

**Chemical Composition of Tobacco
and Cigarette Smoke in Two
Brands of New Zealand Cigarettes**

**Final Report
(revised 25 August, 2003)**

Prepared as part of a New Zealand Ministry of Health
Contract for Scientific Services

By
Jeff Fowles PhD
Project Leader

Dr David Phillips
Programme Manager
Population Health Group

Murray Kaiserman
Health Canada
Peer Reviewer

DISCLAIMER

This report or document ("the Report") is given by the Institute of Environmental Science and Research Limited ("ESR") solely for the benefit of the Ministry of Health, Public Health Service Providers and other Third Party Beneficiaries as defined in the Contract between ESR and the Ministry of Health, and is strictly subject to the conditions laid out in that Contract.

Neither ESR nor any of its employees makes any warranty, express or implied, or assumes any legal liability or responsibility for use of the Report or its contents by any other person or organisation.

Acknowledgements

The author wishes to thank Bill Rickert and Catherine Ambrose (Labstat International Inc., Ontario, Canada) for chemical analyses of the tobacco and cigarette smoke. Thanks also to John Stribling (New Zealand Ministry of Health) for support for the project, Dr Murray Kaiserman (Health Canada) for a peer-review, and to Dr David Phillips and Professor Ian Shaw (ESR) for helpful contributions.

CONTENTS

SUMMARY	1
1. PURPOSE OF THIS REPORT	2
2. INTRODUCTION	2
3. METHODS	3
3.1 BRAND SELECTION	3
3.2 INTENSE SMOKING CONDITIONS	3
3.3 CHEMICAL CONSTITUENTS TESTED	3
3.4 ANALYTICAL TESTING	5
3.5 COMPOSITE HAZARD ESTIMATES	5
3.6 INTERNATIONAL COMPARISONS	5
3.7 STATISTICS	6
3.8 GRAPHICS	6
4. RESULTS	7
4.1 CIGARETTE TOBACCO	7
4.2 CIGARETTE SMOKE	8
5. DISCUSSION	16
6. REFERENCES	18
APPENDIX A.	19

LIST OF FIGURES

FIGURE 1. NICOTINE YIELDS IN HOLIDAY EXTRA MILD, 13 AUSTRALIAN 'MILD' BRANDS, AND 10 BRITISH COLUMBIA 'MILD' BRANDS	11
FIGURE 2. TAR YIELDS IN HOLIDAY EXTRA MILD, 13 AUSTRALIAN 'MILD' BRANDS, AND 10 BRITISH COLUMBIA 'MILD' BRANDS	12
FIGURE 3. TAR:NICOTINE RATIO IN HOLIDAY EXTRA MILD (HEM), 13 AUSTRALIAN 'MILD' BRANDS, AND 10 BRITISH COLUMBIA 'MILD' BRANDS.....	12
FIGURE 4. CARBON MONOXIDE YIELDS IN HOLIDAY EXTRA MILD (HEM), 13 AUSTRALIAN 'MILD' BRANDS, AND 10 BRITISH COLUMBIA 'MILD' BRANDS.....	13
FIGURE 5. CANCER RISK CONTRIBUTION FROM LEADING CARCINOGENS IN SMOKE FROM HOLIDAY EXTRA MILD (HEM), 13 AUSTRALIAN 'MILD' BRANDS, AND 10 BRITISH COLUMBIA 'MILD' BRANDS.....	14
FIGURE 6. CANCER RISK TO NICOTINE RATIO IN SMOKE FROM HOLIDAY EXTRA MILD (HEM), 13 AUSTRALIAN 'MILD' BRANDS, AND 10 BRITISH COLUMBIA 'MILD' BRANDS	14
FIGURE 7. CARDIOVASCULAR TOXICANTS TO NICOTINE RATIO IN SMOKE FROM HOLIDAY EXTRA MILD (HEM), 13 AUSTRALIAN 'MILD' BRANDS, AND 10 BRITISH COLUMBIA 'MILD' BRANDS.....	15
FIGURE 8. RESPIRATORY TOXICANTS TO NICOTINE RATIO IN SMOKE FROM HOLIDAY EXTRA MILD (HEM), 13 AUSTRALIAN 'MILD' BRANDS, AND 10 BRITISH COLUMBIA 'MILD' BRANDS.....	15

SUMMARY

In February 2002, approximately 2000 cigarettes from two commercially available brands were purchased by ESR from a retail outlet in Wellington and sent to a commercial testing laboratory (Labstat International, Inc., Ontario, Canada). The two brands selected for testing were Holiday Special Filter (HSF) and Holiday Extra Mild (HEM). The HSF brand has the largest overall market share in New Zealand, and the HEM brand has the largest market share of the “mild, extra mild, or light” brands. These brands were tested for a range of constituents identified in a previous ESR report. This activity is consistent with similar international efforts in Australia and British Columbia to characterise the toxic constituents of cigarette smoke and the chemical constituents in unburned cigarette tobacco.

The HEM brand was tested under both standard ISO methods, and for smoke constituents also under “intense” conditions, the methodological details of which are supplied by Labstat International, Inc. These methods have been used extensively by public health agencies in Australia and Canada. Intense smoking methods attempt to capture the compensatory smoking behaviour of smokers of low nicotine yield cigarettes, which are not reflected in standard ISO smoking machine yields.

The results of the analyses show that, compared with 13 ‘mild’ or ‘extra mild’ brands in Australia in 2002, nicotine yield in HEM was not significantly different. However, tar from HEM was slightly higher on average ($p = 0.089$), and the T:N ratio of HEM was significantly higher than the Australian brands tested ($p = 0.0029$ intense, and $p = 0.038$ ISO methods). This difference was even more pronounced when compared to 10 brands of ‘mild’ and ‘light’ cigarettes reported by the British Columbia Ministry of Health in Canada in 2000.

The carbon monoxide levels in the HEM were significantly higher than in Australian ‘mild’ brands ($p = 0.04$), but were similar to Canadian ‘mild’ brands. The HEM had greater tar and CO levels than any of the Australian mild brands tested when intense ISO conditions were used.

The yield ratings on packets at the time of the study were: HSF (tar = 16 mg, nicotine = 1.2 mg, and CO = 15 mg per cigarette), and HEM (tar = 12 mg, nicotine = 0.8 mg, and CO = 10 mg). Both products conformed to the ratings on their packets, using ISO test conditions. Under intense ISO smoking conditions, the HEM yields were considerably higher (up to three-fold) than the packet ratings suggest.

Cancer risk was estimated using yield information combined with published cancer potency factors, thereby integrating all of the carcinogenicity data into one cancer risk estimate. The cancer risk to nicotine ratio for HEM was higher than in Australian brands, and much higher than in Canadian brands. The T:N ratio and the cancer risk to nicotine ratio, were also higher for HEM than for HSF. These results show that, for a given intake of nicotine, there is a greater exposure to hazardous substances in HEM than ‘mild’ brands in Australia or Canada, and also even when compared with the ‘regular’ brand HSF.

