

CONFIDENTIAL

UK SMOKE CONSTITUENTS STUDY

Part 11: Determination of Metals Yields in Cigarette Smoke by ICP-MS & CVAAS

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UK SMOKE CONSTITUENTS TESTING STUDY PROTOCOL

Determination of Metals Yields in Cigarette Smoke

1. Introduction

This work was undertaken by Arista Laboratories Europe at the request of the Tobacco Manufacturers' Association in accordance with the Study Protocol provided by, and agreed with, the UK Department of Health.

Arista Laboratories Europe acquired the smoke constituent analytical business of LGC Ltd, on the 23rd December 2002. LGC Ltd was previously the contractor for the study.

In agreement with the client, 'metals' analysis was carried out at Arista Laboratories USA.

2. Summary

The objective of this study is to determine the yield ratings of selected smoke constituents (Appendix 2) in mainstream cigarette smoke as identified by the United Kingdom Department of Health. The study encompassed 25 brands of cigarettes representing a 58% market share (July 2001) of the UK market. In addition, Kentucky reference cigarettes 1R4F and 1R5F have been included in this part of the study.

This report details the results for metals: arsenic, cadmium, chromium, lead, nickel, selenium and mercury. The 'metals' yields were determined by inductively coupled plasma – mass spectroscopy (ICP-MS) with the exception of mercury which is determined using Cold Vapour Atomic Absorption Spectroscopy.

3. Samples

25 brands of cigarettes were selected because their design parameters are representative of the brands in the UK market place. The selection criteria include a range of "tar" values, ventilation, paper permeability, circumference, length, tobacco weight, blend and market share. The Kentucky reference cigarettes 1R4F and 1R5F were included in this part of the study.

2000 cigarettes of each brand were obtained from a single production batch of current specification (November/December 2001), and stored in plastic containers at 4°C. Cigarettes were selected from packets on a random basis for testing.

Cigarettes were conditioned at a temperature of $22 \pm 1^\circ\text{C}$ and $60 \pm 3\%$ relative humidity¹ for a minimum of 48 hours but not exceeding 10 days.

Butt marking was done in accordance with ISO butt length specifications². Filtered cigarettes were smoked to a measured butt length equal to either the tipping paper + 3 mm or filter length + 8 mm whichever was longer. The minimum butt length was 23 mm and this was used for non filter brands. All smoking was conducted in an environment of temperature $22 \pm 2^\circ\text{C}$ and $60 \pm 5\%$ relative humidity¹.

4. Smoking

The cigarettes were smoked on a rotary smoking machine.

20 cigarettes were sub-sampled from packets chosen on a random basis and smoked to determine the yields of 'metals' using the method given below (see section 5). Five

determinations were performed for each of the 25 brands, 1R4F and 1R5F. As far as was practicable sub-samples of each brand were smoked on different days.

ISO conditions³ for smoking cigarettes were used. The smoking machine puffing parameters were $35 \pm 0.3 \text{ cm}^3$ puff volume with 2.0 ± 0.02 second puff duration once every 60.0 ± 0.5 seconds.

5. Method and Validation

This method is applicable to determination of 'metals' in mainstream tobacco smoke. Six metals are determined by ICP-MS and the seventh, mercury by CVAAS.

Metals

For each sample, twenty conditioned cigarettes are smoked on a Borgwaldt RM20 analytical smoking machine equipped with an electrostatic precipitation (EP) unit. A quartz EP tube is used in the EP unit for smoke collection.

The tar/metals in the trap are extracted into methanol. The solution is quantitatively transferred to a digestion tube. A small quantity of nitric acid is added, the tube transferred to a digestion block and loosely covered and the sample is gently heated to remove most of the methanol. The sample is completely digested by further cycles of adding increasingly concentrated nitric acid and heating to ca 90°C for 30 minutes. Hydrogen peroxide solution is then added and the sample heated to 95°C for half an hour. The end result is a concentrated nitric acid solution containing the metals of ca 5 mL volume. The solution is allowed to cool and made up to 50 mL with water and analysed by ICP-MS. Calibration standards are made up in 10% nitric acid

Mercury

For each sample, twenty conditioned cigarettes are smoked on a Borgwaldt RM20 analytical smoking machine. The main stream smoke is passed through a series of two impingers containing acidified potassium permanganate solution. The solutions are transferred to a vessel and subjected to microwave digestion. Excess potassium permanganate is reduced with hydroxylamine hydrochloride and subjected to further microwave digestion. The solutions are allowed to cool, transferred to a volumetric flask and made up to volume with water.

An aliquot of the sample is analysed by CVAAS. The instrument is calibrated by a set of calibration standards prepared from a certified mercury standard solution.

The full methods are given in an Annexe to this report.

The methods are in current use and have been validated. The validation data used to show that the methods are suitable for use in the study is given in an Annexe to this report.

6. Results & Discussion

The results were tabulated for each brand (see Tables). The mean, standard deviation and relative standard deviation were determined for each set of results.

A summary of the results is included at the beginning (Page 3). Linear least squares regression analysis has been carried out for arsenic, cadmium, lead and mercury yields versus carbon monoxide (Page 3 to 3) and versus NFDPM (Page 3 to 3) for the cigarette brands

(excluding 1R4F and 1R5F). Only brands that gave a yield greater than the limit of quantitation have been used in the regression analysis. The other three elements, chromium, nickel and selenium, had insufficient brands with positive yields to carry out the analysis.

Where no analyte was found, the result has been reported as not detected (nd). Brands which gave analyte yields below the limit of quantitation but above the limit of detection have been reported as follows: Arsenic <2.7 ng cig⁻¹; Cadmium <1.2 ng cig⁻¹; Chromium <1.7 ng cig⁻¹; Lead <2.0 ng cig⁻¹; Nickel <4.7 ng cig⁻¹; Selenium <2.7 ng cig⁻¹; Mercury <0.25 ng cig⁻¹.

