Workplace exposure to carcinogens in New Zealand

(HRC 08/569)

Study report for the Department of Labour

Andrea ’t Mannetje
Centre for Public Health Research
Massey University
a.mannetje@massey.ac.nz

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Named Investigators: Andrea 't Mannetje (CPHR), Neil Pearce (CPHR), Dave McLean (CPHR), Jeroen Douwes (CPHR), Evan Dryson, Chris Walls, Lis Ellison-Loschmann (CPHR, Sunia Foliaki (CPHR), Aaron Blair (US National Cancer Institute), Hans Kromhout (IRAS, University of Utrecht), Tania Slater (CPHR), Paolo Boffetta (International Agency for Research on Cancer)
Additional Investigators who worked on this contract: Bill Glass (CPHR), Kerry Cheung (CPHR), Bradley Prezant (CPHR)
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1. Introduction

In 2008 The Centre for Public health Research was awarded a Partnership Programme Research Contract for the project titled "Workplace exposure to carcinogens in New Zealand", which was submitted in response to a 2007 RFP under the Occupational Health Research Strategy, a joint initiative in Occupational Health Research, funded by the Department of Labour and the Health Research Council of New Zealand. This report summarises the work completed under this contract.

2. Summary of Research

The research to be carried out under this contract was summarized in the application as follows:

2.1. Background

The National Occupational Health and Safety Committee (NOHSAC) estimates that 237-425 people die each year from occupational cancer in New Zealand. The lack of national data on the extent and industrial distribution of occupational exposure to carcinogens is limiting the prioritisation and implementation of successful prevention strategies.

2.2. Aims

(i) To provide a detailed assessment of the extent and industrial distribution of workplace carcinogens in New Zealand;
(ii) to identify key industries and key carcinogens for which intervention would result in marked reductions in occupational cancer; and
(iii) in selected key industries, to review the intervention strategies currently in place and evaluate the barriers to the implementation of additional interventions.

2.3. Design

The project will involve:
(i) a literature review of the occupational causes of cancer relevant to New Zealand, and the known solutions for reducing and/or preventing exposures;
(ii) the development of a New Zealand specific Information System on Occupational Exposure to Carcinogens (NZ-CAREX);
(iii) the development of a New Zealand specific Agricultural Chemicals Exposure Matrix (NZ-ACEM);
(iv) a survey in key New Zealand industries, evaluating the work practices regarding occupational carcinogens currently in place, the knowledge and attitudes of employers, employees and health and safety personnel about workplace carcinogens and possible intervention strategies.

2.4. Subjects

The survey in key New Zealand industries will involve recruiting employers, employees and health and safety personnel from each selected industry, who will complete a questionnaire on current exposures, work practices, knowledge and attitudes regarding workplace carcinogens and prevention strategies, and perceived barriers of implementation of additional intervention strategies. Where possible, the subjects will be recruited through

contacts from ongoing studies at the Centre for Public Health Research. The findings of the study will be discussed with industry stakeholders.

2.5. Main outcome measures

This study will provide an overview of the occupational causes of cancer in New Zealand. In addition, it will provide easily accessible, quantitative, and New Zealand-specific data on the extent and industrial distribution of occupational exposure to carcinogens. This will not only provide estimates of the number of workers exposed to carcinogens, but will also help determine the key exposures and key industries for which intervention would result in marked improvements in occupational health. This study will also provide new knowledge on interventions and their effectiveness and the perceptions and behaviours regarding health and safety in key New Zealand industries. The study's stakeholder engagement will result in a greater industry awareness of the occupational cancer problem and the potential benefits of interventions. Finally, this study will build international research partnerships and will increase the occupational health research capacity in New Zealand.

3. Specific outputs of the project

The project has several concrete outputs, apart from the envisaged scientific publications in peer reviewed journals that will flow from this research. The specific outputs are: (1) Literature review; (2) List of occupational carcinogens; (3) NZ-CAREX and (4) NZ-ACEM. Each is discussed in more detail below.

3.1. Literature review

The literature review starts with an introductory chapter on what is currently known about occupational cancer in New Zealand. Background information is given on how occupational exposures are evaluated for carcinogenicity according to the International Agency for Research on Cancer. The question whether occupational cancer is a problem of the past is discussed, followed by estimates of the burden of occupational cancer in the world and in New Zealand specifically. What sources of information are available on exposure to occupational carcinogens are summarised, as well as the most important approaches available for the prevention of occupational cancer.

This is followed by a chapter for each industry subdivision (according to the ANZSIC 3-digit classification). The 42 chapter titles are listed in Table 1, along with the number of people in New Zealand employed in these industries, according to the 2006 census.

Table 1: The Australian and New Zealand Standard Industry Classification and the number of men and women employed in each subdivision according to the 2006 Census.

ANZSIC 3-digit industry subdivision		men	women	total
A01	Agriculture	13,311	10,467	23,784
A02	Services to Agriculture; Hunting and Trapping	12,726	6,180	18,909
A03	Forestry and Logging	6,744	1,227	7,974
A04	Commercial Fishing	2,238	627	2,862
B11	Coal Mining	708	66	771
B12	Oil and Gas Extraction	240	54	297
B13	Metal Ore Mining	384	54	438
B14	Other Mining	1,497	222	1,719
B15	Services to Mining	807	120	927
C21	Food, Beverage and Tobacco	35,436	19,350	54,789
C22	Textile, Clothing, Footwear and Leather Manufacturing	7119	10647	17763
C23	Wood and Paper Product Manufacturing	19,101	3,876	22,980
C24	Printing, Publishing and Recorded Media	12,111	10,131	22,242
C25	Petroleum, Coal, Chemical and Associated Product Manuf.	12,609	5,361	17,955
C26	Non-Metallic Mineral Product Manufacturing	5,607	1,239	6,822
C27	Metal Product Manufacturing	22,503	4,254	26,745
C28	Machinery and Equipment Manufacturing	34,359	8,301	42,654
C29	Other Manufacturing	10,314	3,882	14,193
D36	Electricity and Gas Supply	3,075	1,326	4,401
D37	Water Supply, Sewerage and Drainage Services	1,191	504	1,695
E41	General Construction	57,399	7,509	64,908
E42	Construction Trade Services	70,797	11,832	82,644
F45	Basic Material Wholesaling	20,379	8,190	28,566