In order to ensure that these findings were not a one-off occurrence, we re-tested the brands six months later under the same conditions, using the same internationally accredited laboratory, and obtained similar results for tar, nicotine, and CO.

1. PURPOSE OF THIS REPORT

This report collates and interprets the analytical results of two New Zealand cigarette brands (Holiday Special Filter, and Holiday Extra Mild) as tested by Labstat International, Inc. Canada, for the Ministry of Health.

2. INTRODUCTION

An ESR report in 2000 described priority chemical constituents in cigarette smoke that could be used to quantify the cancer and non-cancer hazards of cigarettes (1). While the concept of a 'safe cigarette' is widely criticised, the basic tenets of toxicology dictate that efforts be made to reduce the dose, and therefore the effect, of the most hazardous chemicals in cigarette smoke. Therefore while a 'safe cigarette' is likely impossible, a 'reduced risk cigarette' is plausible. Thus, moves to reduce exposure to carcinogens, cardiovascular and respiratory toxicants would be expected to reduce the burden of disease from smoking, all other factors remaining the same. This basic idea has been reviewed recently by the US National Academy of Sciences (NAS), where the term "Potential Reduced-Exposure Products" (PREPs) has been proposed (2). In their review, the NAS concluded that "*...current knowledge of the dose-response relationships is sufficient to support risk reduction through exposure reduction as a goal for the individual through the use of these various products.*" Bates (3) suggested that a reduction in nicotine should accompany a reduction in tar, so that the intake of inhaled toxicants did not increase during a smoker's compensation for reduced nicotine yield.

The current project aimed to test two brands of New Zealand cigarettes, purchased from a retail outlet, using test methods that have been established in overseas health agencies, establishing an objective method by which hazard comparisons between cigarettes can thereby be made. This could help form a baseline set of information for use as a template for future testing requirements, if such were desired.

Earlier this year, the Australian Department of Health published a list of hazardous substances in cigarette smoke, by brand, for 15 brands (4). In 1999, Canada was the first country to place chemical information on cigarette brands on their "What's in Tobacco?" website through the British Columbia Ministry of Health (5). The BC data are required by law and updated annually. The data published by BC use methods developed and approved by Health Canada, and the cigarettes tested are available throughout Canada. The New Zealand test results are compared with those from Australia (2002 data) and Canada (2000 data), as the same testing laboratory and test methods were used in all three cases.

3. METHODS

3.1 Brand selection

It was decided that this project should focus on the brand with the largest overall market share, and also include the brand in the 'light' or 'mild' category with the largest market share. Using these criteria, the two brands selected were Holiday Special Filter, and Holiday Extra Mild. Cigarettes were purchased in four cartons of 200 each for each brand from a major supermarket in Wellington on 6 February 2002.

The cigarette cartons were shipped by air freight to Labstat International, Inc. for testing. Complete test results were made available within six weeks of purchase.

3.2 Intense smoking conditions

We had one brand (HEM) tested for both standard ISO and 'intense' ISO smoking machine yields. The significance of the 'intense' ISO method is that it provides an upper estimate of the actual intake, under conditions that mimic compensatory smoking behaviour through blockage of ventilation holes and greater puff volumes and frequency. The method for this is that which is used by Health Canada. It neither sets an absolute upper limit on the intake of chemical constituents, nor does it necessarily provide a more accurate central value. It is probable that a realistic central estimate lies somewhere between the ISO and intense methods.

3.3 Chemical constituents tested

A list of priority chemicals for constituent testing was based on the contribution to health risk identified in a previous report (1). This list is a subset of a much larger list of 44 chemicals used by the British Columbia Ministry of Health. The priority list is shown below in Table 1 (*next page*).

Table 1. Combined list of priority chemicals in cigarette smoke
(from Fowles and Bates, 2000)

Chemical	Health Effect	Analysed in this study
1,3 – butadiene	cancer, reproductive/developmental	Yes
Acetaldehyde	cancer, respiratory irritation	Yes
Acrolein	respiratory irritation	Yes
Acrylonitrile	cancer, respiratory irritation	Yes
Arsenic	cancer, cardiovascular, reproductive/developmental	Yes
Benzene	cancer, reproductive/developmental	Yes
Cadmium	cancer	Yes
Carbon monoxide	cardiovascular	Yes
Chlorinated Dioxins and Furans	cancer, cardiovascular, reproductive/developmental	No*
Chromium (VI)	cancer, respiratory irritation	Yes
m + p + o Cresol	cardiovascular	No
Formaldehyde	cancer, respiratory irritation	Yes
Hydrogen cyanide	cardiovascular	Yes
N-nitrosornicotine (NNN)	cancer	Yes
N-nitrosodimethylamine (NDMA)	cancer	No
N-nitrosopyrrolidine (NP)	cancer	No
Ammonia	Nicotine availability	Yes

* Dioxins were not analysed in the this study, as a subsequent risk assessment indicated that they are not priority contributors to cancer risk from smoking (OTAG, 2002). Cresols were not included as they need a separate analysis that was not felt to be justified, in this project, by their contribution to health risk.

In addition to the compounds listed in Table 1, the following compounds (and pH) were analysed at the same time. These are shown below:

- Acetone
- Propionaldehyde
- Butylaldehyde
- Toluene
- Nitrosoanabasine (NAB)
- Selenium
- pH
- Crotonaldehyde
- Methyl ethyl ketone
- Isoprene
- Nitrosoanatabine (NAT)
- Nickel
- Lead

The results from these additional compounds are tabulated in the raw data report from Labstat, but no further interpretation is made as they are viewed as additional compounds of uncertain health significance at the doses received from smoking. While these compounds would be expected to contribute to the overall toxicity of the smoke, there were no published values that specifically allowed for the quantification of cancer, cardiovascular, or respiratory risk from exposure to these compounds. The exception is lead, for which there is a cancer potency factor available and this was included in the cancer risk estimate. However, the influence of lead on overall cancer risk was negligible.

3.4 Analytical testing

The chemical analyses of cigarette smoke and unburned tobacco were conducted by Labstat International Inc., using accredited methods originally developed by Health Canada.

3.5 Composite hazard estimates

A proportion of cancer risk attributable to the leading carcinogens (Table 1) was assigned by combining the yield measurements with the respective cancer potency estimate (CPF) published by the USEPA or California EPA, using the method already described (1).

$$\text{Constituent}_1 \text{ (mg/cigarette)} \times \text{CPF}_1 \text{ (mg/kg/day}^{-1}\text{)} = \text{cancer risk}_1 \text{ (per cigarette/kg bodyweight/day)}$$

Table 2. Cancer potency factors and reference exposure levels used for composite hazard estimates

Chemical	CPF (mg/kg/day)-1	REL (µg/m ³)
Acetaldehyde	0.01	9
Acrolein		2
Acrylonitrile	1	2
Benzene	0.1	
1,3-Butadiene	0.6	
Cadmium	15	
CO		10000
Formaldehyde	0.021	2
HCN		3
Lead	0.042	
NNN	1.4	

The CPFs and RELs in this table can be found at the California EPA website (6,7).

