459
Air transport	13	65	7	12	5	2	1	1	0	1	1	108	2761
Sanitary and similar services	2	49	20	22	7	6	1	3	0	0	1	111	2954
Medical, dental, other health and veterinary services	687	4805	757	314	65	29	7	50	9	17	19	6759	72811
Personal and household services	63	3193	394	232	57	25	8	12	2	1	1	3988	23989
Total of workers considered in the study	1461	28611	7959	5709	1976	978	272	817	142	112	264	48301	949896
Total all workers in Toronto	4249	50518	13175	9690	3192	1565	415	1297	236	182	147	84666	1271789

5.1.3. Results and discussion

Tables 5.1.3.1 to 5.1.3.5 summarize the results of the analysis. Table 5.1.3.6 describes the kinds of establishments that are included in the selected sectors. The first table (5.1.3.1) shows the number of workers potentially exposed to individual carcinogens above the background levels in each sector considered. The table also provides some summary statistics for each of the assessed carcinogens. There are several ways to examine the results and to manage occupational exposure to carcinogens.

The first approach is to examine which carcinogens affect the most number of workers in Toronto and to design strategies to manage these contaminants across industrial sectors. To supplement this approach, top ranking industrial sectors, based on the number of workers exposed above the background levels, can be identified for each of these carcinogens. The analysis to support this approach is presented in Table 5.1.3.1 and table 5.1.3.5. Tetrachloroethylene, PAHs and benzene together account for the vast majority (about 80%) of individuals potentially exposed above background levels. A straightforward application of this knowledge is to attempt to reduce exposure to these three contaminants in the workplace and to potentially focus on the sectors where these contaminants have led to the greatest number of exposed workers.

An alternative approach is to examine the relative importance of individual industrial sectors in terms of the overall number of workers exposed to above background levels in that industry. Such an approach is supported by the summary statistics in table 5.1.3.2. Based on the estimates presented in this table, well over 80% of all workers exposed to above background levels comes from only four top-ranking sectors (manufacture of wearing apparel, land transport, personal and household services, and wholesale and retail trade and restaurants and hotels). This information could direct effort to overall reduction of exposure in these selected high-exposure sectors.

The third alternative is to rank the number of workers exposed occupationally to above background levels to each contaminant in each sector separately. The results are presented in detail in table 5.1.3.3 and summarized in table 5.1.3.4. Bolding highlights the top 20 ranking contaminant-sector combinations with respect to the largest number of workers exposed to above background levels and additional shading further emphasizes the top 10 sectors in the tables. The top 3 ranking contaminant-sectors account for 65%, the top 5 account for 73%, the top 10 for 80% and the top 20 for about 90% of the total number of workers exposed to above background levels. The highest numbers of exposed workers are found in the sector that manufactures wearing apparel (exposed to tetrachloroethylene), in the land transport sector (exposed to PAHs) and the sector that provides personal and household services (exposed to benzene). The risk management approach based on this method of data interpretation may have a narrower range of options and focuses on a few selected contaminants in a few selected sectors.

Although the three methods of looking at the data are different, the outcomes tend to be similar. Table 5.1.3.4, which lists 11 of the 32 sectors examined, contains 8 top ranking sectors and 20 top ranking sector-contaminant combinations. ToxProbe favours a sector-by-sector approach, because many risk management options allow a reduction of exposure to several contaminants simultaneously.

The results of the CAREX-based data analyses are in general agreement with ToxProbe's understanding of the use and releases of selected contaminants and with the number of people employed in different

sectors. However, these estimates are based on extrapolation from jurisdictions other than Toronto. Therefore, ToxProbe recommends the results be used for prioritization for further investigation rather than as the factual basis for making regulatory decisions.

Caution must also be exercised in interpreting the results. The size and heterogeneity of the industrial sector described in this report affect the overall estimate for the sector. For example, dry-cleaning plants are considered personal and household services in this report. Although the number of exposed workers to tetrachloroethylene is expected to be high in the dry-cleaning industry, because of the low number of exposed workers in many other personal and household services, the overall number of exposed workers in the personal and household services sector is relatively low. Furthermore, some findings are hard to reconcile. For example, since PAHs are emitted from cars and trucks, it is understandable why workers in land transport are often exposed to above background levels of PAHs. In contrast, although benzene and 1,3-butadiene are also present in car and truck emissions, the estimate of exposed workers for these two contaminants is much lower than for PAHs. At the same time, it is difficult to account for the high estimated number of workers exposed to benzene in the personal and household services sector since benzene has been largely eliminated from consumer products. The number of workers in the wholesale and retail trade and restaurants and hotels sector exposed to benzene is high. ToxProbe has not identified any obvious source of benzene in this sector except indoor cigarette smoking. Smoking in public buildings is restricted in Toronto, therefore it is likely that the actual number of workers exposed to benzene above background levels in this sector could be lower than predicted.

It should be noted that most of the workers occupationally exposed to above background levels in Toronto is not predicted to occur in establishments recognised as large point sources of environmental contamination. In fact, most of these workers seems to be employed in industries not generally thought of as large point sources of environmental contamination. Most of the exposed workers in Toronto probably work in small establishments with less than 50 workers (the average of the sectors considered in this study was about 42 employees/establishment). This finding is consistent with and supports ToxProbe's recommendation that the City focuses its effort on small sources and area sources of environmental emissions.

This section only examines the number of workers who are occupationally exposed to above background levels of selected contaminants. Even if the number of workers exposed is relatively large, the health effects need not be significant as long as the levels of exposure are low. As a result, prioritization based solely on the number of workers exposed may not always reflect the true risk priority of a given contaminant in a given sector. It is therefore important to establish sector-by-sector and activity-by-activity estimates of worker exposure. This issue is discussed in section 5.2.