F46 Machinery and Motor Vehicle Wholesaling	26,295	9,279	35,577
F47 Personal and Household Good Wholesaling	23,088	20,424	43,530
G51 Food Retailing	33,252	47,772	81,024
G52 Personal and Household Good Retailing	39,807	66,804	106,596
G53 Motor Vehicle Retailing and Services	39,243	11,250	50,490
H57 Accommodation, Cafes and Restaurants	34,686	59,904	94,590
I61 Road Transport	27,261	6,174	33,432
I62 Rail Transport	1,563	291	1,857
I63 Water Transport	1,341	810	2,151
I64 Air and Space Transport	5,502	3,441	8,949
I65 Other Transport	1,146	276	1,419
I66 Services to Transport	12,357	9,924	22,272
I67 Storage	3,588	1584	5,172
J71 Communication Services	13,119	11,220	24,333
K73 Finance	15,957	22,449	38,415
K74 Insurance	3,993	5,046	9,039
K75 Services to Finance and Insurance	8,367	8,316	16,686
L77 Property Services	27,537	24,801	52,329
L78 Business Services	105,156	96,255	201,414
M81 Government Administration	23,217	34,044	57,267
M82 Defence	7,380	2,454	9,834
N84 Education	38,028	101,097	139,134
O86 Health Services	21,246	85,047	106,305
O87 Community Services	7,203	47,634	54,834
P91 Motion Picture, Radio and Television Services	6,105	5,043	11,151
P92 Libraries, Museums and the Arts	7,056	8,748	15,801
P93 Sport and Recreation	12,060	12660	24,717
Q95 Personal Services	13,050	21,252	34,299
Q96 Other Services	23,007	18,729	41,739
Q97 Private Households Employing Staff	9	24	33

The numbers are based on the 2006 Census data

Each chapter covers the following:

1. Description of the industry
2. Potential for work-related carcinogen exposure
3. Exposure studies
4. Cancer risk
5. Gaps in knowledge
6. Prevention strategies
7. References

The **description of the industry** gives background information on what activities are performed in that industry, the number of people working in that industry, and the main occupational groups within that industry. The paragraph on the **potential for work-related carcinogen exposure** discusses the tasks and circumstances during which workers can be exposed to carcinogens, and lists these carcinogens. The paragraph on **exposure studies**, lists whether specific exposure studies have been reported for carcinogens within this industry. The paragraph on **cancer risk**, summarises whether epidemiological studies have reported any increases in cancer risk for this particular industry or for occupational groups that are prevalent within this particular industry. New Zealand specific studies are discussed separately. The following paragraph briefly points out the main **gaps in knowledge** regarding exposure to carcinogens and cancer risk for this industry, followed by a review of documents or other information available regarding **prevention strategies**.

The literature review's division into industry groups, resonates with the National Action Agenda 2010-2013 (of the Workplace Health and Safety Strategy for New Zealand to 2015) approach of identifying priority industries and developing action plans by industry sector.

STATUS: The literature review is currently being edited for publication as a CPHR report (see draft report in Appendix 1). It can be used as a stand-alone information source on the exposure circumstances of occupational carcinogens in New Zealand, but is also an accompanying document to CAREX-NZ.

3.2. List of occupational carcinogens

Based on the IARC evaluations and the information stored in CAREX, a list of occupational carcinogens was compiled. This list contains industrial chemicals, fibres and dusts, combustion products, metals, microbial agents, pesticides, hormones, radiation, pharmacological agents and exposure circumstances, which can be present in the workplace and workers can potentially be exposed to as part of their work. Included are IARC Group 1, 2A and 2B carcinogens, with classifications updated to the end of 2011.

IARC evaluation (updated to end 2011):
Group 1: The agent is carcinogenic to humans.
Group 2A: The agent is probably carcinogenic to humans.
Group 2B: The agent is possibly carcinogenic to humans.

For each carcinogen listed, basic background information is provided. This includes:

1. The IARC evaluation (group 1, 2A or 2B) and the reference to the IARC Monograph in which the compound was evaluated.

2. The CAS number, which is a unique numerical identifier of the agent, published by the Chemical Abstracts Service (CAS) of the American Chemical Society.

3. The exposure category (all agents are categorized into one of the following groups):
   - Industrial chemicals
   - Metals
   - Pesticides
   - Fibres and dust
   - Radiation
   - Pharmacological
   - Hormones
   - Microbial agents
   - Combustion product
   - Exposure circumstances

4. A short summary of the agent's uses. Information mainly obtained from CAREX, the 11th RoC (Report on Carcinogens of the US National Toxicology Program; http://ntp.niehs.nih.gov/) and HazMap (http://hazmap.nlm.nih.gov/).

5. The New Zealand exposure standard for the compound - if available - obtained from the New Zealand Workplace Exposure Standard, published in 2002 (updates published since 2002 are included).

6. Definition of the agent for the purpose of the CAREX evaluation. Obtained from the original CAREX database.

The list currently includes 81 Group 1 carcinogens; 56 Group 2A carcinogens and 118 Group 2B carcinogens. The list of carcinogens is part of the CAREX-NZ ACCESS database, which has the advantage it can be easily updated (e.g. when exposure standards or IARC classifications change), and can be printed out in different ways (e.g. alphabetical; grouped by exposure category; grouped by IARC evaluation, etc.).

STATUS: this document is available as a background document for CAREX-NZ, as well as a stand-alone document (See draft report in appendix 2).