7. Outlier Test

It was agreed as part of the study protocol that Dixon's outlier test would be performed on each set of (positive) results. This has been carried out and where an outlier has been detected then the result has been flagged "95%". A judgement was then made as to whether to use the original results or recalculate the mean excluding the outlier. The CV values for each analyte across the 25 brands were examined before making this judgement. As a result of this, the original results have been used in the summary table as comparison of the CV values did not confirm that there are true outliers present in the original data.

8. Information provided in the Appendices and Annex

Appendix 1 contains technical opinions and interpretations about the method, validation data and the results.⁴

Appendix 2 lists the specific analytes to be determined in the study.

Appendix 3 contains a brief glossary of selected abbreviations and terms used in this report.

Appendix 4 contains a brief description of the cigarettes used in this survey. It also lists the butt lengths determined for each brand of cigarette.

The Annex to this report lists the method used to determine the 'metals' yields in cigarette smoke. It also contains a summary of the validation data used to show that the method was suitable for the purposes of the bench mark study.

¹ ISO 3402:1999 – Tobacco and tobacco products – atmosphere for conditioning and testing

² ISO 4387: 2000 - Methods for chemical analysis of tobacco and tobacco products: Determination of total and nicotine- free dry particulate matter using a routine analytical smoking machine

³ ISO 3308:2000 – Routine analytical cigarette smoking machine: Definitions and standard conditions

⁴ NB When evaluating a set of results obtained using a particular method it is important to put the results in context and this is what we have set out to do in this Appendix.