Table 5.1.3.1. Estimated number of Toronto workers exposed to above background levels of selected carcinogens in various industries

	asbestos	1,3-butadiene	benzene	cadmium	chromium (VI)	formaldehyde	PAHs	tetrachloroethylene	trichloroethylene
Food manufacturing					145		69	158	0
Beverage industries					18	62		25	6
Tobacco manufacture									
Manufacture of textiles				18	1060	153		103	
Manufacture of wearing apparel, except footwear				1	101	1794	842	41148	12
Manufacture of leather and products of leather					37		14	8	1
Manufacture of footwear				1	6		7		
Manufacture of wood and wood and cork products				1	92	380	16		
Manufacture of furniture and fixtures					17	4846			
Manufacture of paper and paper products	55				171	68	27	209	
Printing, publishing and allied industries				154	365		11	284	
Manufacture of industrial chemicals	45	33	55	50	136	45	45		
Manufacture of other chemical products	120	28	187	2	182	40			
Manufacture of miscellaneous products of petroleum			14				26		
Manufacture of rubber products		5		7	13		55		
Manufacture of plastic products not elsewhere classified		116	145	298	326	193			
Manufacture of pottery, china and earthenware				3	1		7		
Manufacture of glass and glass products				8	10	5	14	4	2
Manufacture of other non-metallic mineral products				638	10	36	126		3
Iron and steel basic industries			45		41	112	295	57	
Non-ferrous metal basic industries			1	374	148	79	102	42	
Manufacture of fabricated metal products				70	617	16	179	176	63
Manufacture of machinery except electrical				50	494	16	89	186	66
Manufacture of electrical machinery, apparatus,				65	287			171	98
Manufacture of transport equipment	36			14	287		184	52	58
Manufacture of instruments, photographic and optical				131	174				
Other manufacturing industries				230	121				
Electricity, gas and steam	15			31	33		251	159	
Water works and supply								2	
Construction	1240			164	115	121	121	406	

	asbestos	1,3-butadiene	benzene	cadmium	chromium (VI)	formaldehyde	PAHs	tetrachloroethylene	trichloroethylene
Wholesale and retail trade and restaurants and hotels	4746		6059				569		
Land transport	84		247		48		29469	188	
Water transport			4		7		1	1	
Air transport			2	26	140			43	
Sanitary and similar services	9		8	8	5		104		1
Medical, dental, other health and veterinary services		1				156			
Personal and household services	783		8123	117	734	10	861	1957	196
Total exposed	7133	183	14891	2460	5942	8132	33485	45378	506
Rank	5	9	3	7	6	4	2	1	8
% exposed	6.0	0.2	12.6	2.1	5.0	6.9	28.4	38.4	0.4
% Toronto workforce	0.53	0.01	1.12	0.18	0.45	0.61	2.51	3.40	0.04

Total exposed – estimated number of Torontonians occupationally exposed to selected contaminants at above “background levels” in selected occupational sectors

Rank – ranking of a given carcinogen in terms of the number of occupationally exposed Torontonians (1 is the highest rank)

% exposed – represent % exposed to a given contaminant relative to all exposed Toronto workers in this study.

% Toronto workforce - represents % of the number exposed/number in Toronto workforce

Table 5.1.3.2. Occupational exposures in individual industry sectors

	Total exposures	Rank	% of sector exposed	% of total exposed	Fraction of Toronto workforce exposed x 1000
Food manufacturing	372	22	1.27	0.32	0.279
Beverage industries	111	28	1.80	0.09	0.083
Tobacco manufacture	0	37	0.00	0.00	0.000
Manufacture of textiles	1334	7	22.71	1.13	0.999
Manufacture of wearing apparel, except footwear	43897	1	232.34	37.17	32.866
Manufacture of leather and products of leather	59	30	5.29	0.05	0.044
Manufacture of footwear	15	33	0.68	0.01	0.011
Manufacture of wood and wood and cork products	490	20	12.03	0.41	0.366
Manufacture of furniture and fixtures	4862	5	27.65	4.12	3.641
Manufacture of paper and paper products	530	18	4.70	0.45	0.397
Printing, publishing and allied industries	813	11	2.28	0.69	0.609
Manufacture of industrial chemicals	410	21	7.03	0.35	0.307
Manufacture of other chemical products	560	16	2.86	0.47	0.419
Manufacture of miscellaneous products of petroleum	40	32	11.20	0.03	0.030
Manufacture of rubber products	80	29	10.55	0.07	0.060
Manufacture of plastic products not elsewhere classified	1078	9	8.23	0.91	0.807
Manufacture of pottery, china and earthenware	12	35	3.89	0.01	0.009
Manufacture of glass and glass products	42	31	5.82	0.04	0.032
Manufacture of other non-metallic mineral products	813	12	18.85	0.69	0.608
Iron and steel basic industries	550	17	18.91	0.47	0.412
Non-ferrous metal basic industries	746	13	15.02	0.63	0.558
Manufacture of fabricated metal products	1122	8	13.08	0.95	0.840
Manufacture of machinery except electrical	902	10	6.01	0.76	0.676
Manufacture of electrical machinery, apparatus,	621	15	2.48	0.53	0.465
Manufacture of transport equipment	632	14	6.97	0.53	0.473
Manufacture of instruments, photographic and optical	304	24	3.36	0.26	0.228
Other manufacturing industries	350	23	3.03	0.30	0.262
Electricity, gas and steam	490	19	6.92	0.42	0.367
Water works and supply	2	36	0.73	0.00	0.001
Construction	2168	6	4.59	1.84	1.623
Wholesale and retail trade and restaurants and hotels	11374	4	2.17	9.63	8.516
Land transport	30036	2	141.99	25.43	22.488
Water transport	13	34	2.86	0.01	0.010

	Total exposures	Rank	% of sector exposed	% of total exposed	Fraction of Toronto workforce exposed x 1000
Air transport	210	25	6.80	0.18	0.158
Sanitary and similar services	135	27	4.49	0.11	0.101
Medical, dental, other health and veterinary services	157	26	0.20	0.13	0.118
Personal and household services	12782	3	52.45	10.82	9.570

Total exposures – represent the total number of workers exposed to above background levels of any of the 10 contaminants in each sector

% of total exposed – represent % of exposed workers in the sector relative to all exposed workers in all sectors

Fraction of Toronto workforce exposed – represents the ratio of the number of exposed workers in the sector to the number of workers in the Toronto workforce.