3.3. NZ-CAREX

NZ-CAREX stands for **CA**rcinogen **EX**posure **N**ew **Z**ealand. It is an ACCESS based information system, listing for each industry the carcinogens that may occur in that industry. The industry classification follows the same classification as applied for the literature review (see 3.1). The carcinogen classification follows the same classification as that applied for the list of occupational carcinogens (see 3.2.).

NZ-CAREX provides for each industry an estimate of the fraction of workers within that industry potentially exposed to each carcinogen expected to be present in that industry. These estimates are based on the international CAREX evaluations and local expert assessment (i.e. industrial hygienists and other professionals in the field). By combining the fraction of workers with the total number of men and women working in that industry, the total number of men and women potentially exposed within that industry is automatically calculated within the ACCESS database.

This information can be presented in different ways within NZ-CAREX, in the form of automatic ACCESS reports. When information within NZ-CAREX is updated, these reports are automatically updated as well. The reports include:

1. Carcinogens
2. Carcinogens by industry
3. Industries by carcinogen

The **Carcinogens** report lists all carcinogens and the estimated total number of men and women with potential occupational exposure to this carcinogen in New Zealand. The **Carcinogens by industry** report lists the carcinogens that can occur in each industry, plus the estimated number of men and women potentially exposed to them within that industry.

This report gives a quick overview of the total number of carcinogens within that industry and which carcinogens are the most common within that industry.
The **Industries by carcinogen** report lists the industries in which occupational exposure to a certain carcinogen can occur, together with the total number of men and women potentially exposed to that carcinogen in each industry. This report gives a quick overview of which industries contain the highest number of workers exposed for each particular industry.

STATUS: the NZ-CAREX database is ready for use for a wide range of carcinogens and industries, and we will continue to update the database for other carcinogens and industries (not yet included). We propose to present the database at Department of Labour (DoL) at a date/time convenient for the DoL.

3.4. NZ-ACEM

Farmers have an increased risk of certain cancers, but which exposures are responsible is not known. Pesticide exposure is likely to be related to this increased risk, but it has been very difficult to associate specific pesticides with the increased risk because of the difficulties in assessing the exposure to specific pesticides. Therefore, as part of this project, a New Zealand specific Agricultural Chemicals Exposure Matrix (NZ-ACEM) was developed. This is supplementary to NZ-CAREX and specifically focuses on pesticide exposure within the agricultural industry. NZ-ACEM was set up separately from NZ-CAREX because:

1. The IARC classification used for NZ-CAREX is not very complete regarding the classification of the carcinogenicity of pesticides
2. The industry classification used for NZ-CAREX is not specific enough to characterize pesticide exposure

To illustrate that the IARC classification used for NZ-CAREX is not very complete regarding the classification of the carcinogenicity of pesticides, the pesticides evaluated to be Group 1 or 2A or 2B by the IARC Monographs for their carcinogenicity are listed below.

Pesticides (or pesticide groups) evaluated by IARC to be a group 1, 2A or 2B carcinogen
Group 1: Arsenical pesticides
Group 2A: non-arsenical pesticides (occupational exposure in spraying and application); captafol; ethylene dibromide
Group 2B: 1,2-Dibromo-3-chloropropane; aramite; chlordane; chlordecone; chlorphenoxy herbicides; chlorothalonil; DDT; dichlorvos; heptachlor; hexachlorobenzene; lindane; mirex; nitrofen; pentachlorophenol; sodium ortho-phenylphenate; toxaphene

For many pesticides the evidence of carcinogenicity has never been evaluated by IARC. In addition, many of the pesticides that were evaluated are no longer used in New Zealand. Also, some evaluations refer to a very broad group of pesticides (e.g. non-arsenical pesticides; chlorophenoxy herbicides) which is not informative regarding potential risk associated with specific pesticides.

Table 2. Active ingredients most commonly used in New Zealand (2004) and their evaluation of human carcinogenicity

active ingredient (pesticide group) CAS	tonnes active ingredient/yr	Evaluation of human carcinogenicity		
		HSNO (NZ)	EPA (US)	IARC (WHO)
Herbicides	2000			
MCPA (phenoxy hormones) 94-74-6	447		not likely (2003)	possibly (chlorophenoxy herbicides) (1987)
glyphosate (phosphonyls) 1071-83-6	344		evidence of non-carcinogenicity (1991)	
2,4-D (phenoxy hormones) 94-75-7	282		not classifiable (1997)	possibly (chlorophenoxy herbicides) (1987)
terbuthylazine (triazines) 5915-41-3	224		not classifiable (1994)	
mecoprop (phenoxy hormones) 93-65-2	178			possibly (chlorophenoxy herbicides) (1987)
MCPB (phenoxy hormones) 94-81-5	174		not likely (2008)	possibly (chlorophenoxy herbicides) (1987)
isoproturon (urea derivates) 34123-59-6	73			
acetochlor (amides) 34256-82-1	63		suggestive evidence (2007)	
hexazinone (triazines) 51235-04-2	53		not classifiable (1994)	
atrazine (triazines) 1912-24-9	49		not likely (2000)	possibly -> not classifiable (1999)
triclopyr (other hormones) 55335-06-3	44		not classifiable (1996)	
alachlor (amides) 15972-60-8	40	suspected	multiple indicators (1997)	
propachlor (amides) 1918-16-7	27	suspected	likely (1997)	
trifluralin (dinitroanilines) 1582-09-8	19		possible (1986)	not classifiable (1991)
linuron (urea derivates) 330-55-2	14		possible (2001)	
glufosinate-ammonium (phosphonyls) 77182-82-2	12		not likely (1999)	
picloram (other hormones) 1918-02-1	11		evidence of non-carcinogenicity (1994)	not classifiable (1991)
fungicides	900			
mancozeb (dithiocarbamate) 8018-01-7	442		probable (1999)	(ethylenethiourea) possibly -> not classifiable (2001)
sulphur (inorganics) 7704-34-9	99			
captan (other fungicides) 133-06-2	47	suspected	multiple descriptors (2004)	not classifiable (1987)
chlorothalonil (other fungicides/organochlorine) 1897-45-6	25	suspected	likely (1994)	possibly (1999)
metalaxyl-m (other fungicides) no CAS	15			
metiram (dithiocarbamate) 9006-42-2	15		probable (1999)	
tolylfluanid (other fungicides) 731-27-1	14		likely (2002)	
thiram (dithiocarbamate) 137-26-8	11		not likely (2003)	not classifiable (1991)
phosphorous acid (inorganics)13598-36-2	7			
ziram (dithiocarbamate) 137-30-4	6		suggestive evidence (2003)	not classifiable (1991)
insecticides	200			
diazinon (organophosphate) 333-41-5	93		not likely (1997)	
methamidophos (organophosphate)10265-92-6	19		not likely (1997)	
chlorpyrifos (organophosphate) 2921-88-2	17		evidence of non-carcinogenicity (1993)	
carbaryl (carbamate) 63-25-2	16	suspected	likely (2002)	not classifiable (1987)
fenamiphos (organophosphate) 22224-92-6	11		evidence of non-carcinogenicity (1993)	
pirimiphos-methyl (organophosphate) 29232-93-7	8		cannot be determined (1998)	
phorate (organophosphate) 298-02-2	6		evidence of non-carcinogenicity (1993)	
plant growth regulators	300			
hydrogen cyanamide 420-04-2	216		possible (1993)	
ammonium thiosulphate 7783-18-8	45			
chlormequat-chloride 999-81-5	19		not likely (2007)	
mepiquat-chloride 24307-26-4	15		not likely (2003)	