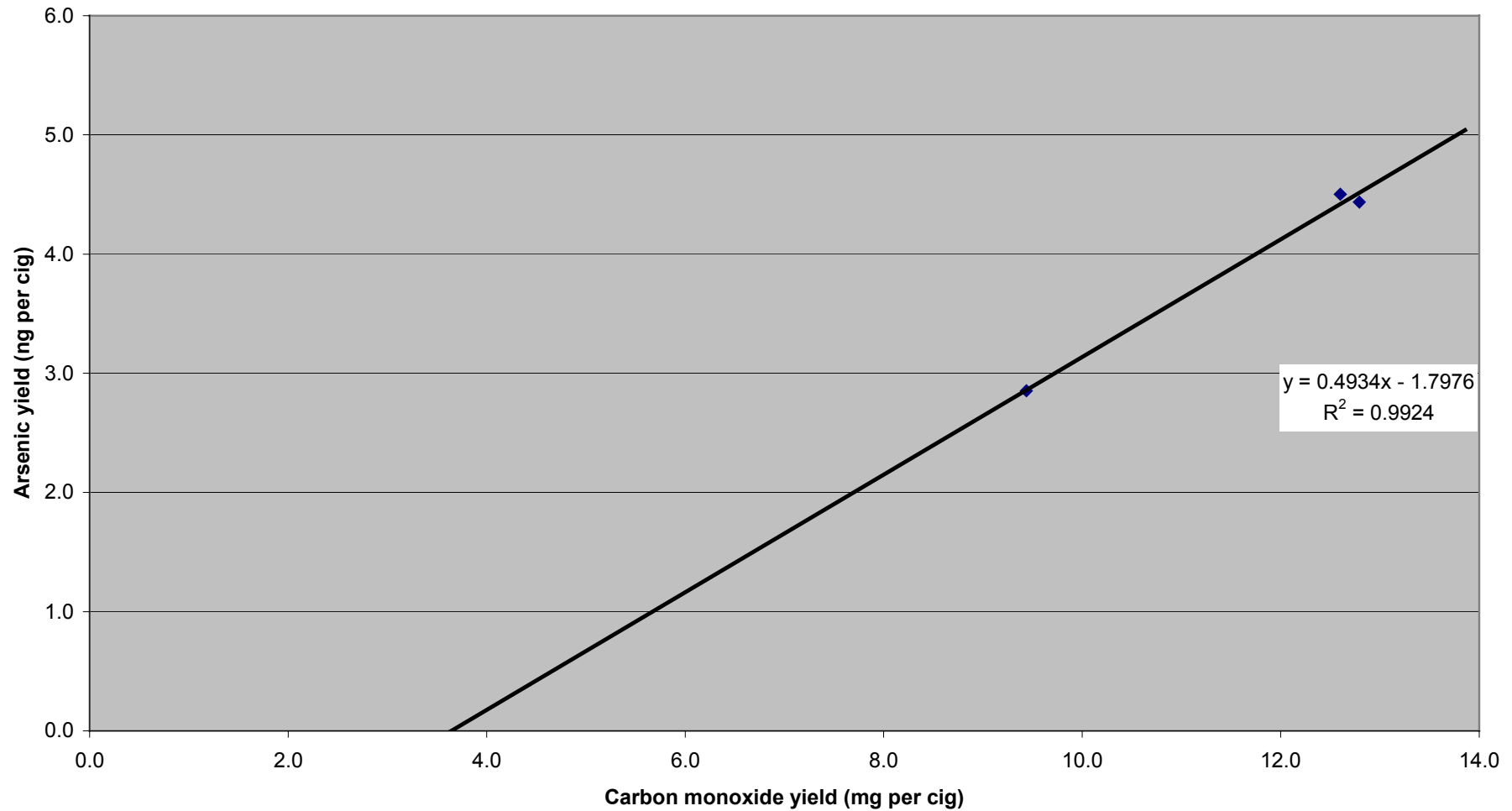
Tables

Summary of mean results for 25 cigarette brands plus 1R4F and 1R5F

	Arsenic	Cadmium	Chromium	Lead	Nickel	Selenium	Mercury	NFDPm	Carbon Monoxide
	ng/cig	ng/cig	ng/cig	ng/cig	ng/cig	ng/cig	ng/cig	mg/cig	mg/cig
1R4F	6.5	62.8	nd	41.4	nd	<2.3	4.3	9.06	12.26
1R5F	nd	9.6	nd	4.4	nd	nd	1.4	1.92	3.36
Benson & Hedges King Size	<2.7	19.1	nd	14.9	nd	<2.3	2.6	10.30	11.74
Berkely Superkings	<2.7	15.8	nd	17.9	nd	<2.3	2.2	9.69	11.50
Camel Ultra Lights	nd	9.2	nd	2.8	nd	nd	1.0	3.09	3.13
Consulate Menthol	<2.7	10.9	nd	8.9	nd	nd	1.6	7.06	8.30
Gitanes Caporal Filter	4.5	90.3	nd	23.1	nd	10.3	2.8	12.00	12.60
Lambert & Butler King Size	<2.7	34.5	nd	31.0	nd	<2.3	2.7	11.93	13.30
Lambert & Butler Lights King Size	nd	8.8	nd	8.3	nd	nd	1.3	5.24	6.48
Lambert & Butler Ultra Lights	nd	1.5	nd	<2.0	nd	nd	<0.25	1.61	1.49
Marlboro King Size	4.4	46.9	nd	18.8	nd	<2.3	2.6	12.69	12.79
Marlboro Lights King Size	<2.7	21.2	nd	8.1	nd	nd	1.7	6.10	7.19
Mayfair Lights King Size	<2.7	12.3	nd	14.0	nd	<2.3	1.8	7.23	8.73
Mayfair Menthol King Size	<2.7	7.6	nd	7.9	nd	nd	1.3	4.65	5.95
Red Band Lights King Size	<2.7	23.7	nd	8.0	nd	<2.3	2.6	5.55	6.41
Regal Filter	<2.7	15.5	nd	15.1	nd	nd	1.7	10.65	10.92
Regal King Size	<2.7	21.9	nd	19.3	nd	<2.3	2.2	11.96	13.86
Rothman Royals 120s	2.9	23.6	nd	17.1	nd	<2.3	2.0	10.39	9.44
Rothman Royals King Size	<2.7	24.1	nd	17.4	nd	<2.3	2.0	11.00	10.86
Senior Service	<2.7	11.9	nd	11.1	nd	<2.3	1.8	11.92	7.71
Silk Cut Extra Mild	nd	3.1	nd	2.5	nd	nd	0.8	2.67	3.16
Silk Cut King Size	<2.7	5.3	nd	5.5	nd	nd	1.4	5.62	5.78
Silk Cut Ultra King Size	nd	<1.2	nd	nd	nd	nd	0.3	1.01	1.20
Superkings	<2.7	1.6	nd	<2.0	nd	<2.3	2.1	10.71	11.41
Superkings Lights	<2.7	10.7	nd	12.1	nd	<2.3	1.4	8.09	7.54
Superkings Ultra Lights	nd	5.0	nd	3.0	nd	nd	0.8	3.08	3.53
Vogue Superslims	<2.7	16.3	nd	15.2	nd	nd	1.7	7.38	6.05

Regression analysis of arsenic versus carbon monoxide for brands with measurable yields

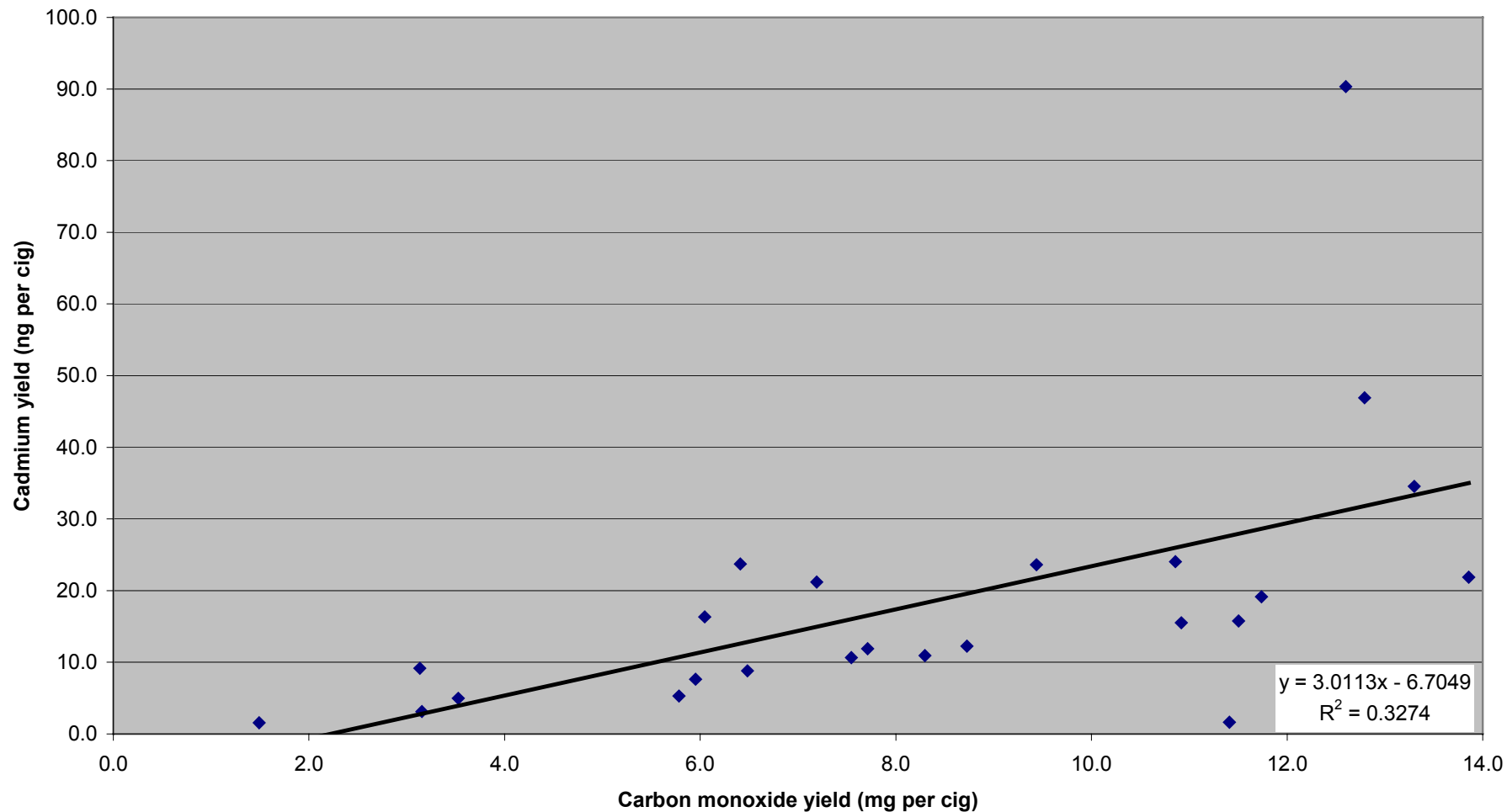
Regression analysis of arsenic versus carbon monoxide for 3 cigarette brands