Table 5.1.3.3. Ranking of occupational exposures to individual contaminants in different sectors based on the number of workers potentially exposed to above background levels of the contaminants (Ranking of 1 represents the contaminant/sector with the largest number of workers exposed)

	Asbestos	1,3-butadiene	benzene	cadmium	chromium (VI)	Formaldehy.	PAHs	Tetrachloro.	Trichloroethyl
Food manufacturing					52		76	47	
Beverage industries			161		110	81		109	136
Tobacco manufacture									
Manufacture of textiles				111	10	50		67	
Manufacture of wearing apparel, except footwear				157	69	8	12	1	122
Manufacture of leather and products of leather					99		118	131	158
Manufacture of footwear				151	137		133		
Manufacture of wood and wood and cork products			155	71	20	114			
Manufacture of furniture and fixtures					112	5			
Manufacture of paper and paper products	86	159			44	77	106	32	
Printing, publishing and allied industries				49	22		123	28	
Manufacture of industrial chemicals	92	102	84	89	55	92	92		
Manufacture of other chemical products	61	105	36	148	39	98			
Manufacture of miscellaneous products of petroleum		119				107			
Manufacture of rubber products		140		134	121		85		
Manufacture of plastic products not elsewhere classified	63	53	24	23	34				
Manufacture of pottery, china and earthenware				144	149		132	160	
Manufacture of glass and glass products				130	125	139	120	142	145
Manufacture of other non-metallic mineral products			15	124	100	57		143	
Iron and steel basic industries			91		97	65	25	83	
Non-ferrous metal basic industries			154	21	51	74	68	96	
Manufacture of fabricated metal products				75	16	115	40	41	80
Manufacture of machinery except electrical				88	18	113	72	37	78
Manufacture of electrical machinery, apparatus,				79	26			43	70
Manufacture of transport equipment	101			117	27		38	87	82
Manufacture of instruments, photographic and optical			56	42					
Other manufacturing industries				31	60				
Electricity, gas and steam	116			104	103		29	46	

	Asbestos	1,3-butadiene	benzene	cadmium	chromium (VI)	Formaldehy.	PAHs	Tetrachloro.	Trichloroethyl
Water works and supply								147	
Construction	9			45	64	58	58	19	
Wholesale and retail trade and restaurants and hotels	6		4				17		
Land transport	73		30		90		2	35	
Water transport			141		135		152	152	
Air transport			146	108	54			95	
Sanitary and similar services	127		128	128	138		66		150
Medical, dental, other health and veterinary services	156				48				
Personal and household services	13		3	62	14	126	11	7	33

Table 5.1.3.4. Contaminants and sectors with highest number of exposed workers (subset of table

5.1.3.3.)

	Asbestos	1,3-butadiene	benzene	cadmium	chromium (VI)	Formaldehyde.	PAHs	Tetrachloroethylen	Trichloroethylene
Manufacture of textiles					10				
Manufacture of wearing apparel, except footwear						8	12	1	
Manufacture of wood and wood and cork products						20			
Manufacture of furniture and fixtures						5			
Manufacture of other non-metallic mineral products				15					
Manufacture of fabricated metal products					16				
Manufacture of machinery except electrical					18				
Construction	9							19	
Wholesale and retail trade and restaurants and hotels	6		4				17		
Land transport							2		
Personal and household services	13		3		14		11	7	

The sectors/contaminants are ranked according to the number of workers exposed to above background levels of individual contaminants in each industrial sector. Ranking of 1 represents the contaminant/sector with the largest number of exposed workers.

Table 5.1.3.5. 3 Sectors with the largest number of workers exposed for each contaminant.

	Asbestos	1,3-butadiene	benzene	cadmium	chromium (VI)	Formaldeh.	PAHs	Tetrachloro.	Trichloroethyl
Manufacture of textiles					1				
Manufacture of wearing apparel, except footwear						2	3	1	
Manufacture of wood and wood and cork products,						3			
Manufacture of furniture and fixtures						1			
Manufacture of industrial chemicals		2							
Manufacture of other chemical products		3							
Manufacture of plastic products not elsewhere classified		1		3					
Manufacture of other non-metallic mineral products				1					
Non-ferrous metal basic industries				2					
Manufacture of fabricated metal products					3				
Manufacture of machinery except electrical									3
Manufacture of electrical machinery, apparatus,									2
Manufacture of transport equipment									
Construction	2							3	
Wholesale and retail trade and restaurants and hotels	1		2						
Land transport			3				1		
Personal and household services	3		1		2		2	2	1

Table 5.1.3.6. Descriptions of key sectors

Manufacture of textiles	Establishments engaged in performing any of the following operations: (1) preparation of fibre and subsequent manufacturing of yarn, thread, braids, twine, and cordage; (2) manufacturing broad woven fabrics, narrow woven fabrics, knit fabrics, and carpets and rugs from yarn; (3) dyeing and finishing fibre, yarn, fabrics, and knit apparel; (4) coating, waterproofing, or otherwise treating fabrics; (5) the integrated manufacture of knit apparel and other finished articles from yarn; and (6) the manufacture of felt goods, lace goods, non-woven fabrics, and miscellaneous textiles.
Manufacture of wearing apparel, except footwear	Establishments producing clothing and fabricating products by cutting and sewing purchased woven or knit textile fabrics and related materials, such as leather, rubberized fabrics, plastics, and furs. Also included are establishments that manufacture clothing by cutting and joining (for example, by adhesives) materials such as paper and non-woven textiles.
Manufacture of wood and wood and cork products	Establishments engaged in cutting timber and pulpwood; merchant sawmills, lath mills, shingle mills, cooperage stock mills, planning mills, and plywood mills and veneer mills engaged in producing lumber and wood basic materials; and establishments engaged in manufacturing finished articles (such as wooden kitchen cabinets) made entirely or mainly of wood or related materials, except furniture and some other products.
Manufacture of furniture and fixtures	Establishments engaged in manufacturing household, office, public building, and restaurant furniture; and office and store fixtures.
Manufacture of industrial chemicals	Establishments producing basic chemicals such as acids, alkalis, salts, and organic chemicals.
Manufacture of other chemical products	Establishments manufacturing products by predominantly chemical processes, producing chemical products to be used in further manufacture, such as synthetic fibres, plastics materials, dry colours, and pigments; and finished chemical products to be used for ultimate consumption, such as drugs, cosmetics, and soaps; or to be used as materials or supplies in other industries, such as paints, fertilizers, and explosives.
Manufacture of plastic products not elsewhere classified	Establishments manufacturing products, not elsewhere classified, from plastics resins.
Manufacture of other non-metallic mineral products	Establishments engaged in manufacturing cement, structural clay products, concrete and gypsum products, cut stone, abrasive and asbestos products, and other products from materials taken principally from the earth in the form of stone, clay, and sand.
Non-ferrous metal basic industries	Establishments engaged in smelting and refining nonferrous metals from ore, pig, or scrap; in rolling, drawing, and alloying metals; in manufacturing castings and other basic metal products; and in manufacturing nails, spikes, and insulated wire and cable.