Other agencies have a more complete list of pesticides evaluated for carcinogenicity, for example, the United States Environmental protection Agency (EPA). Table 2 lists the

pesticide active ingredients most commonly used in New Zealand according to figures published in 2004, the evaluation of human carcinogenicity by IARC and US EPA, and the information regarding carcinogenicity given on these active ingredients under HSNO.

This indicates that for several pesticides that are widely used in New Zealand, there is suspicion of carcinogenicity to humans. It also indicates that in some cases the information from different agencies is conflicting.

For this reason, NZ-ACEM includes not only pesticides that are suspected to be carcinogenic, but all commonly used pesticides in New Zealand. The list of pesticides was based on 'Trends in pesticide Use in New Zealand: 2004", published in 2005 as a report to the Ministry for the Environment by HortResearch.

The ANZSIC 5-digit industry classification was used as a starting point for the industry axis of NZ-ACEM. A further subdivision based on specific crops within each industry was made, because pesticide use can vary significantly between crops, and pesticide use is reported for each of these crops in the 'Trends in pesticide Use in New Zealand: 2004" report.

Table 3. The Australian and New Zealand Standard Industry Classification for the agricultural industry and the number of men and women employed in each industry according to the 2006 Census, as well as specific crops within each industry

industry	Men (n)	Women (n)	Total (n)
A0111 Plant Nurseries	1677	1893	3570
A0112 Cut Flower and Flower Seed Growing	651	837	1485
A0113 Vegetable Growing asparagus carrots cauliflower/cabbage/b.sprouts/broccoli cucumbers/tomatoes/capsicums forage brassicas kumara lettuce onions/garlic peas/beans potatoes pumpkins silverbeet/spinach squash sweetcorn tomatoes - outdoor	2697	2025	4722
A0114 Grape Growing	2175	1509	3687
A0115 Apple and Pear Growing apples pears/nashi	2199	1428	3630
A0116 Stone Fruit Growing apricots cherries peaches/nectarines plums	189	123	312
A0117 Kiwi Fruit Growing	1758	1161	2919
A011910 Citrus Growing	210	141	354
A011920 Berry Fruit Growing blackcurrants blueberries boysenberries/blackberries/raspberries strawberries	282	345	627
A011990 Other Fruit Growing nec avocado	1473	1005	2478

feijoas olives passionfruit persimmons tamarillos walnuts/macadamias/chestnuts			
A0121 Grain Growing barley cereal silage or balage maize-grain maize-silage or balage oats wheat	402	159	561
A0122 Grain-Sheep and Grain-Beef Cattle Farming	501	180	681
A0123 Sheep-Beef Cattle Farming	6333	3033	9369
A0124 Sheep Farming	12021	5337	17355
A0125 Beef Cattle Farming	6918	3747	10665
A0130 Dairy Cattle Farming	21798	11715	33513
A0141 Poultry Farming (Meat)	504	423	927
A0142 Poultry Farming (Eggs)	357	324	681
A0151 Pig Farming	552	210	762
A0152 Horse Farming	600	630	1230
A0153 Deer Farming	1020	501	1518
A015910 Mixed Livestock	2046	1011	3057
A015930 Beekeeping	525	234	759
A015990 Livestock Farming nec	1227	744	1971
A016910 Tobacco and Hops Growing	78	27	105
A016920 Cultivated Mushroom Growing	189	288	480
A016990 Crop and Plant Growing nec	411	237	648
A0212 Shearing Services	1908	1011	2919
A0213 Aerial Agricultural Services	282	60	342
A0219 Services to Agriculture nec	10296	5058	15354
A0220 Hunting and Trapping	240	51	294
A0301 Forestry	1800	498	2301
A0302 Logging	2934	318	3252
A0303 Services to Forestry	2010	411	2421

The NZ-ACEM database is an ACCESS database listing the pesticides used for each specific crop in New Zealand (for the industries and crops listed above in Table 3). The pesticides are grouped into FAO categories, as specified in Table 4.

STATUS: The NZ-ACEM is completed and can be used to assess occupational exposure to specific pesticides in epidemiological studies that collected information on crop. It can also be used as a general information source on the potential pesticide exposure in each agricultural sector. Similar to NZ-CAREX, we propose to present the NZ-ACEM database at Department of Labour at a date/time convenient for the DoL.