The most critical cardiovascular toxicants, hydrogen cyanide, arsenic, and carbon monoxide, were all assessed individually, and are shown as a composite hazard index to published reference exposure levels (RELs). Similar comparisons were made for the most significant respiratory toxicants (acrolein, acrylonitrile, acetaldehyde, formaldehyde, and chromium).

$$\text{Constituent}_1 \text{ (µg/cigarette)} / \text{REL}_1 \text{ (µg/m}^3\text{)} = \text{hazard index (per cigarette/ cu m inhaled per day)}$$

3.6 International comparisons

The Australian Department of Health and the British Columbia Ministry of Health each publish cigarette smoke yield data on websites. All of the available Australian data for 'milds' (n = 13 brands) were used for comparison with the HEM, and an additional 10 'mild' or 'light'

brands from the BC MOH data (randomly chosen) were also added for comparison. For the purposes of this report, no distinction was made between cigarettes that were labelled "Light", "Extra Light", "Ultra Light", "Mild", "Extra Mild", "Super Mild", or "Ultra Mild".

Similar comparisons were not done for Holiday Special Filter, as there were only two brands for comparison in the Australian data, and also because we did not have intense smoking data for this brand. Instead, the HSF data, using ISO methods, is included for comparison with the equivalent ISO results from the HEM.

Table 3. The international brands selected for comparison

Australia (2002 data)	Canada (2000 data)
Long Beach Mild	Benson & Hedges light 100s
Long Beach Ultra Mild	Rothmans Special Mild King Size
Long Beach Super Mild	Players Extra Light King Size
Peter Jackson Ultra Mild	Rothmans Ultra Light King Size
Peter Jackson Super Mild	Players Light King Size
Peter Jackson Extra Mild	Viscount Extra Mild
Horizon Mild	du Maurier Extra Light King Size
Horizon Super Mild	Craven A Special Mild Regular
Horizon Ultra Mild	Matinee Extra Mild King Size
Holiday 8 Super Mild HP	Matinee Slims Extra Mild
Benson & Hedges Extra Mild 8	
Winfield Super Mild King Size HP	
Winfield Extra Mild 25 HP	

The tar to nicotine ratio was used to compare the machine measured yields of the New Zealand brands with published mean values of the brands in Table 3 as well as reported yield ratios from thousands of brands (US NCI, 2001). The T:N ratio has been proposed by researchers as a way to standardise the regulation of cigarettes (NCI, 2001).

3.7 Statistics

All results are expressed as arithmetic mean and standard deviations. Comparisons between mean values were performed using the Student's t-Test (2-tailed) assuming equal variance. A 95% confidence interval comparison was also performed on the brands reported by Australia and Canada in comparison with the New Zealand brand.

3.8 Graphics

The bar graphs in this report are overlaid to show ISO and intense smoke yields. The intense smoke yield segment of each bar is in addition to, or inclusive of the ISO part of the bar.

4. RESULTS

4.1 Cigarette tobacco

In addition to the composition of cigarette smoke, which was the main focus of this project, several components of cigarette tobacco were chemically analysed by Labstat International, Inc. Constituents of unburned tobacco are important because they can influence the composition of the smoke that is inhaled and they also help to identify the source of the tobacco (personal communication with Murray Kaiserman, Health Canada 2002). The unburned cigarette tobacco was analysed and the results are summarised in Table four below:

Table 4. Cigarette Tobacco Composition (per gram of tobacco)

Constituent tested	NZ Holiday Extra Mild	NZ Holiday Special Filter
Nicotine ($\mu\text{g/g}$)	16084 (354) ^a	18465 (506)
Nornicotine ($\mu\text{g/g}$)	316 (16)	299 (10)
Anabasine ($\mu\text{g/g}$)	91.5 (0.3)	105 (5)
Myosmine ($\mu\text{g/g}$)	---	---
Anatabine ($\mu\text{g/g}$)	536 (9)	603 (24)
Nitrate (mg/g)	2.53 (0.43)	1.78 (0.29)
NNN (ng/g)	212 (72)	--- ^b
NAT (ng/g)	281 (32)	331 (28)
NAB (ng/g)	---	---
NNK (ng/g)	90 – 307 ^c	90 – 307
Sorbitol ($\mu\text{g/g}$)	---	---
pH	5.30 (0.01)	5.15 (0.01)
Moisture (%)	9.41	11.5
Dry matter (%)	90.6 (0.2)	88.5 (0.3)

^a Data are expressed as averages of three replicates with standard deviations in parentheses. Missing values indicate the result was below the detectable limit for that constituent.

^b The Limit of quantification for NNN was 203 ng/g, and the limit of detection was 61 ng/g.

^c The Limit of quantification for NNK was 307 ng/g, and the limit of detection was 90 ng/g. NNK was detected in both brands and in all replicates, but the levels were not quantifiable and are given as the range.

^d The LOD for sorbitol was 82.8 $\mu\text{g/g}$, and all replicates were below this level.

The unburned tobacco did not appear to differ greatly between the two brands. Nicotine content was slightly less per gram of tobacco in HEM compared with HSF. On the other hand, the amount of NNN, an important tobacco-specific nitrosamine, was high enough to be able to be quantified in HEM but not in HSF, while the concentration of NAT was not significantly different. The Limit of Quantification (LOQ) for NNN was at a level close to that reported for HEM, so the two brands may not actually be greatly different in NNN content. Nitrate levels were higher in HEM, which, combined with the slightly higher nornicotine content, may help explain the higher NNN value. The pH value was slightly higher with HEM compared to HSF (this is also true of the pH of the smoke, as shown in Table 5 below).

The US National Cancer Institute (8) published measurements of nicotine content in American, British, and Canadian cigarettes. Of the brands tested in these countries, the highest nicotine content per cigarette (18.3 mg) was found in one brand of Canadian cigarettes, British cigarettes had a high of 15.9 mg, and American cigarettes a high of 13.4 mg. The nicotine content of HSF in this report (18.46 mg/g tobacco) corresponds to a level of approximately 13.2 mg/cigarette, assuming a cigarette contains about 0.7 g of tobacco. This is at the high end of the range of American brands tested, and is in the mid-range for Canadian and British brands. The HEM nicotine content (16.08 mg/g tobacco) corresponds to a value of about 11.6 mg per cigarette. There were no equivalent data on unburned tobacco from the Australia Department of Health.