<p>Manufacture of fabricated metal products</p>	<p>Establishments engaged in fabricating ferrous and nonferrous metal products, such as metal cans, tin ware, hand tools, cutlery, general hardware, non-electric heating apparatus, fabricated structural metal products, metal forgings, metal stampings, ordnance (except vehicles and guided missiles), and a variety of metal and wire products. Not included are transport equipment, precision instruments and jewellery.</p>
<p>Manufacture of machinery except electrical</p>	<p>Establishments engaged in manufacturing industrial and commercial machinery and equipment. Included are the manufacture of engines and turbines; farm and garden machinery; construction, mining, and oil field machinery; elevators and conveying equipment; hoists, cranes, monorails, and industrial trucks and tractors; metalworking machinery; special industry machinery; general industrial machinery; and refrigeration and service industry machinery.</p>
<p>Manufacture of electrical machinery, apparatus</p>	<p>Establishments engaged in manufacturing machinery, apparatus, and supplies for the generation, storage, transmission, transformation, and utilization of electrical energy. Included are the manufacturing of electricity distribution equipment; electrical industrial apparatus; household appliances; electrical lighting and wiring equipment; radio and television receiving equipment; communications equipment; electronic components and accessories; and other electrical equipment and supplies. The manufacture of household appliances is included in this group.</p>
<p>Manufacture of transport equipment</p>	<p>Establishments engaged in manufacturing equipment for transportation of passengers and cargo by land, air, and water. Important products produced by establishments classified in this major group include motor vehicles, aircraft, guided missiles and space vehicles, ships, boats, railroad equipment, and miscellaneous transportation equipment, such as motorcycles, bicycles, and snowmobiles.</p>
<p>Construction</p>	<p>Includes: (1) general contractors and operative builders primarily engaged in the construction of residential, farm, industrial, commercial, or other buildings; (2) general and specialized contractors primarily engaged in heavy construction other than building, such as highways and streets, bridges, sewers, railroads, irrigation projects and flood control projects; (3) special trade contractors who undertake activities of a type that are specialized either to building construction, including work on mobile homes, or to both building and non-building projects. These activities include painting (including bridge painting and traffic lane painting), electrical work (including work on bridges, power lines, and power plants), carpentry work, plumbing, heating, air-conditioning, roofing, and sheet metal work.</p>

<p>Wholesale and retail trade and restaurants and hotels</p>	<p><i>Wholesale:</i> establishments selling merchandise to retailers; to industrial, commercial, institutional, farm, construction contractors, or professional business users; or to other wholesalers; or acting as agents or brokers in buying merchandise.</p> <p><i>Retail:</i> establishments engaged in selling merchandise for personal or household consumption and rendering services incidental to the sale of the goods (includes eating places and (alcoholic beverage) drinking places.</p> <p><i>Hotels etc.:</i> commercial and non-commercial establishments engaged in furnishing lodging, or lodging and meals, and camping space and camping facilities.</p>
<p>Land transport</p>	<p>Establishments providing, to the general public or to other business enterprises, land passenger and freight transportation and postal services. The establishment is represented by a relatively permanent office, shop, station, terminal, or warehouse, etc. that is either (1) directly responsible for supervising such activities or (2) the base from which personnel operate to carry out these activities.</p>
<p>Personal and household services</p>	<p>Establishments primarily engaged in providing services generally to individuals, such as laundries, dry-cleaning plants, portrait photographic studios, and beauty and barbershops. Also included are establishments operating as industrial launderers and those primarily engaged in providing linen supply services to commercial and business.</p>

5.1.4. Discussion of uncertainty

The discussion in section 5.1.3 refers to some sources of uncertainty in the current exercise. In this section, uncertainty will be discussed in a more comprehensive and systematic manner.

Uncertainty can be classified into 3 major categories.

- Uncertainty associated with building of the CAREX database
- Uncertainty associated with matching UN industrial codes to the SIC codes, which were used in Canada until recently
- Uncertainty due to differences between the industrial processes, practices and regulations in the US and Finland at the time the data were collected for CAREX and today's situation in Toronto

CAREX was developed based on the exposure data obtained in USA and Finland. The American data were derived from the National Occupational Exposure Survey (NOES) conducted by the US National Institute for Occupational Safety and Health (NIOSH). NOES was a nationwide observational survey conducted with a sample of 4,490 establishments in 1981-83. The target population was defined as employees working in US establishments or job sites employing eight or more workers in a defined list of Standard Industrial Classifications (SIC). Generally, these classifications emphasized the coverage of construction (USSIC1972 classes 15-17), manufacture (20-39), transportation (40-47), private and business service (72-76), and hospital industries (80). The NOES had little or no sampling activity among 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. NOES potential exposure data displayed in the CAREX system are limited to those industries, which were sampled and surveyed in the NOES. In order for the CAREX system to include the NOES data, the US 1987 SIC codes had to be converted to the ISIC Rev2 system commonly used in European Union.