Table 4. The grouping of pesticides used in NZ-ACEM

agrichemical group	FAO Category	active ingredients
FUNGICIDES & BACTERICIDES		
	Benzimidazoles	Benomyl; carbendazim; fuberidazole; thiabendazole; thiophanate-methyl
	Botanicals and Biologicals	Bacillus subtilis; Ulocladium oudemansii
	Diazines, Morpholines & other EBIs	Bupirimate; dimethomorph; fenarimol; triforine
	Dicarboximides	Iprodione; procymidone
	Dithiocarbamates	Mancozeb; metiram; thiram; ziram
	Inorganics	bordeaux mixture; calcium polysulfide; copper ammonium complex; copper ammonium complex (acetate/carbonate); copper hydroxide; copper oxychloride; copper sulphate; cuprous oxide; phosphorous acid; sulphur
	Strobilurins	Azoxystrobin; kresoxim-methyl; trifloxystrobin
	Triazoles and Diazoles	Bitertanol; cyproconazole; difenoconazole; epoxiconazole; flusilazole; flutriafol; imazalil; myclobutanil; penconazole; prochloraz; propiconazole; tebuconazole; triadimefon; triadimenol
	Other fungicides	2-hydroxy benzoic acid; captan; carboxin; chlorothalonil; cymoxanil; cyprodinil; dichlofluanid; dicloran; dithianon; dodine; ethylene glycol; fenamidone; fenhexamid; fluazinam; fludioxonil; folpet; fosetyl-aluminium; metalaxyl; metalaxyl-m; pencycuron; propamocarb; pyrazophos; pyrimethanil; quintozene; streptomycin; tolclofos-methyl; tolylfluanid
HERBICIDES		
	Amides	Acetochlor; alachlor; metolachlor; propachlor; propyzamide
	Bipyridyls	Diquat; paraquat; paraquat dichloride
	Carbamate herbicides	Asulam; chlorpropham; phenmedipham
	Dinitroanilines	Pendimethalin; trifluralin
	FOPs and DIMs	Clethodim; clodinafop-propargyl; fenoxaprop-p-ethyl; flamprop isopropyl; fluazifop-p-butyl; haloxyfop; haloxyfop [(r)-isomer]; sethoxydim; tralkoxydim
	Other hormone types	Clopyralid; dicamba; picloram; triclopyr; triclopyr butoxyethyl ester: triclopyr bee
	Phenoxy hormones	2,4-D; 2,4-D amine; 2,4-D ester; 2,4-DB; dichlorprop; dichlorprop-p; MCPA; MCPB; mecoprop; mecoprop-p
	Phosphonyls	glufosinate-ammonium; glyphosate; glyphosate-trimesium
	Sulfonylureas	chlorimuron-ethyl; chlorsulfuron; halosulfuron-methyl; iodosulfuron-methyl-sodium; metsulfuron-methyl; primisulfuron-methyl; thifensulfuron-methyl; tribenuron-methyl
	Triazines	Atrazine; hexazinone; metribuzin; prometryn; simazine; terbuthylazine
	Uracils	terbacil
	Urea Derivatives	Diuron; isoproturon; linuron; methabenzthiazuron
	Other herbicides	Amitrole; bentazone; bromoxynil; chloridazon; clomazone; dichlobenil; diflufenican; dimethenamid; ethofumesate; fluroxypyr; ioxynil; norfluazon; oxyfluorfen
INSECTICIDES		
	Acaricides	Azocyclotin; clofentezine; dicofol; fenbutatin oxide; fenpyroximate; milbemectin; propargite
	Botanicals and Biologicals	Abamectin; Bacilli; Cydia pomonella granulosis virus, mexican strain; pyrethrins; Serratia entomophila; spinosad
	Carbamate insecticides	Carbaryl; furathiocarb; methiocarb; methomyl; oxamyl; pirimicarb; primicarb
	Insect Growth Regulators	Buprofezin; diflubenzuron; lufenuron; s-methoprene; tebufenozide
	Organophosphates	Acephate; azinphos-methyl; chlorpyrifos; diazinon; dichlorvos; dimethoate; fenamiphos; maldison; methamidophos; parathion-methyl; phorate; pirimiphos-methyl; prothiofos; terbufos
	Pyrethroids	alpha-cypermethrin; bifenthrin; cyfluthrin; cypermethrin; deltamethrin; esfenvalerate; fluvalinate; lambda-cyhalothrin; permethrin; tau-fluvalinate
	Other insecticides	Clothianidin; emamectin benzoate; endosulfan; fipronil; imidacloprid; indoxacarb; indoxycarb; metaldehyde; pymetrozine; thiacloprid; thiamethoxam; thiocloprid

3.5. Industry surveys

As specified in the study proposal, it was not feasible within the time and financial constraints of the study to survey all industries for their exposure to carcinogens and their specific intervention and prevention strategies. Instead we made use of the infrastructure already in place for studies being conducted by CPHR in industries with exposure to key carcinogens (e.g. asbestos, silica and wood dust). The surveys conducted in these selected industries are summarized below.

3.5.1. Joiners and Furniture industry (wood dust and formaldehyde)

A study entitled "Exposures to hazardous airborne substances in the wood conversion industry", which was principally funded by ACC, also included parts particularly relevant for the aims of the current study. In particular, the study included an exposure survey in the New Zealand joinery and furniture industry involving measurements of airborne substances including wood dust and formaldehyde. The study also included an assessment of which strategies have been most effective in reducing exposure in other countries.