4.2 Cigarette smoke

Table 5 shows the breakdown of cigarette smoke constituent yields for both standard ISO smoking machine methods, and intense smoking yields. Both New Zealand brands tested were compared with Canadian and Australian brands as shown (*next page*).

Table 5. Yields of chemicals in cigarette smoke from Holiday Special Filter and Holiday Extra Mild brands of New Zealand cigarettes.

Chemical Constituent	‘Mild’ brands			Regular brand	
	Holiday Extra Mild (NZ)	Australian ‘Milds’ (n = 13)	British Columbia ‘Milds’ (n = 10)	Holiday Special Filter (NZ)	Comments
Nicotine (mg/cig)					
ISO	0.64	0.72 (0.21) ¹	0.85 (0.36)	1.1	3-fold higher yield with intense method
Intense	1.82	1.96 (0.32)	2.72 (0.52)		
Tar (mg/cig)					
ISO	9.07	7.57 (2.50)	8.02 (3.76)	14.3	*HEM > Australian milds (p = 0.089 Int.)
Intense	32.6*	25.33 (3.79)	32.69 (5.17)		
Tar:Nicotine					
ISO	14.08*	10.40 (1.01)	9.26 (1.01)	13	*HEM > others (p = 0.004 ISO, p < 0.0005 Int.)
Intense	17.92	12.94 (0.81)	12.22 (1.37)		
Carbon monoxide (mg/cig)					
ISO	9.31	6.98 (2.0)	8.01 (3.69)	13.6	*HEM > Aus milds (p = 0.04)
Intense	26.4*	21.29 (2.16)	30.99 (4.41)		
Cyanide (µg/cig)					
ISO	93.4	70.08 (33.5)	70.53 (38.8)	138	*HEM > Aus milds (p = 0.1)
Intense	282*	230.5 (28.8)	296.9 (37.9)		

continued ...

Table 5 (continued)

Chemical Constituent	'Mild' brands			Regular brand	
	Holiday Extra Mild (NZ)	Australian 'Milds' (n = 13)	British Columbia 'Milds' (n = 10)	Holiday Special Filter (NZ)	Comments
Acetaldehyde (µg/cig)					No significant difference across brands
ISO	424	404 (147)	389 (176)	545	
Intense	1198	1098 (152)	1340 (167)		
1,3-Butadiene (µg/cig)					HEM > BC milds (p = 0.01) intense
ISO	35.4	31.75 (11.4)	22.46 (8.9)	46.9	
Intense	94.6	88.86 (11.3)	72.28 (7.7)		
Ammonia (mg/cig)					No significant differences across brands
ISO	8.45	9.06 (3.28)	8.19 (2.80)		
Intense	21.1	21.58 (3.92)	24.69 (4.68)	11.1	
pH					No significant difference across brands
ISO	6.14	6.09 (0.07)	6.21 (0.11)	6.07	
Intense	5.94		5.98 (0.10)		
Cancer risk (x10 ⁻⁴) /cigarette/day					No significant difference across brands
ISO	4.8	4.3 (1.6)	3.8 (1.6)	4.5	
Intense	13.3	12.3 (1.6)	13.5 (1.5)		
Cancer risk: Nicotine (risk x 10 ⁻⁴) /cig/mg nicotine/day					HEM > BC milds (p = 0.001)
ISO	7.5	5.6 (1.6)	4.4 (0.7)	5.8	
Intense	11.3	9.8 (0.8)	7.2 (0.6)		
Cardiovascular Hazard Index (HI/cigarette/day)					
ISO	1.6	1.2 (0.55)	1.2 (0.67)	2.4	
Intense	4.8	3.9 (0.69)	5.1 (0.84)		
Respiratory Hazard Index (HI/cigarette/day)					HEM > Aus milds (p = 0.14 Int.)
ISO	128	100 (41)	102 (56)	176	
Intense	381*	305 (46)	387 (61)		

¹ Results are expressed as means with standard deviations in brackets. The NZ brands represent the mean of 5 replicates.

The values in Table 6 describe the variability in the means within a brand (i.e. HEM and HSF), and between brands (Australian and Canadian results). It can be seen that the inter-brand variability is far higher than the variability between replicates (shown for HEM and HSF), which is essentially the variability inherent in the measurement. All statistical comparisons to overseas values were done assuming that a similar degree of variability exists between New Zealand brands and those from overseas.

Table 6a. Comparison of coefficients of variation among replicates – Canadian, Australian, and New Zealand cigarettes.

<i>ISO</i>				
	Nicotine	Tar	CO	
HEM	4.0%	1.9%	3.9%	1 brand, 5 replicates
HSF	3.4%	3.1%	4.4%	1 brand, 5 replicates
Australian	4.2 - 7.0%	4.7 – 11.3%	4.9 - 9.1%	Range of 13 brands
Canadian	3.5 - 9.8%	5.2 – 15.6%	4.5 - 8.6%	Range of 10 brands
<i>Intense</i>				
	Nicotine	Tar	CO	
HEM	4.3%	4.8%	3.6%	1 brand, 5 replicates
Australian	3.2 - 7.1%	6.7 – 11.1%	3.3 - 7.9%	Range of 13 brands
Canadian	4.6 - 8.4%	2.7 - 12.1%	1.9 - 9.2%	Range of 10 brands

Coefficient of variation = SD/Mean x 100

Table 6b. Coefficient of Variation Between Brands Tested in Australia and Canada

<i>ISO</i>				
	Nicotine	Tar	CO	
Canadian	41.9%	47%	46.1%	10 brands
Australian	28.8%	33%	28.5%	13 brands
<i>Intense</i>				
	Nicotine	Tar	CO	
Canadian	19.3%	15.8%	14.2%	10 brands
Australian	16.5%	14.9%	10.1%	13 brands

The coefficients of variation for nicotine, tar, and CO among replicates for the HEM and HSF brands tested were consistent with the ranges of variability reported from Australia and Canada (Table 6a).

Figure 1. Nicotine Yields in Holiday Extra Mild, 13 Australian 'mild' brands, and 10 Canadian 'mild' brands. The Holiday Special Filter brand is shown for comparison.