The Finnish estimates were based on the results of a comprehensive estimation survey (SUTKEA project) conducted by the industrial hygienists at the Finnish Institute of Occupational Health (FIOH) in the late 1980s and early 1990s. SUTKEA summarized the exposure data and FIOH's experience with the Finnish situation. The SUTKEA project was not a systematic field survey but was a collection of industrial hygienic data from separate research projects and compliance testing. Much of the SUTKEA exposure data have been included in CAREX as background data to indicate roughly the levels of exposure corresponding to different work tasks. Because some of the measurements were conducted for compliance testing purposes, they cannot be generalized to all exposed workers in specific industries. The numbers of exposed workers are estimates generated by individual Finnish experts responsible for the SUTKEA reports. CAREX used the national register of workers exposed to carcinogens in Finland (ASA Register kept by FIOH since 1979) as another basic source of information. The ASA data are based on annual notifications submitted by employers on the use of carcinogens and exposed workers. ASA notifications are obligatory and cover all salaried workers in Finland. However, the coverage of ASA is incomplete because occasional low-level

exposures are often not reported, and there are employers who are not aware of exposures or who neglect the obligation to notify. Generally, CAREX made use of ASA estimates that had been subjectively adjusted for incompleteness, when SUTKEA did not provide an estimate of exposed workers. If neither SUTKEA nor ASA provided any estimates, other available sources had been used as the basis for estimation.

The reference countries differ in their concept of exposure. The Finnish protocol required that *typical* ambient exposure, measured as annual dose, had to be exceeded in most cases, whereas the United States protocol considered the potential exposure. The Finnish approach set the minimum exposure generally at a higher level than the United States approach, therefore resulting in lower proportions of exposed workers. The CAREX system generally applied the average of the United States and Finnish incidences to arrive at the preliminary estimates for other countries. This means that “exposure” in CAREX lies somewhere between the potential exposure (as in the United States) and the exposure exceeding non-occupational background (as in Finland). CAREX therefore includes some exposures, which may be lower than the background. If exposures marked as low (close to the non-occupational background) were excluded, the total number of exposures decreases by 3% in Finland and by 31% in the United States. For other countries, whose estimates are mainly based on the average exposure incidences occurring in Finland and the United States, 15%-20% of all exposures would be considered low.

The numbers of exposures in CAREX were mainly estimated for industrial sectors classified by United Nations ISIC Revision 2 (1968) at the 3-digit level. Some estimates were made for some non-manufacturing sectors at the 1- or 2-digit levels. The number of employed persons used in the calculation was the average number of the employed in 1990-93. The Organization for Economic Co-operation and Development (OECD), which has uniformly collected industrial structure and workforce statistics according to the ISIC Rev 2 classification since the late 1960s, was the major source of labour force data. In the OECD database, the manufacturing and mining industries are divided into 76 sectors at the 3-digit level. Selected industrial data are also at the 4-digit level, if available. Non-manufacturing sectors are reported only at the 1-digit level in the OECD statistics, which was not accurate enough for the CAREX purposes. Therefore, workforce data by Nomenclature Général des Activités Economiques dans les Communautés Européennes (NACE) Revision 1 (1993) of EUROSTAT, 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 in CAREX. National experts surveyed, corrected, and completed the data from various sources available to them.

The authors of CAREX (Timo Kauppinen *et al.* 1998) summarized the uncertainty of their assessment, as cited below.

Empirical validity testing of CAREX would require well defined and comprehensive field surveys and measurements because validity may vary by agent, industry, and country. Such surveys are laborious and expensive to carry out. We think that the CAREX procedure, especially when supplemented by the assessments of national experts, has produced relatively valid estimates. However, the continuation of this work is recommended for several reasons. Firstly, some of the estimates reported are already outdated. Exposure in many countries has been recently restricted for some

agents including asbestos and passive smoking at work. Also leaded gasoline (including ethylene dibromide) has been replaced in some countries largely by unleaded gasoline (including MTBE). Secondly, national exposure patterns were not taken into account in all countries. For example, new data on national radon concentrations would help to improve estimates on occupational radon exposure. Thirdly, the estimates of the reference countries could be critically reviewed against industrial hygiene measurement data which may lead to exclusions of some exposures in CAREX. By contrast, some exposures may have to be added to CAREX. For example, exposure to silica in potato farming (machine sorting of potatoes grown in sandy ground) was not considered to entail exposure elsewhere than in The Netherlands. Industrial hygiene data could be surveyed to find out if exposures like this should be recognised also in other countries. The assessment team could learn from each other's data, which would probably increase awareness of unidentified exposures and risks at a national level. The continuation of work would increase the validity of national estimates and would thereby facilitate quantitative risk assessment, priority setting, and effective prevention of occupational cancer at the European and national levels.

When matching the industrial codes, there was always uncertainty about whether or not a completely correct match was made or whether there were subtle but possibly important differences in the definition of sectors in the UN ISIC codes and Canada's SIC codes. Furthermore, Toronto is home to many head offices, which could distort the occupational profile of industries within the city. For example, according to Toronto Business Directory, Toronto has a large number of workers in the mining sector. One can assume that all these workers are employed in the head offices and these workers' exposure patterns differ from those of workers associated with the mining operation. The CAREX procedure probably also provides incorrect non-zero estimates for Toronto for rare exposures, which normally do not occur in smaller jurisdictions with less diverse economic structure.

5.1.5. Conclusion

Despite the various sources of uncertainty, the magnitude of uncertainty associated with the Toronto estimates may not be large. In CAREX's experience, adjustment made to default estimates to correspond to the national situation led to an increase in the total estimated number of workers exposed to CAREX agents in Denmark (+15%) and France (+4%), but a decrease in Italy (-7%) and the Netherlands (-17%). However, the impact of the adjustment was bigger on an agent-by-agent basis. The exposure rates estimated for Toronto (see section 5.1.3) are within the expected range in most instances. These estimates are a reasonable starting point to direct further investigation and to use, with caution, for planning risk-reduction activities.