The regression analysis trend line has been calculated on the basis of a linear relationship ($y = mx + c$)

Regression analysis of cadmium versus carbon monoxide

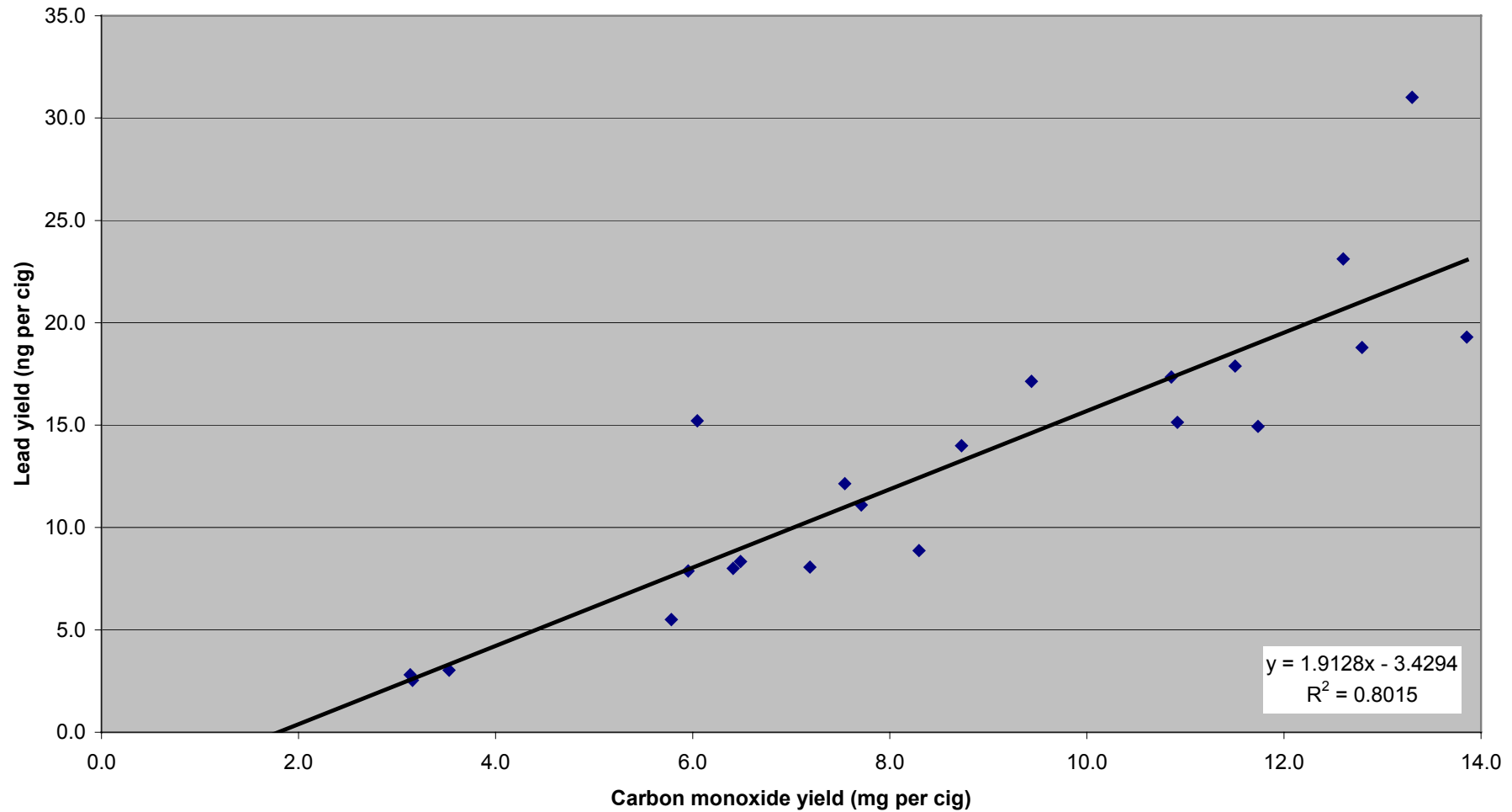
Regression analysis of cadmium versus carbon monoxide for 24 cigarette brands



The regression analysis trend line has been calculated on the basis of a linear relationship ($y = mx + c$)