This study showed that the majority of New Zealand joinery and furniture workers (87% and 63% respectively) are exposed to inhalable wood dust levels in excess of international standards of 1 mg/m^3. Formaldehyde exposure levels were very low in both joinery and furniture workers. A review of available wood dust prevention strategies showed that educational intervention measures alone, such as risk education and providing information on good work practice, results in only a modest reduction in (wood) dust exposure. For more effective control measures to be developed – directed at the conditions and tasks that contribute most to these exposures - more detailed information on peak exposures is essential. The results of this study are reported in a CPHR technical report:
Cheung K, McLean D, Pearce N, Douwes J. Exposures to hazardous airborne substances in the wood conversion sector. Technical Report No. 33. Wellington: CPHR, 2010.
Another study currently being conducted at the Centre for Public Health Research entitled "Workplace interventions to reduce wood dust exposures in joinery and furniture workers" which is funded by the HRC and DoL, focuses specifically on the intervention strategies to reduce wood dust exposure. This study is on-going.

3.5.2. Building industry (asbestos and silica)

A study entitled "Asbestos exposure levels in demolition sites", which was principally funded by DoL, also included parts particularly relevant for the aims of the current study. As part of this study, a variety of asbestos demolition projects across New Zealand were sampled (time-weighted average and short-term) for personal exposure to asbestos fibres using standard methodology (both PCM and TEM). Workers reported variable adherence to the administrative controls portions of the DoL Asbestos Guidelines, with initial training, initial medical evaluation, and the requirement that a supervisor be present consistently achieved, but follow-up exams and implementation of required asbestos work practices, including

proper use of respiratory protection, were poorly achieved. In particular, containment was noted to be in place, but in all but one of the 9 sampled projects, required negative air pressurization was not achieved or even realistically attempted. Air sampling (25 TWA samples, 10 STEL samples) indicated a median exposure for all 9 projects to be well below applicable WES time-weighted average and STEL levels (median TWA 0.03 fibres/cc., median STEL 0.15 fibres/cc.). Eight of the nine sites would be in compliance with applicable WES PCM asbestos exposure requirements (1.0 fibres/cc. TWA), 7 of these 8 with measured levels less than 0.1 fibres/cc. A PCM sample of 0.122 fibres/cc. from one project, on reanalysis by TEM, indicated levels of 3.3 structures/cc., chrysotile. The ninth site (PCM levels exceeding the WES at 0.871 fibres/cc.) involved demolition of a material suspected by the type of facility to contain high asbestos content. TEM levels of 8.3 structures/cc., (amosite and chrysotile present), were measured on reanalysis of this sample.
As part of this study a questionnaire assessing perceived risk and safety behaviours regarding asbestos was administered to 91 maintenance workers (86 male, 2 female, 3 unspecified sex) working in older buildings at 2 universities (both located on the North island) and 2 city maintenance divisions (1 North island, 1 South island). Carpenters, electricians, painters, plumbers, fitters, and supervisors were represented. Virtually all respondents claimed to be aware of health risks associated with asbestos, but on average reported only moderate confidence, maybe 40% of the time, in their ability to detect asbestos-containing building materials. About half had received prior training on asbestos safety and health issues. The reported frequency of encountering asbestos-containing materials was infrequent; 16% of respondents (15 of 91) encountered one of 6 building material types likely to contain asbestos more than 1x per month. Over 60% used outside contractors to handle it when identified. When handling it themselves, protective equipment and appropriate work practices were used only about 50% of the time. The report of this study was presented to DoL: Measurement of asbestos exposure levels in a sample of demolition, trade and maintenance work sites. RFP Number 264. The Workplace Group Of The Department Of Labour. FINAL REPORT 3/09/2010.

Another small exposure study entitled “Measuring Silica-Containing Dust Exposure in Workers Skill-Sawing Hardie Linea® Weatherboard” was a cooperative study between the Department of Labour (DoL), a Contractor, and the Centre for Public Health Research (CPHR), Massey University, during which an inhalable dust exposure monitor was worn by one worker for about 2 hours while skill sawing linea® board to size. The study showed that even after only two hours of cutting linea® board , there were twenty instances where peak levels reached from 1.68 to 210.01 mg/m^3. An 8-hour TWA was calculated to be 7.3 mg/m^3. In New Zealand, there is no short term exposure limit (STEL) for silica dust exposure; however, there are time-weighted averages (TWAs) for cristobalite (0.1 mg/m^3 respirable dust), quartz (0.2 mg/m^3 respirable dust), tridymite (0.1 mg/m^3 inhalable dust), Tripoli (0.2 mg/m^3 respirable dust of contained respirable quartz), and silica (2 mg/m^3 respirable dust). However, in spite of the two hours of sampling, it was evident that the worker and other workers in a close proximity were being exposed to high levels of silica dust. The results of this study are available in a report: Measuring Silica-Containing Dust Exposure in Workers Skill-Sawing Hardie Linea® Weatherboard. July 2011. Kerry Cheung and Gerry Kalogeropoulos. Centre for Public Health Research. Massey University, Wellington.

3.5.3. Other industries

Other CPHR studies are currently on-going which will also provide information on occupational exposure to carcinogens and potential prevention strategies. These include studies in the sawmilling industry (Occupational asthma in New Zealand sawmill workers); the spray painting industry (Neurotoxic effects of occupational solvent exposure), the agricultural sector (Occupational exposures in farmers in Australia) and meat industry (Cancer in meat workers: identifying the causal exposures).

3.6. Other outcomes of the study

3.6.1. Stakeholder engagement

Over the duration of the study, the regular PROHM meetings (Practitioners and Researcher Occupational Health) have developed into a platform for stakeholder engagement. Since the start of PROHM, a total of 5 meetings have been held (listed below).

PROHM meetings
1st PROHM meeting: 21 April 2009
2nd PROHM meeting: 20 November 2009
3rd PROHM meeting: 14 October 2010
4th PROHM meeting: 10 May 2011
5th PROHM meeting: 16 November 2011

The PROHM meetings are full-day meetings organized by CPHR and in first instance attended by CPHR and DoL staff, and are now also attended by ACC staff, employers and occupational health physicians. The discussions during these PROHM meetings often illustrated that better communication between Health and Safety professionals, Health and Safety researchers, DoL and industry will be beneficial for all parties and will ultimately benefit the health and safety of New Zealand workers. The participants of the meeting showed great interest in the specific outputs of this project (in particular, the list of occupational carcinogens and the literature review) and indicated that access to these outputs would be useful to them.