5.2. Industries, work activities and exposures

This section describes the levels of selected contaminants in different industries associated with different work activities. It should be noted that most of the data are obtained from readily available sources, which describe the situation that existed years ago in the USA and in other countries. The current Toronto exposure levels are likely to be lower in most cases due to the following reasons:

- general improvement of working conditions over the years;
- change in the industrial processes; and
- difference in industrial processes being used in different jurisdictions.

Furthermore, some of the industries or specific operations within the industry may not be located in Toronto. Therefore, readers are recommended to view the levels presented in this section generally as the upper bounds on the actual exposures.

5.2.1. Asbestos

Asbestos has been used in more than 5,000 products. It has been used in the production of textiles, electrical insulation and pharmaceutical and beverage filters, asbestos-cement pipes and sheets, clutch facings, break linings, asbestos paper, packaging, gaskets and pipe coverings. Short fibres can also be used as a reinforcer in plastics, floor tiles, coatings, papers, and roofing felts (NTP, 2000). Asbestos continues to be present in products that are being used today. Exposure levels to asbestos are summarised in table 5.2.1.1.

Table 5.2.1.1 Asbestos: occupational exposure levels

Industry/Occupation	Exposure level (f/mL)	Remarks (year of publication)	Reference
Industrial exposures	10-100,000 ng/m ³	USA, range of asbestos levels in industrial air (1977)	NTP, 2000
Cement pipe	0.2-6.3	USA (before 1971)	IARC, 1977
Cement shingles, millboard and gasket	0.1-4.4	USA (before 1971)	IARC, 1977
Friction	0.1-14.4	USA (before 1971)	IARC, 1977
Insulation	0.1-74.4	USA (before 1971)	IARC, 1977
Paper packaging and asphalt production	0.2-13.6	USA (before 1971)	IARC, 1977
Textile	0.1-29.9	USA (before 1971)	IARC, 1977

5.2.2. Benzene

Benzene is a major raw material and is used extensively as a solvent in the chemical and drug industry. It is used in the synthesis of many chemicals and is a natural constituent of gasoline (NTP, 2000). Exposure levels to benzene are summarised in table 5.2.2.1.

Table 5.2.2.1 Benzene: occupational exposure levels

Industry/Occupation	Exposure level (mg/m ³)	Remarks (year of publication)	Reference
Artificial leather	320-1600	(1936-1939)	IARC, 1982
Australian Air Force workshop	33-116	(1947)	IARC, 1982
Car mechanic	0.14	Median concentration (1998)	NTP, 2000
Car mechanic	3.5	Maximum exposure (1994)	NTP, 2000
Chemical plant	0.3-1.3	(1979)	IARC, 1982
Coal liquefaction	0.06	(1980)	IARC, 1982
General medical and surgical hospitals	-	According to a NIOSH 1981-83 survey, this sector consisted of half of all the benzene-exposed workers in the US.	ATSDR, 1997a
Leatherette factory	150-1000; 80-150 (improved control)	(1953-1957)	IARC, 1982
Metal painting	0.5-10	(1978)	IARC, 1982
Paint manufacture	Trace-362	(1963)	IARC, 1982
Petroleum refinery	2-103	(1978)	IARC, 1982
Printing	32-3392	(1939)	IARC, 1982
Refinery wastewater treatment	0.06-1.5	Personal samples (1978)	IARC, 1982
Rubber coating	204-640	(1935-1937)	IARC, 1982
Rubber coating	64-80	(1960-1963)	IARC, 1982
Rubber factory	320	(1942)	IARC, 1982
Rubber raincoat factory	438-698	(1977)	IARC, 1982
Service stations	0.08-10	(1980)	IARC, 1982
Shoe factory	130-140	(1964)	IARC, 1982

Industry/Occupation	Exposure level (mg/m³)	Remarks (year of publication)	Reference
	480-2080	(1966-1978)	IARC, 1982
Tank loader	1.4	Bottom loading	NTP, 2000
	6.1	Top loading (IARC, 1989)	NTP, 2000
Tanker truck drivers	0.68	Median concentration (1998)	NTP, 2000
Tire manufacturing	0.3-18.9	Personal breathing sample (1973-1977)	IARC 1982

5.2.3. 1, 3-Butadiene

1,3-Butadiene is mainly used in the manufacture of synthetic rubber, such as tires. Workers are also exposed to butadiene in facilities that manufacture products that use rubber components (NTP, 2000). Since 1,3-Butadiene is a product of incomplete combustion commonly found in combustion engine exhaust, workers in the transport sector are expected to be exposed to 1,3-butadiene. However, exposure levels in the transport sector are not readily available. Occupational exposure levels to 1,3-butadiene are summarized in table 5.2.3.1.

Table 5.2.3.1 1,3-butadiene: occupational exposure levels

Industry/Occupation	Exposure level (mg/m ³)	Remarks (year of publication)	Reference
Loading	0.17-273		NTP, 2000
Maintenance technician	0.026-94.38		NTP, 2000
Manufacturing facilities	0.06-39 ppm	TWA range in 6 facilities (1984)	NTP, 2000
Manufacturing facilities	0.006-374 ppm	Personal exposures (1990)	ATSDR, 1992
Manufacturing facilities (installation of rubber/plastic components)	0.06-39 ppm	Area samples (1984)	ATSDR, 1992
Monomer plant	0.04-827		NTP, 2000
Petrochemical plants	11.2-18.6 1.2	Workers handling containers, maintenance and laboratory workers (1996)	NTP, 2000 NTP, 2000
Plant laboratory	<0.0132- 822.8		NTP, 2000
Polymer industry	<0.01-94.9	Personal exposure, full shift	NTP, 2000
Polymer industry	<0.01-19.9	Area samples, 8 hr TWA	NTP, 2000
Polymer plant	2.57	Arithmetic mean (1993)	NTP, 2000
Polymerisation process	<0.011- 76.78		NTP, 2000
Rubber plant (styrene-butadiene)	0.44-6.5 ppm	Area samples (1983)	ATSDR, 1992
Rubber plant (styrene-butadiene)	1.24-13.5 ppm	Mean (1977)	ATSDR, 1992
Tank farm	0.02-52.8		NTP, 2000

5.2.4. Cadmium

Cadmium is mainly use for coating and electroplating of metal parts. It is also used for making batteries, pigments, plastic and synthetic products, as well as for alloys and other metal products (NTP, 2000). Exposure levels to cadmium are described in table 5.2.4-1.