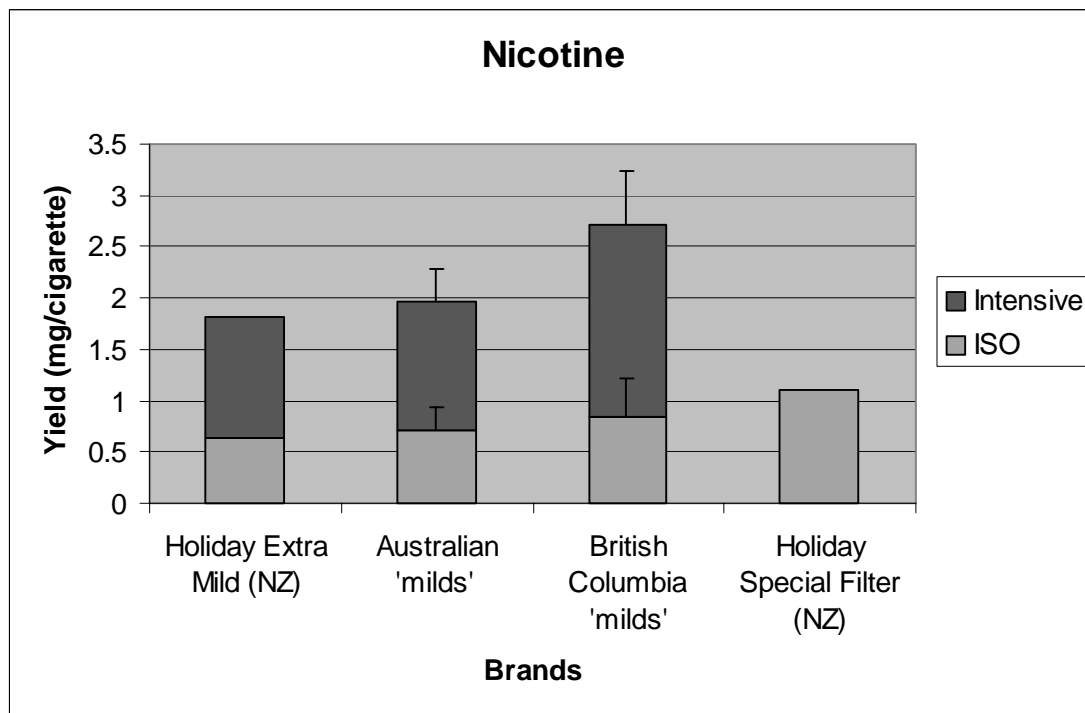


Figure 2. Tar Yields in Holiday Extra Mild, 13 Australian 'mild' brands, and 10 Canadian 'mild' brands. The Holiday Special Filter brand is shown for comparison.

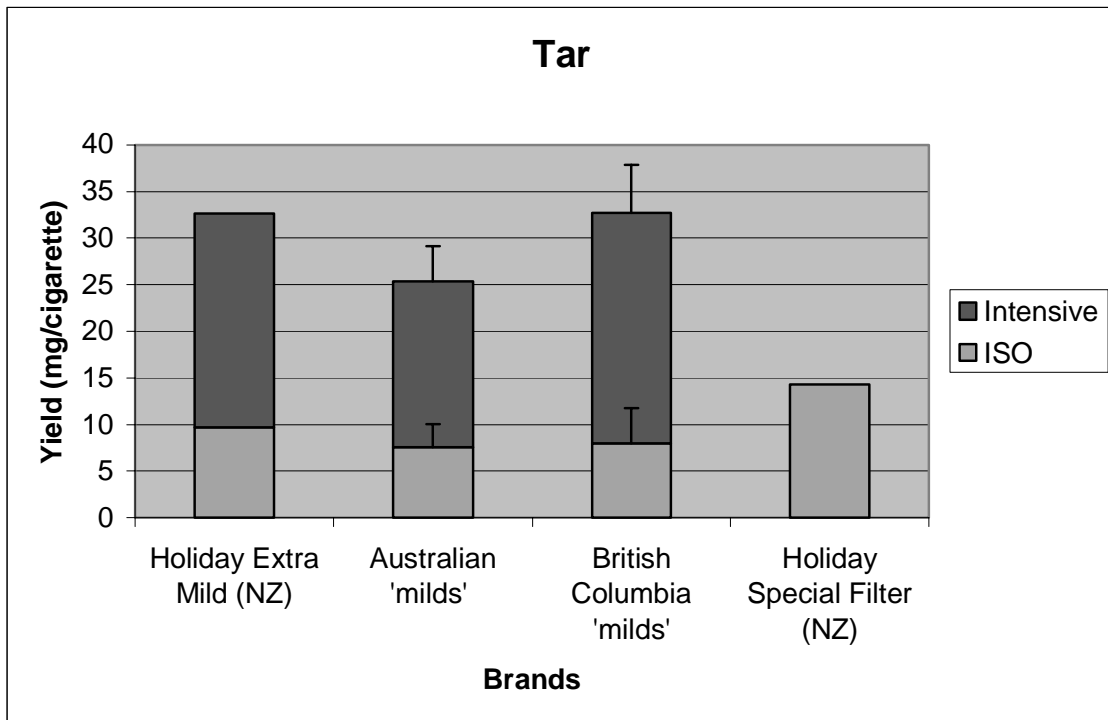
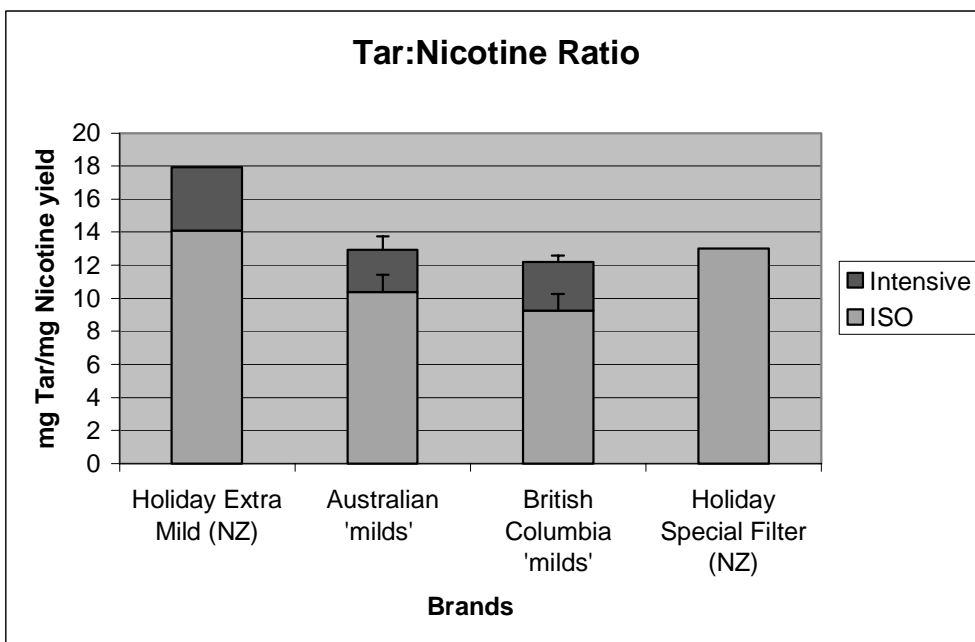


Figure 3. Tar:nicotine ratio in Holiday Extra Mild (HEM), 13 Australian 'mild' brands, and 10 Canadian 'mild' brands. The HEM is significantly higher ($p = 0.0029$) than all other mild brands examined, and not significantly different than Holiday Special Filter.