Regression analysis of lead versus carbon monoxide

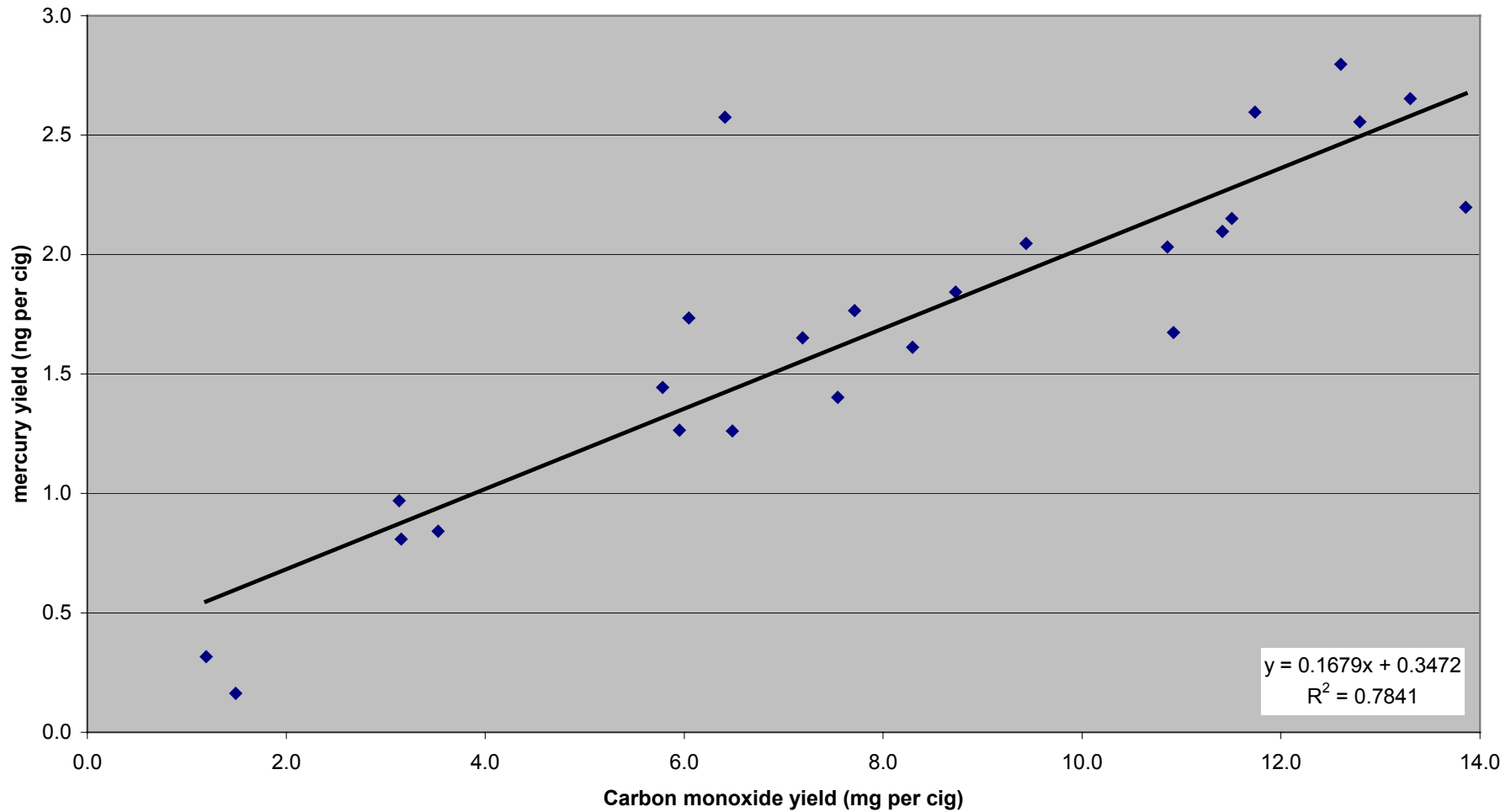
Regression analysis of lead versus carbon monoxide for 22 cigarette brands



The regression analysis trend line has been calculated on the basis of a linear relationship ($y = mx + c$)

Regression analysis of mercury versus carbon monoxide

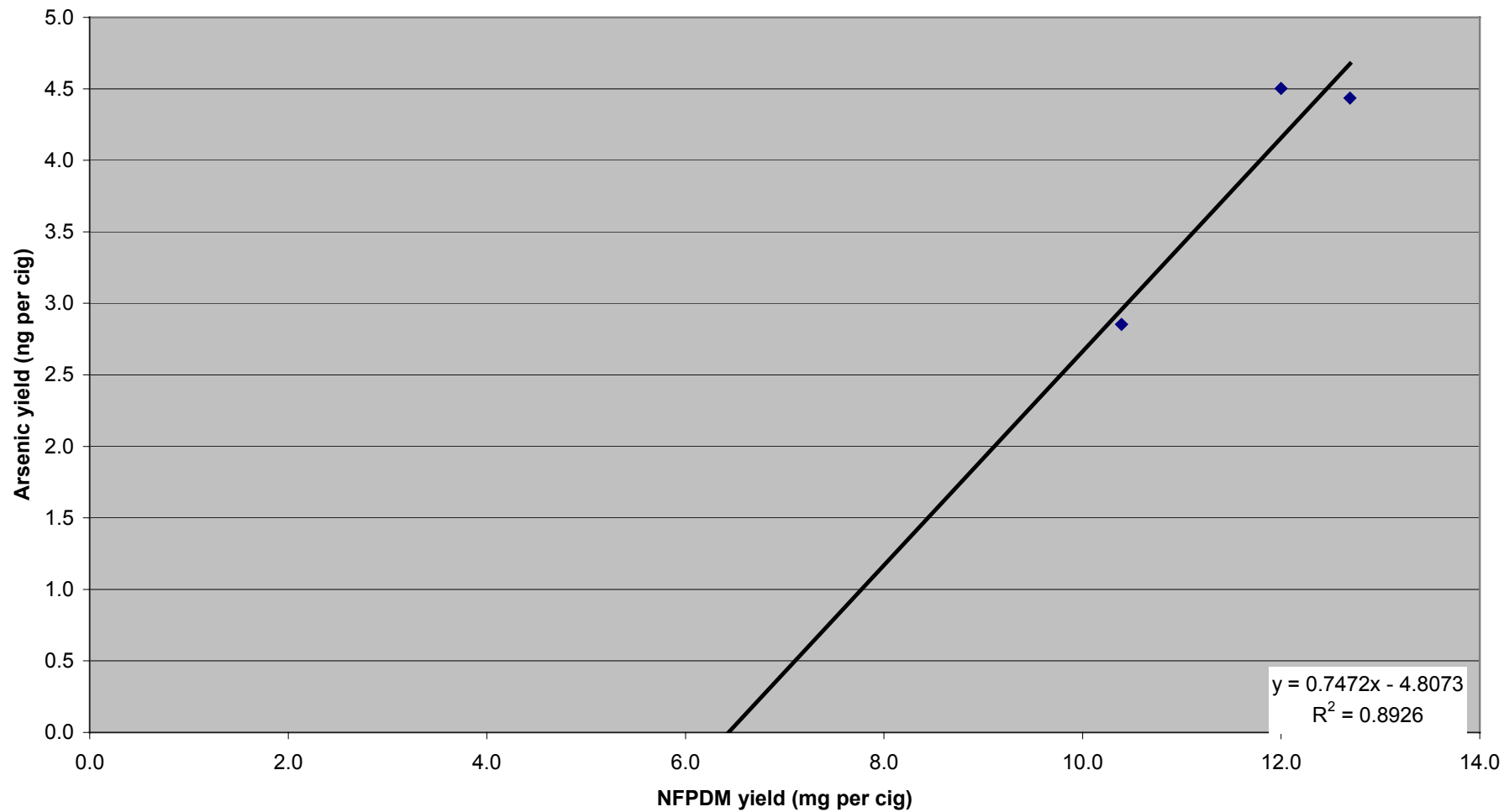
Regression analysis of mercury versus carbon monoxide for 25 cigarette brands