Table 5.2.4-1 Cadmium: occupational exposure levels

Industry/Occupation	Exposure levels (µg/m ³)	Remarks (year of publication)	Reference
Industry (US)	< 5	Estimated 70% of workers exposed below the TWA	NTP, 2000
Industry (US)	1-39	65% of workers exposed to this range, 1987 NIOSH survey	IARC, 1993
Alloy production	50	Sweden (1979)	IARC, 1993
	28	UK (1980)	
	67	Mean, personal exposure in foundry, Italy (1982)	
	3	Mean, during alloy processing Italy (1982)	
Battery manufacture	870	Singapore (1973-80)	IARC, 1993
	< 50	UK (1975)	
	< 7.6	Sweden, mean (1977)	
Cadmium producing factories and nickel-cadmium plant	< 90	Belgium (1976)	IARC, 1993
Pigment production and use	3-350	Japan (1986)	IARC, 1993
Plastics production	< 10	PVC production, Singapore, (1982)	IARC, 1993
Smelting and refining	15	Mean, zinc-lead-cadmium smelter, UK (1977)	IARC, 1993
Soldering	> 50	UK, small specialised trades (1986)	IARC, 1993

5.2.5. Chromium

Chromium is used primarily by the metallurgical and chemical industries and to a lesser extent as an ingredient in the lining of high temperature furnaces. In the metallurgical industry, chromium is used to produce stainless steels and alloys. In the chemical industry, chromium is mainly used in production of pigments. Smaller amounts of chromium are also used in leather tanning, textiles manufacture, wood preservation, toners for copying machines, magnetic tapes, and as a catalyst (ATSDR, 1993b). Exposure levels to chromium are described in table 5.2.5.1.

Table 5.2.5.1 Chromium: occupational exposure levels

Industry/Occupation	Exposure levels ($\mu\text{g}/\text{m}^3$)	Remarks (year of publication)	Reference
Chromate production	100-500	(1982)	ATSDR, 1993b
Chrome pigment	60-600	Cr III, VI (1982)	ATSDR, 1993b
Chromium plating	5-25	Cr III, VI (1982)	ATSDR, 1993b
Ferrochrome alloys	10-140	Cr III, VI (1982)	ATSDR, 1993b
Stainless steel welding	50-400	Cr III, VI (1982)	ATSDR, 1993b
Stainless steel welding	4-10	(1987)	ATSDR, 1993b
Tanning	10-50	Cr III (1982)	ATSDR, 1993b

5.2.6. Dioxins and dibenzofurans

Polychlorinated dibenzo-p-dioxins (or dioxins) and dibenzofurans are not manufactured intentionally except for research purposes. Rather, they are by-products of many processes including incineration (municipal and hospital wastes), production of chlorinated compounds, pulp and paper bleaching and some smelting operations. The primary source of exposure to dioxins for humans is food (NTP, 2000).

5.2.7. Formaldehyde

Formaldehyde is used in the production of urea-formaldehyde resins, phenol-formaldehyde resins, plastics and the production of other chemicals used as intermediates. Formaldehyde resins are used as adhesives for particleboard, fibreboard, and plywood. Formaldehyde is used for moulding, paper treating and coating, treating of textiles, surface coating and foam insulation. It is also used in human and animal medicine. Occupational exposure to formaldehyde occurs during the production of end products, where formaldehyde and its solutions are used as in the garment industry, various preservation processes and in laboratories.

Healthcare professionals can also be exposed to formaldehyde (NTP, 2000; EHC, 1989). Exposure levels to formaldehyde are summarized in table 5.2.7.1.

Table 5.2.7.1 Formaldehyde: occupational exposure levels

Industry/Occupation	Exposure levels ($\mu\text{g}/\text{m}^3$)	Remarks (year of publication)	Reference
Formaldehyde production	0.01	Median emission levels from production plants in the US	NTP, 2000
Textile plant	0-2.7 ppm, mean 0.68 ppm 0.1-0.5 ppm, 0.2 ppm avg	(1960's and early 70's) (late 70's)	IARC, 1982
Garment factory	0.9-2.7 ppm	(1960's and early 70's)	IARC, 1982
Clothing store	0.9-3.3 ppm	(1960's and early 70's)	IARC, 1982
Laminating plant	0.04-10 ppm	(1960's and early 70's)	IARC, 1982
funeral homes	0.09-5.26 ppm, 0.25-1.39 ppm avg	(1960's and early 70's)	IARC, 1982
resin manufacture and paper production	16-30 ppm	(1960's and early 70's)	IARC, 1982
paper conditioning	0.9-1.6 ppm	(1960's and early 70's)	IARC, 1982
wood processing	31.2 ppm max	(1960's and early 70's)	IARC, 1982
Plywood plant	0.1-1.2 ppm, 0.35 ppm avg	(late 70's)	IARC, 1982
Wooden furniture manufacturing plant	0.1-5.4 ppm, 1.35 ppm avg	(late 70's)	IARC, 1982
Adhesive plants	0.8-3.5 ppm, 1.75 ppm avg	(late 70's)	IARC, 1982
Foundries	0.05-2.0 ppm, 0.6 ppm avg	(late 70's)	IARC, 1982
Construction sites	0.5-7.0 ppm, 2.8 ppm avg	(late 70's)	IARC, 1982
Hospitals and clinics	0.05-3.5 ppm, 0.7 ppm avg	(late 70's)	IARC, 1982

5.2.8. Polycyclic Aromatic Hydrocarbons (PAHs)

There is potential exposure to PAHs in the following activities: coal tar production, coking plants, coal gasification, smoke houses, foundries, aluminum production, bitumen and asphalt production, road and roof tarring operations, municipal waste incineration and cooking fumes (NTP, 2000). Use of coal tar, pitch, asphalt, creosote, soot, anthracene oils is widespread in the manufacture of fuel, dyes, plastics, paints, insulating materials, building materials, road building materials, rubber inks and brushes (ATSDR, 1995b). Exposure levels to PAHs are described in table 5.2.8.1.