The tar:nicotine (T:N) ratio (Figure 3) shows a highly significant difference between HEM and the Australian or Canadian brands. The range of Australian brands for the T:N ratio was 11.9 - 14.5 for intense smoking conditions, compared with 17.92 for HEM. The highest T:N ratio in the Australian brands was the Holiday 8 Super Mild HP. For the ten Canadian brands, the range of T:N ratios was 8.8 - 14.9 under intense smoking conditions. The same relative difference between brands exists whether FTC ISO or intense conditions are used.

Figure 4. Carbon monoxide yields in Holiday Extra Mild (HEM), 13 Australian 'mild' brands, and 10 Canadian (British Columbia) 'mild' brands. The HEM intense yield was significantly higher ($p = 0.04$) than for the 'mild' brands tested by Australia, but lower than the BC brands. Holiday Special Filter is also shown.

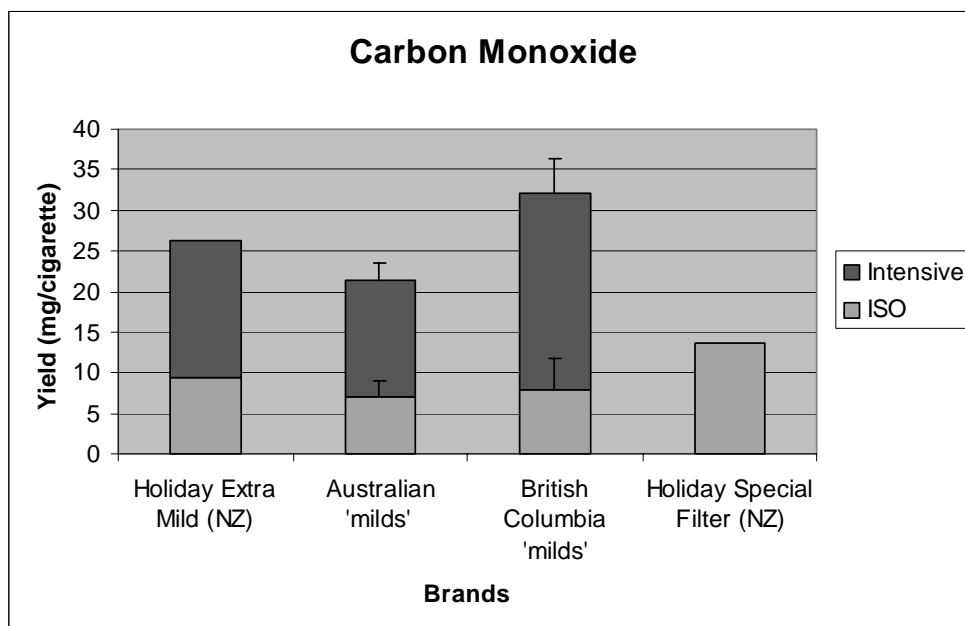


Figure 5. Cancer risk contribution from leading carcinogens in smoke from Holiday Extra Mild (HEM), 13 Australian 'mild' brands, and 10 Canadian (BC) 'mild' brands. There is no significant difference between the groups of brands and HEM.

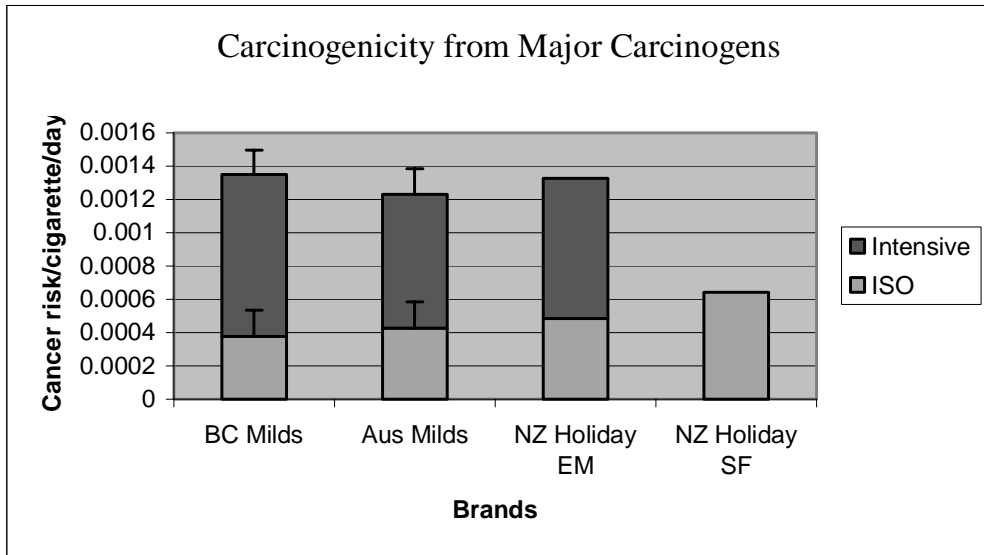


Figure 6. Cancer risk to nicotine ratio in smoke from Holiday Extra Mild (HEM), 13 Australian 'mild' brands, and 10 Canadian (BC) 'mild' brands. Data are expressed as cancer risk per mg nicotine per cigarette per day. The HEM has a highly significant increase in cancer risk per mg of nicotine compared with BC milds ($p = 0.001$). The intense smoking method produced added risks compared to the ISO method even when normalised to the nicotine yield.

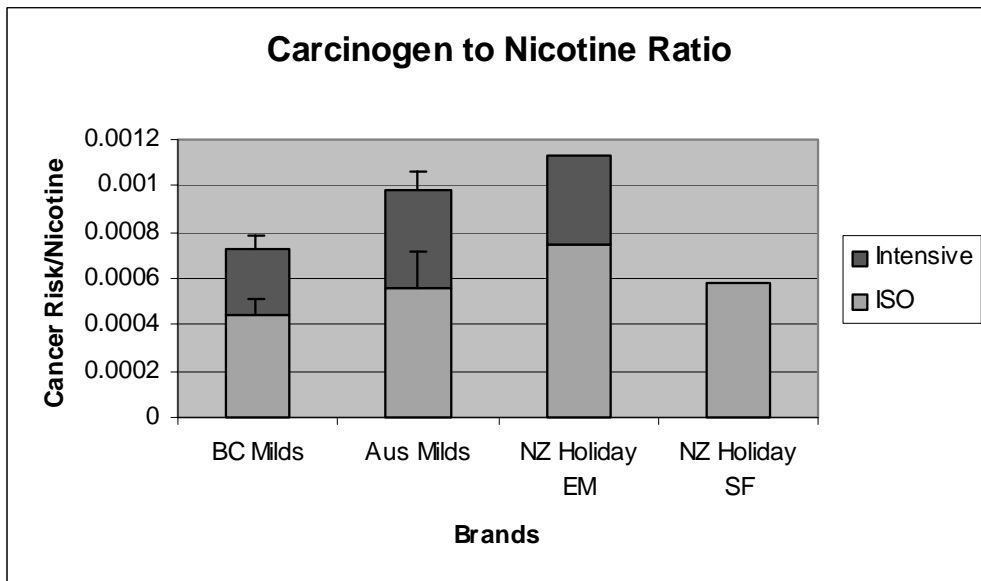


Figure 7. Cardiovascular toxicants to nicotine ratio in smoke from Holiday Extra Mild (HEM), 13 Australian 'mild' brands, and 10 Canadian (BC) 'mild' brands. The HEM was slightly higher compared with Australian or BC 'milds' ($p = 0.08$).