The regression analysis trend line has been calculated on the basis of a linear relationship ($y = mx + c$)

Regression analysis of arsenic versus NFDPM for brands with measurable yields

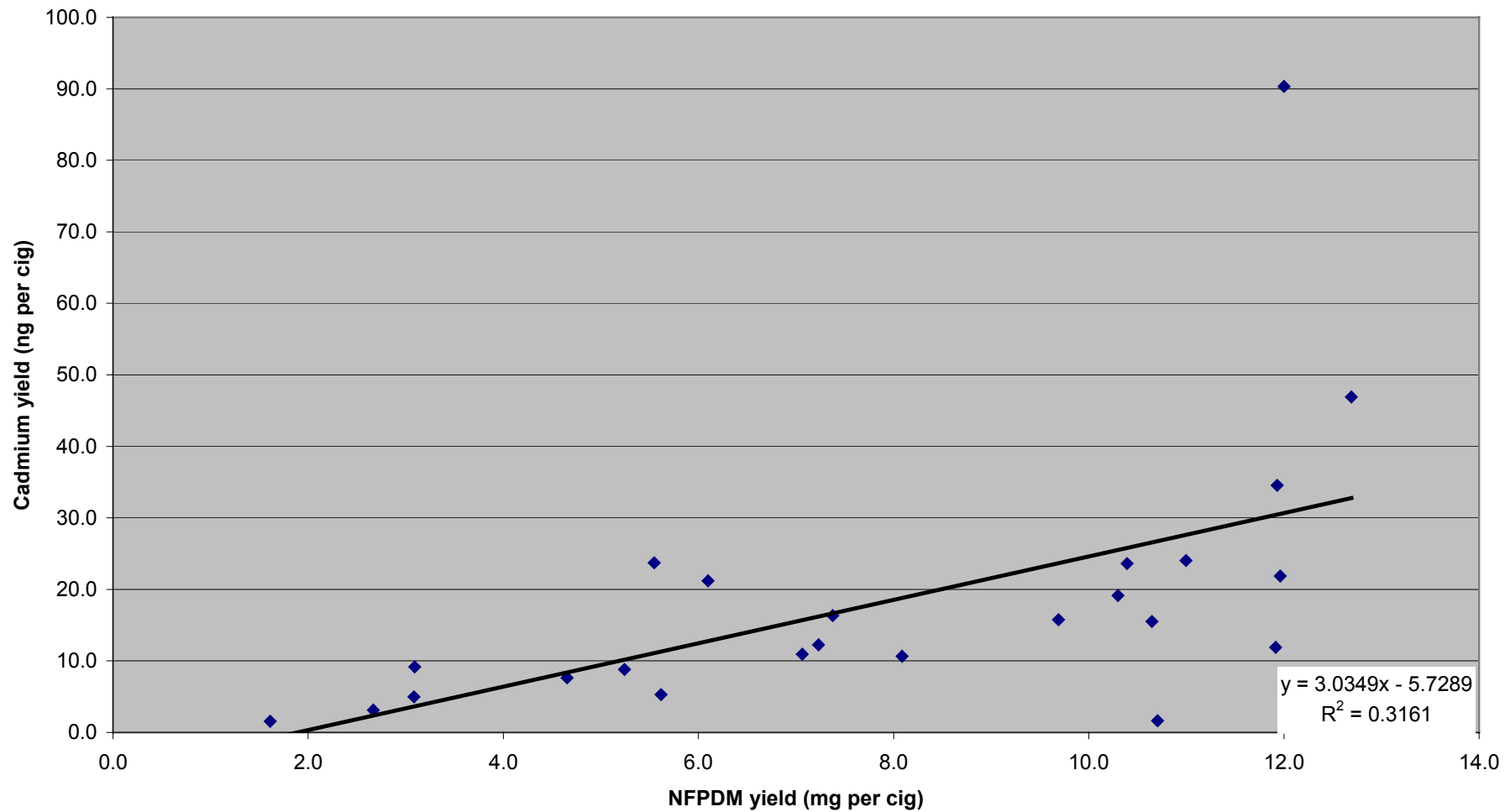
Regression analysis of arsenic versus NFDPM for 25 cigarette brands



The regression analysis trend line has been calculated on the basis of a linear relationship ($y = mx + c$)