Table 5.2.8.1 PAHs: occupational exposure levels

Industry/Occupation	Exposure levels (µg/m ³)	Remarks (year of publication)	Reference
Aluminum production	ND-975	from IARC	ATSDR, 1995b
Aluminum production	0.03-53	US (from IARC)	ATSDR, 1995b
Aluminum production	1.85-3.7 36-38	Area samples, B[a]P (1977) Personal samples, B[a]P (1977)	IARC, 1984
Aluminum production	0.7-9.0 19.7-202	B[a]P (1978) Total (1978)	IARC, 1984
Bitumen processing	1-40	Primarily naphthalene derivatives Area samples(1985)	ATSDR, 1995b
Bitumen refining	9.5 1.4-49.8	23 PAHs, outdoor workers (1980) 23 PAHs (1981)	IARC, 1985
Bitumen roofing operations	0.43-2.25 ND-0.04	Benzene soluble, personal sample (1977) B[a]P, personal samples (1977)	IARC, 1985 IARC, 1984
Bus drivers	<1-44 ng/m ³	(1993)	ATSDR, 1995b
Coal gasification plant	0.2 3.4-60.4	B[a]P, area samples (1982) B[a]P, personal samples, maintenance personnel (1982)	IARC, 1984

Coal tar pitch roofing	228-548 64.8-145	Total PAH, applicator (1982) B[a]P, applicator	IARC, 1985
Coke ovens	0-383	B[a]P (from IARC)	ATSDR, 1995b
Coke Ovens	0.15-6.72	B[a]P, US (from IARC)	ATSDR, 1995b
Coke production	14-135 0-1.5	B[a]P, particulate (1976) B[a]P, gaseous, (1976)	IARC, 1984
De-asphalting unit	2.3-49.8	Primarily naphthalene derivatives, area samples (1985)	ATSDR, 1995b
Electrode paste	14.4	Mean PAH (1994)	ATSDR, 1995b
Electrode plant (graphite)	19.7	(1993)	ATSDR, 1995b
Gas-works (coal gasification)	1.4-4.8	B[a]P (1965)	IARC, 1984
Gas-works (coal gasification)	2-7.3	B[a]P (1959)	IARC, 1984
Indoor flooring/waterproofing	1.7-2.5	11 PAHs, personal samples (1985)	IARC, 1985
Iron and steel foundry	1.78 41	B[a]P, area samples (1982) Total, area samples (1982)	IARC 1984
Optical industry	0.12-0.95	Area samples melting and moulding pitch (1983)	IARC 1985
Refineries	10	Personal samples (1983)	ATSDR, 1995b
Road paving operators	< 0.05 < 0.1-4.2	B[a]P (1979) Total particulates, personal samples (1979)	IARC, 1985
Road paving, asphalt mixing plant	0.011-0.19 200-5400	B[a]P (1977) Total, benzene soluble fraction (1977)	IARC, 1985
Roofing operations	14.5-112.5	11 PAHs, personal samples (1982)	IARC, 1985
Silicon carbide production	0.05-0.44	B[a]P, area samples (1983)	IARC, 1985

5.2.9. Tetrachloroethylene

Tetrachloroethylene is primarily used for dry cleaning and textile processing. It is also used as a chemical intermediate and metal degreasing agent. Minor application includes use as an insulation liquid and cooling gas in transformers, adhesives aerosols, in paints and coatings (NTP, 2000). Various consumer products contain tetrachloroethylene: printing ink, glues, sealants, polishes, lubricants, silicones, paint removers, rug and upholstery cleaners, stain, spot and rust removers (ATSDR, 1996). Exposure levels to tetrachloroethylene are described in table 5.2.9.1.

Table 5.2.9.1 Tetrachloroethylene: occupational exposure levels

Industry/Occupation	Exposure levels (mg/m ³)	Remarks (year of publication)	Reference
Automotive parts	1.3	(1984)	IARC, 1995
Degreasing	106	Mean, area samples (1980)	IARC, 1995
	271	Mean, personal samples (1981)	
	115	Mean, personal samples (1985)	
	130.3	Mean, area samples (1984)	
	86.1	Personal sample (1984)	
	78	Mean, area samples (1977)	
	57	Mean, personal samples (1977)	
	20	Mean (1992)	
Dry-cleaning (General)	47-328	(1990)	ATSDR, 1996
	70-350	(Late 1980s)	IARC, 1995
Dry-cleaning, machine operators	146	Mean of 44 facilities (1983)	ATSDR, 1996
Dry-cleaning, other	20-22	Mean of 44 facilities (1983)	ATSDR, 1996
Electroplating	753	Mean, personal samples (1986)	IARC, 1995
Graphic arts	13	Mean, personal samples (1982)	IARC, 1995
Motion picture film processing	9.5	Mean, area samples (1982)	IARC, 1995
	16.4	Mean, personal samples (1982)	
Printing plate manufacture	65.1	Mean, area samples (1982-85)	IARC, 1995

Industry/Occupation	Exposure levels (mg/m³)	Remarks (year of publication)	Reference
Protective coatings	2.7	Mean (1980)	IARC, 1995
Spray painting	21.4	Mean, personal samples (1983)	IARC, 1995
Painters, power plant	0.13	Mean, personal samples (1981)	IARC, 1995
	0.29	Mean, area samples (1981)	
Polyether urethane foam, car industry	2.1	Mean, area samples (1978)	IARC, 1995
	4.2	Mean, personal samples (1978)	
Urethane foam	0.6	Mean (1979)	IARC, 1995
Taxidermy	403	Mean, personal samples (1979)	IARC, 1995