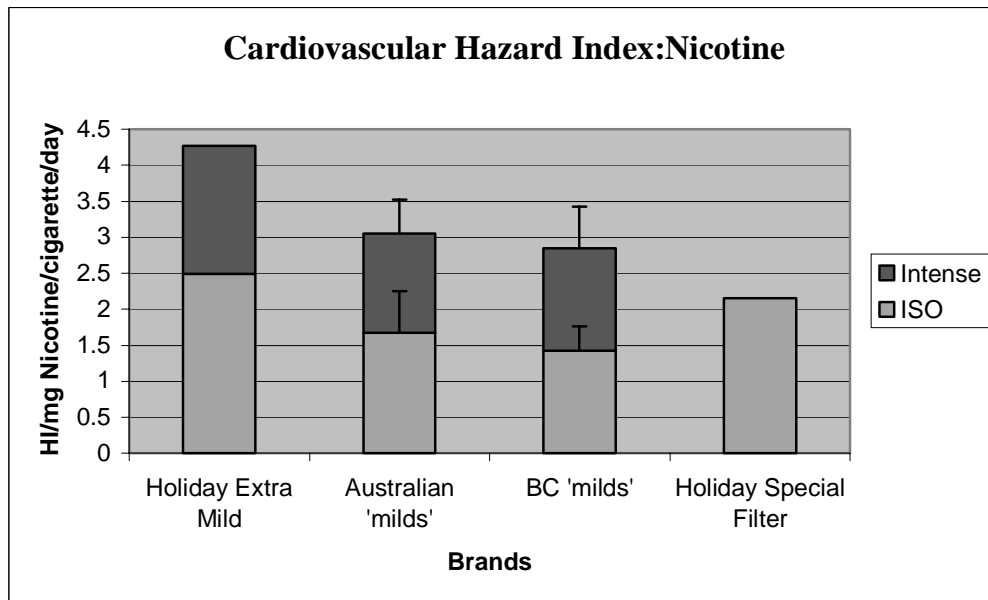
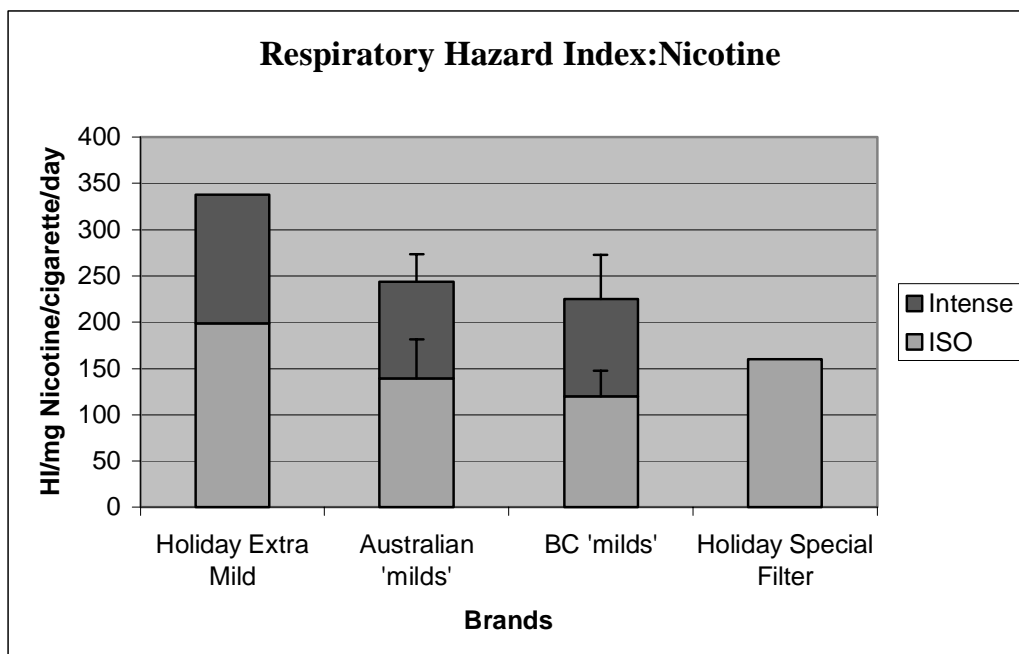


Figure 8. Respiratory toxicants to nicotine ratio in smoke from Holiday Extra Mild (HEM), 13 Australian 'mild' brands, and 10 Canadian (BC) 'mild' brands. The HEM was significantly higher compared with Australian or BC 'milds' ($p = 0.02$).



5. DISCUSSION

The results from this project show that there are brand and possibly country variations in important chemical constituents in cigarette smoke that contribute to cancer, cardiovascular, and respiratory disease risk. It is also clear from these results that brands labelled as “mild” can be just as or even more toxic per milligram of nicotine delivered as regular brands. This is of concern since tobacco products are not tightly regulated for toxic constituent yields, and particularly since consumers may mistakenly believe that certain brands are less harmful than others, based on the name of the brand.

A significant issue with the data in this report is batch variability within a product line. While it may be argued that a single batch of one brand will not capture the "intra-brand" variability, it should be clear from this report that variability within a brand does not, by itself, explain the statistical differences seen. It stands to reason, for example, that any variability from batch to batch would also be reflected in the variability one sees between different brands from different manufacturers (and from different parts of the world). It should also be noted that a subsequent testing of these same brands purchased 6 months after this initial test showed very comparable results for tar, nicotine, and CO, such that the results would not change from those presented here (data shown in Appendix A).

The variability between brands tended to decrease in many of the parameters when intense yield measurements were taken, which implies that the standard ISO method introduces experimental variability in the measurement that results in artificial distinctions between brand yields. It is possible that different cigarette paper designs (i.e. paper perforations, etc) would differentially influence the ISO yields to a greater extent than with intense methods that occlude ventilation holes.

The cigarettes tested in this report were simply purchased from a single retail outlet, as we knew this would represent what a consumer of that brand would experience at that time. For this reason, the comparability of the New Zealand to Australian and Canadian results could be questioned if the sample selection process was not based on retail samples, but without considerably more sampling and testing of these products, this issue of comparability cannot be resolved. We can say with confidence that the cigarettes we selected for testing (for that brand and batch) were significantly different in several parameters involving hazardous constituents from those reported in Australia and Canada.