Regression analysis of cadmium versus NFDPM

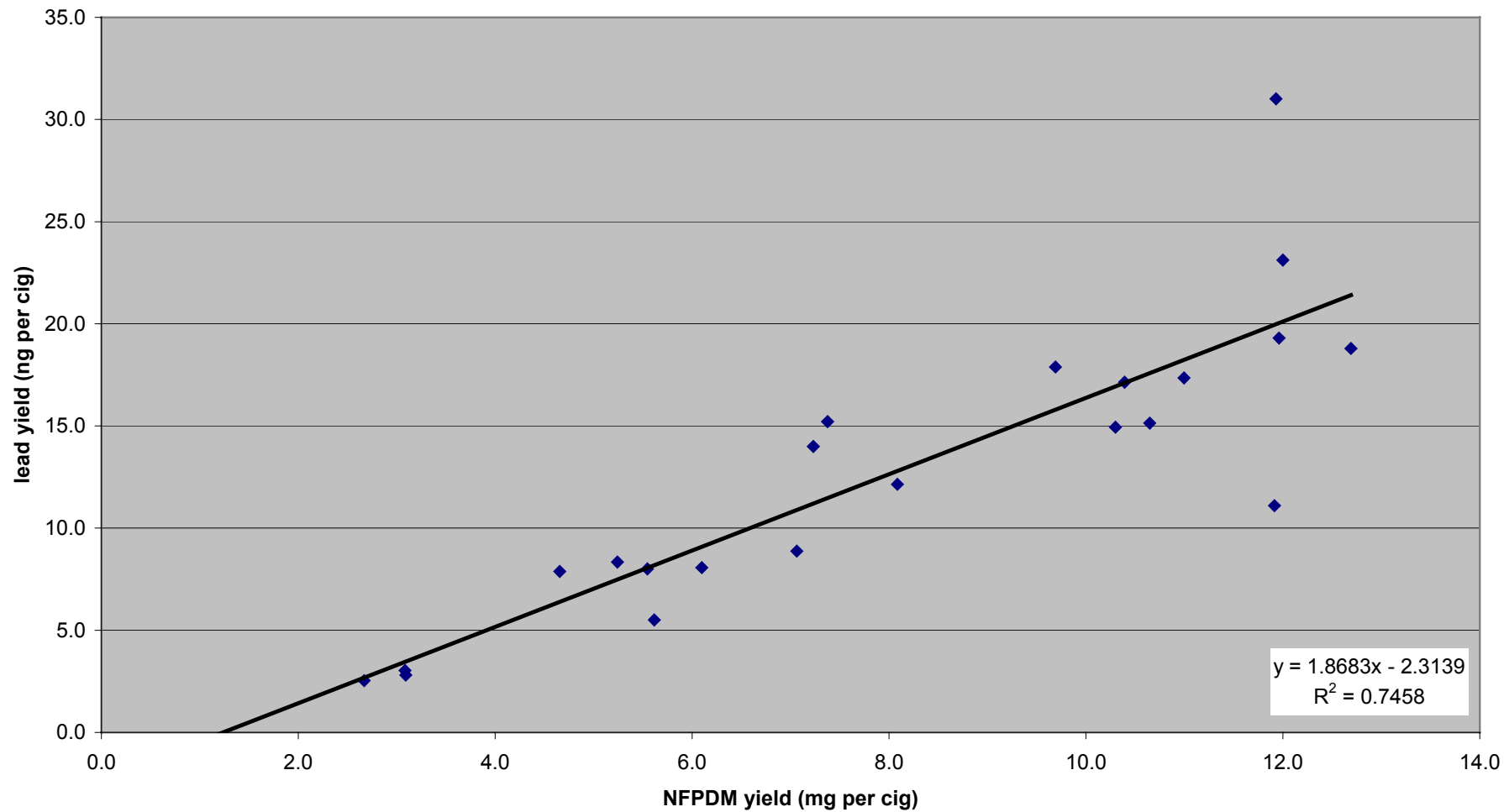
Regression analysis of cadmium versus NFDPM for 24 cigarette brands



The regression analysis trend line has been calculated on the basis of a linear relationship ($y = mx + c$)