In addition to the PROHM meetings, the different studies into a variety of occupational health and safety issues that have been and continue to be conducted at the Centre for Public Health Research are also platforms for stakeholder engagements including DoL, Industry associations and the Unions.

Also, Dr Bill Glass has since the start of the project been employed by the Centre for Public health Research, and has been instrumental for establishing contacts with industry stake holders.

3.6.2. International research partnerships

Throughout the course of the study international research partnerships in the area of occupational carcinogens have been strengthened. In particular CPHR has strong contacts with the International Agency for Research on Cancer (IARC); the creators of the Finnish and European CAREX as well as the Canadian CAREX.

In late 2011, a new initiative started to update the international CAREX database, and add additional countries. This initiative is led by Kurt Straif (StraifK@iarc.fr), of the International Agency for Research on Cancer and is envisaged to develop further in 2012. NZ-CAREX which was developed as part of the here presented project, will also be part of this initiative.

4. Synthesis of research outcomes / conclusions

The aims of this study were (i) to provide a detailed assessment of the extent and industrial distribution of workplace carcinogens in New Zealand; (ii) to identify key industries and key carcinogens for which intervention would result in marked reductions in occupational cancer; and (iii) in selected key industries, to review the intervention strategies currently in place and evaluate the barriers to the implementation of additional interventions.
The main findings of the study are summarized below.

4.1. The extent and industrial distribution of workplace carcinogens in New Zealand

The literature review and NZ-CAREX illustrate that there are very few industries with no known or suspected exposure to carcinogens. Most industries have potential for exposure to several known human carcinogens. There are more than 50 known human carcinogens present in New Zealand workplaces and more than an additional 100 possible or probable human carcinogens present in New Zealand workplaces.

4.2. The key industries for which intervention would result in marked reductions in occupational cancer

The following criteria were used to identify those industries for which intervention would result in a marked reduction in occupational cancer, using the information in the literature review and NZ-CAREX.

1. The strength of the evidence of an increased cancer risk for that industry (as summarized in the literature review).
2. The total number workers exposed to carcinogens within that industry (which is the product of the carcinogen exposure prevalence for that industry and size of the industry in New Zealand, as listed in NZ-CAREX).

Table 5. Prioritizing of industries for intervention regarding carcinogen exposure.

	Low number exposed	Medium number exposed	High number exposed
Not associated with increased cancer risk/ not studied	Storage Communication services Property services Government administration Community services Motion picture/radio/tv services Sport and recreation	Machinery & motor vehicle wholesaling	Personal and household good retailing
Occasionally associated with increased cancer risk	Commercial fishing Food, beverage Electricity & gas supply Defence Libraries, museums, arts	Food retailing Motor vehicle retailing Accommodation, cafes &restaurant education	Printing & publishing Petroleum & chemical
Repeatedly associated with increased cancer risk	Forestry and logging Mining and extraction	Textile, clothing, footwear Transport Business services (Includes painting, carpentry, chimney sweeping Personal services (Includes hairdressers)	Agriculture Construction Health services Machinery & equipment mfg Metal product mfg Wood & paper product mfg

Increasing priority

Increasing priority

Table 5 categorizes 6 industries as being repeatedly associated with an increased risk of cancer and having a high number of workers potentially exposed to carcinogens (due to the large size of the industry and high exposure prevalence within the industry). These industries with the highest priority for intervention include (in alphabetical order): Agriculture; Construction; Health services; Machinery & equipment manufacturing (mfg); Metal product mfg; and Wood & paper product mfg. It is noteworthy that the here identified industries overlap to a large extent with the five priority sectors specified in the National Action agenda 2010-2013 and Occupational Health Action plane 2011-2013 of the Workplace Health and Safety Strategy for New Zealand 2015 (Agriculture, Construction, Fishing, Forestry, and Manufacturing).

4.3. The key carcinogens for which intervention would result in marked reductions in occupational cancer

The following criteria were used to identify key carcinogens for which intervention would result in reductions in occupational cancer, using the information in the literature review and NZ-CAREX.

1. The strength of the evidence on the association between exposure and cancer outcome (based on the IARC classification).
2. The prevalence in the New Zealand working population (from NZ-CAREX).

Table 6. Prioritizing of occupational carcinogens for intervention.

	Low prevalence of exposure	Medium prevalence of exposure	High prevalence of exposure
2B (possibly carcinogenic to humans)	*Examples:* Acrylonitrile Marine diesel fuel Occup exp in drycleaning Occup exp in printing processes	*Examples:* Bitumens Chlordane Chlorophenoxy herbicides ELF EMF	*Examples:* Chlorinated solvents (Carbon tetrachloride; methylene chloride) Carpentry and joinery Gasoline engine exhaust Styrene Welding fumes
2A (probably carcinogenic to humans)	*Examples:* PCBs	*Examples:* Ethylene bromide Hairdresser & barber	*Examples:* Diesel engine exhaust [1)] Shiftwork Chlorinated solvents (1,2,3-trichloropropane; tertrachloroethylene; trichloroethylene) High temperature frying (emissions from) Inorganic lead compounds Non-arsenical insecticides
1 (carcinogenic to humans)	*Examples:* Beryllium acrylamide	*Examples:* Arsenic nickel Ethylene oxide X and gamma radiation	Asbestos Benzene Chromium VI compounds Formaldehyde Involuntary smoking Painter – occup exp as Silica Solar radiation Wood dust

Increasing priority ↓

Increasing priority →

[1)] Since submission of this report, diesel engine exhaust has been classified as a group 1 carcinogen by IARC

Table 6 categorizes 9 occupational carcinogens as having high prevalence in the working population (due to the large size of the industries and high exposure prevalence within the industry) and having sufficient evidence of being carcinogenic to humans (IARC group 1 carcinogens). These occupational carcinogens with the highest priority for intervention include (in alphabetical order): Asbestos; Benzene; Chromium VI compounds; Formaldehyde; Involuntary smoking; Painter (occupational exposures as); Silica; Solar radiation; Wood dust.