The nicotine, tar and CO levels found in this report are all within the written limits on the cigarette packets, when standard ISO analytical methods, which the Smoke-free Environments Regulations 1999 specify should be used for this measurement, are applied. However, if the intense methods from Health Canada are used, these limits are all exceeded by a considerable margin. This is true not only of the HEM, but for all brands reported internationally.

It is apparent that the BC cigarettes yield more nicotine, especially under intense smoking conditions. The BC cigarettes also had a significantly higher CO yield generally than the Australian brands. The respiratory and cardiovascular toxicant profiles were higher in BC cigarettes than in Australian brands, but this difference disappeared when the yields were normalised to nicotine yield. The HEM was comparable to the BC milds in terms of CO and

tar yields, but was significantly higher in terms of T:N ratio and in the carcinogen or respiratory toxicant to nicotine ratio.

The nicotine content of the HSF tobacco was at the high end of the range of values reported by the NCI for American cigarettes, but was comparable to the mid-range of values reported in Canadian and British cigarettes.

In this report, the statistics on yields are reported as straight values and as values normalised to mg nicotine. The HEM brand, when nicotine intake is normalised, was significantly outside the Canadian and Australian group means for tar, as well as for cancer risk, cardiovascular, and respiratory risk. It has been argued for many years that smokers adjust their smoking behaviour to accommodate different nicotine yields (9). Therefore, this may be an improved way to assess the actual hazard posed to consumers.

Data in this report shows that nicotine yield varies greatly between standard ISO and 'intense' conditions. However, normalising constituent measurements to that of the nicotine yield removes much of the difference for a given measurement. The T:N ratio was also consistent across different brands in both Australia and Canada, which implies that this is a fairly stable parameter. The US National Cancer Institute reports that T:N ratios for 2052 brands of cigarettes ranges up to a mean of 15.8 for high tar cigarettes. Rickert and associates (10) found that light and ultra light cigarettes smoked under intense conditions had T:N ratios of 11.9 and 12.2, respectively. These values did not differ from each other significantly, and are entirely consistent with the T:N ratios found for the Australian and Canadian brands tested in this report. However, the HEM cigarettes tested in this study had significantly higher T:N ratios (14.08 and 17.92 for standard ISO and intense conditions, respectively) than other brands in this report. The T:N ratio for this brand smoked intensely (17.92) was higher than mean ratios of various tar yield cigarettes reported for over 2052 brands in the USA (8). If such a difference can be explained by inter-batch variability, this calls into question why such variability exists, and what the potential health implications are of such variability for smokers.

Historical data on T:N ratios in Australia provide additional context for the current results. Data on T:N ratios from 1980 ranged from 8.5:1 to 16.3:1 with a mean of 11.94:1. For the 1994 data set, T:N ratios ranged from 5.56:1 to 12.44:1 with a mean of 9.03:1. These results are for samples of Australian cigarettes from three manufacturers and for standard test yields (Cancer Council of Victoria, 2002).

The formation of a composite value for cancer risk, cardiovascular risk, and respiratory risk, assists in the evaluation of hazards from different brands. This idea has been proposed previously (Rickert 2000), using occupational workplace standards for the various constituents as a basis for risk evaluation. However, the workplace standards are not ideally suited for this type of use as they do not represent absolute thresholds for the onset of adverse effects, and the methodology used for many cannot be reproduced independently. In addition, the occupational standards cannot account for low dose effects of genotoxic carcinogens. The specific indices used in this report have no international precedent, but we believe such

measures facilitate the interpretation of complex analytical data with many compounds in smoke that contribute to given adverse health outcomes. All of the reference values and cancer potency factors are publicly available and are suited for risk assessment of air pollutant sources. The results show that the composite risk values, normalised to nicotine yield, are dependent upon the type of smoking method used. These measures are proposed for use in interpreting the hazards from constituents in any future cigarette smoke-testing programme.

6. REFERENCES

- (1) Fowles J, Bates M. The chemical constituents of cigarettes and cigarette smoke: priorities for harm reduction. A report by the Institute of Environmental Science and Research for the New Zealand Ministry of Health. Porirua: Institute of Environmental Science and Research; 2000.
- (2) Stratton KR, editor. Clearing the smoke: assessing the science base for tobacco harm reduction. Washington, D.C.: Institute of Medicine, National Academy Press; 2001.
- (3) Bates M. Control of nicotine and tar in tobacco products: policies of other jurisdictions. A report by the Institute of Environmental Science and Research for the New Zealand Ministry of Health. Porirua: Institute of Environmental Science and Research; 1998.
- (4) Smoke constituents. (2000). Available (2002) from Government of British Columbia, Ministry of Health Services web site: <http://www.hlth.gov.bc.ca/ttdr/pdf/sc.html>
- (5) Cigarette emissions disclosure. (2001). Available (January 2002) from Australian Dept of Health & Ageing web site: <http://www.health.gov.au/pubhlth/strateg/drugs/tobacco/>.
- (6) Office of Environmental Health Hazard Assessment. California Environmental Protection Agency. 2002. List of chemicals known to cause cancer under State Proposition 65. <http://www.oehha.ca.gov>.
- (7) Office of Environmental Health Hazard Assessment. California Environmental Protection Agency. 2002. Chronic Reference Exposure Levels for Airborne Exposures. <http://www.oehha.ca.gov>.
- (8) Risks associated with smoking cigarettes with low machine-measured yields of tar and nicotine. Bethesda, Md: National Cancer Institute, U.S. Dept of Health and Human Services; 2001. Smoking and tobacco control monograph; 13.
- (9) Benowitz N, Hall SM, Herning RI, Jacob P, Jones RT, Osman AL. Smokers of low yield cigarettes do not consume less nicotine. *N Engl J Med* 1983;309:139-42.
- (10) Rickert WS, Robinson JC, Young JC, Collinshaw NE, Bray DF. A comparison of the yields of tar, nicotine, and carbon monoxide of 36 brands of Canadian cigarettes tested under three conditions. *Prev Med* 1983;12:682-94.

Appendix A.

6-month follow-up sampling of the HSF and HEM brands for nicotine, tar, and carbon monoxide levels.

Comparison of cigarette smoke yields

ISO	Feb-02	Aug-02	Feb-02	Aug-02	Feb-02	Aug-02	Feb-02	Aug-02
	Nicotine	Nicotine	Tar	Tar	CO	CO	T:N	T:N
Holiday Special Filter	1.1	0.94	14.3	12.7	13.6	12.3	13	13.5
Holiday Extra Mild	0.64	0.63	9.07	8.8	9.3	9.4	14.08	13.9
<i>Intense</i>								
Holiday Special Filter	nd	2.22	nd	31.7	nd	25.9	nd	14.3
Holiday Extra Mild	1.82	1.72	32.6	28.6	26.4	26.5	17.9	16.6

nd = not determined