4.4. Intervention strategies and barriers to the implementation of additional interventions

The third aim of this study was, in selected key industries, to review the intervention strategies currently in place and evaluate the barriers to the implementation of additional

interventions. The intervention strategies available are discussed in the literature review. From CPHR's studies in different industries, the following aspects were identified as barriers to the implementation of additional interventions:

1) Lack of knowledge about carcinogenicity of certain occupational exposures

The industry surveys summarized under 3.5 as well as stakeholder engagement during PROHM meetings revealed in some cases a general lack of knowledge about whether certain exposures were carcinogenic to humans or not. This was also the case for some human carcinogens very common in New Zealand workplaces. For example, wood dust is not often regarded as a human carcinogen although it has been classified as such by IARC since 1995. There appears to be very little awareness of the carcinogenicity of crystalline silica which has been classified as a human carcinogen by IARC since 1997. Several commonly used chlorinated solvents are classified as probably carcinogenic to humans by IARC (group 2A), but little awareness of this was noted.

This indicates that more awareness of the classifications produced by objective international agencies is required. New Zealand specific reference materials or databases (e.g. the WES or HSNO database) do not provide a complete overview of the carcinogenicity of all exposures present in the workplace. The IARC classifications on the other hand, are not limited to chemical exposures alone and are publicly available, thus giving a broad overview of what chemicals/metals/fibres/dusts/radiation/microbial agents/combustion products/exposure circumstances are carcinogenic to humans. The list of occupational carcinogens produced as part of this project restricts the list of the IARC classifications to only occupational exposures, thus providing a quick reference guide of what occupational exposures are carcinogenic to humans.

2) Lack of awareness of the presence and exposure levels of carcinogens in the workplace

The industry surveys as well as stakeholder engagement during PROHM meetings also revealed a general lack of awareness of the presence of certain occupational carcinogens in the workplace. This is directly associated with the lack of regular exposure measurements in the workplace. For example, people are not aware of the presence of silica in the dust (e.g. building industry) if the silica content is never quantified.

The literature review which was one of the outputs of this study, will provide a quick reference guide of which carcinogens could potentially be present in each industry and more exposure measurements will also contribute towards a better awareness of the presence (and levels) of carcinogens in the workplace.

3) Lack of awareness of the magnitude of occupational cancer problem in New Zealand

The difficulties in quantifying the number of cancer cases that occur each year due to occupational exposures have resulted in a severe under-estimation of the size of the occupational cancer problem in New Zealand and are therefore a barrier to the implementation of interventions. The NOHSAC reports have already highlighted the lack of awareness of the size of the occupational health problem in New Zealand and the estimates of the number of deaths and incident cases of occupational disease (including occupational cancer) published in the first NOHSAC report have resulted in a better awareness of the potential health gain to be made by preventing workers' exposure to carcinogens. In addition, occupational carcinogens have now been identified as a priority area of focus in

Occupational Health Action Plan 2011-13 of the Workplace Health and Safety Strategy for New Zealand to 2015. The continued assessment of the number of occupational cancer cases and deaths, as has been undertaken by the Centre for Public health Research (project: Indicators for Surveillance of occupational disease) and part of the National Occupational Diseases Framework, will further increase the awareness of the size on the occupational cancer problem in New Zealand.

4) Lack of technical know-how to control exposure

The industry surveys as well as stakeholder engagement during PROHM meetings also revealed in some cases a lack of know-how to control exposure and limited access to sources that could provide such information. In addition, even for very obvious carcinogens such as asbestos, methods to control exposures may be in place but may not be functioning properly (see 3.5.2).

5) Lack of knowledge and tools for evaluation of effectiveness of the intervention

Following on to the previous point, there is also a need for tools evaluating the effectiveness of interventions. If such tools were available and could demonstrate significant reductions in exposure, this would remove an important barrier for the implementation of control measures. For example, video exposure monitoring can be useful in visualising the effect of control measures, from simple changes in work practices to technical solutions for reducing exposure (as is currently being tested in the joinery and furniture industry).

6) Lack of financial means

During the industry surveys and stakeholder engagement during PROHM meetings, the financial costs of implementing control measures were not reported as an important barrier, as it would only be a potential barrier if the other barriers had been removed. However, a lack of motivation to put in the financial means was reported in situations where the effectiveness of the investment is not clear.

4.5. Main conclusions

Main conclusions:

- There are more than 50 known human carcinogens commonly present in New Zealand workplaces.
- The most common of these are: Asbestos; Benzene; Chromium VI compounds; Formaldehyde; Involuntary smoking; occupational exposures as a Painter; Silica; Solar radiation; Wood dust.
- There are more than an additional 100 possible or probable human carcinogens present in New Zealand workplaces.
- The industries for which an increased cancer risk has been observed repeatedly in epidemiological studies and have the highest number of potentially exposed workers include: Agriculture; Construction; Health services; Machinery & equipment manufacturing (mfg); Metal product mfg; Wood & paper product mfg.
- Of the agricultural chemicals currently in use in New Zealand's agricultural sector, none are known human carcinogens, but numerous are suspected to be carcinogenic to humans.
- A number of barriers for the implementation of intervention strategies were identified, which could be removed by improving access to knowledge regarding the occurrence of carcinogens in New Zealand workplaces and improving access to control tools and methods to evaluate their effectiveness.
- The specific outputs of this study (literature review, list of carcinogens, NZ-CAREX, NZ-ACEM) can contribute towards improving access to knowledge regarding the occurrence of carcinogens in New Zealand workplaces.
- Workplace exposure measurements and video exposure monitoring can also play an integral part in removing barriers for implementation and evaluation the effectiveness of control measures.