Regression analysis of lead versus NFDPM

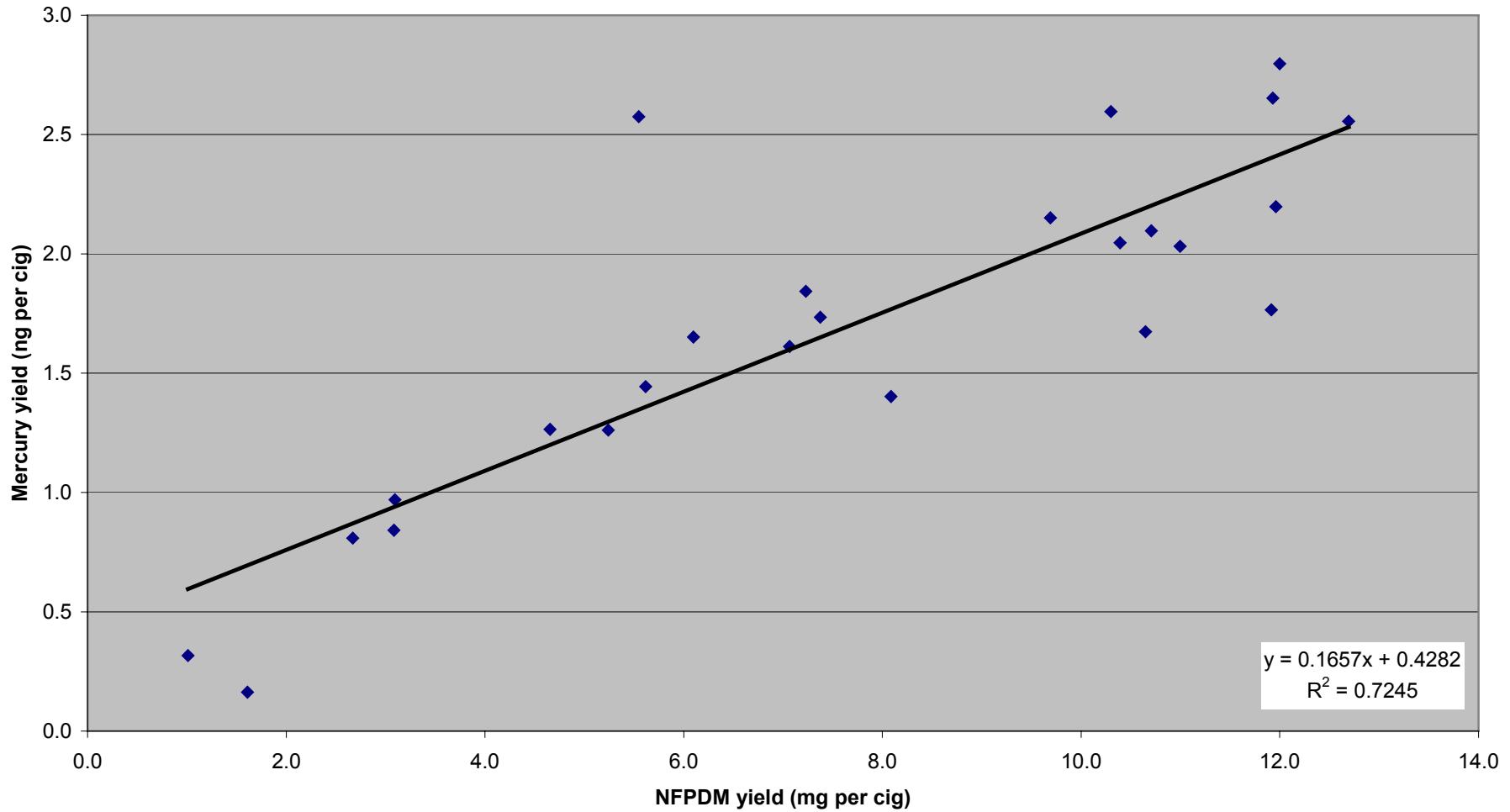
Regression analysis of lead versus NFDPM for 22 cigarette brands



The regression analysis trend line has been calculated on the basis of a linear relationship ($y = mx + c$)

Regression analysis of mercury versus NFDPM

Regression analysis of mercury versus NFDPM for 25 cigarette brands



The regression analysis trend line has been calculated on the basis of a linear relationship ($y = mx + c$)

1R4F

Brand	Arsenic	Cadmium	Chromium	Lead	Nickel	Selenium	Mercury
1R4F	6.5	47.0	nd	37.3	nd	<2.3	3.8
1R4F	6.7	74.7	nd	46.0	nd	<2.3	4.6
1R4F	6.7	69.7	nd	42.6	nd	<2.3	4.3
1R4F	6.5	64.2	nd	40.3	nd	<2.3	4.6
1R4F	6.0	58.5	nd	40.5	nd	<2.3	4.5
Mean (ng/cig)	6.5	62.8	nd	41.4	nd	<2.3	4.3
Standard Deviation	0.30	10.7		3.22		n/a	0.32
CV (%)	4.6	17.1		7.8		n/a	7.4
<i>Outlier Test</i>							
Dixons outlier test was applied to the above data							
Data sorted	5.97	46.952		37.303		<2.3	3.8
	6.47	58.471		40.311		<2.3	4.3
	6.54	64.213		40.518		<2.3	4.5
	6.67	69.681		42.598		<2.3	4.6
	6.69	74.703		46.027		<2.3	4.6
Statistical test applied							
Dixons low end test	0.691	0.415		0.345			0.602
Outlier detected at 95%							
Dixons high end test	0.035	0.181		0.393			0.002
Outlier detected at 95%							
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>							
Summary of Results							
Mean (ng/cig)	6.5	62.8	nd	41.4	nd	<2.3	4.3
Standard Deviation	0.30	10.7		3.22		n/a	0.32
CV (%)	4.6	17.1		7.8		n/a	7.4

1R5F

Brand	Arsenic	Cadmium	Chromium	Lead	Nickel	Selenium	Mercury
1R5F	nd	8.3	nd	3.7	nd	nd	1.4
1R5F	nd	10.3	nd	4.4	nd	nd	1.6
1R5F	nd	9.6	nd	4.6	nd	nd	1.4
1R5F	nd	9.9	nd	4.8	nd	nd	1.4
1R5F	nd	9.8	nd	4.4	nd	nd	1.3
Mean (ng/cig)	nd	9.6	nd	4.4	nd	nd	1.4
Standard Deviation		0.77		0.43			0.09
CV (%)		8.0		9.8			6.3
<i>Outlier Test</i>							
Dixons outlier test was applied to the above data							
Data sorted		8.301		3.694			1.332375
		9.584		4.415			1.359345
		9.758		4.430			1.372067
		9.908		4.636			1.438379
		10.346		4.829			1.553801
Statistical test applied							
Dixons low end test		0.628		0.635			0.122
Outlier detected at 95%							
Dixons high end test		0.214		0.170			0.521
Outlier detected at 95%							
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>							
Summary of Results							
Mean (ng/cig)	nd	9.6	nd	4.4	nd	nd	1.4
Standard Deviation		0.77		0.43			0.09
CV (%)		8.0		9.8			6.3

Benson & Hedges King Size

Brand	Arsenic	Cadmium	Chromium	Lead	Nickel	Selenium	Mercury
Benson & Hedges King Size	<2.7	15.3	nd	14.9	nd	<2.3	2.4
Benson & Hedges King Size	<2.7	21.1	nd	14.8	nd	<2.3	2.8
Benson & Hedges King Size	<2.7	20.3	nd	15.8	nd	<2.3	2.5
Benson & Hedges King Size	<2.7	20.3	nd	15.0	nd	<2.3	2.7
Benson & Hedges King Size	<2.7	18.8	nd	14.2	nd	<2.3	2.5
Mean (ng/cig)	<2.7	19.1	nd	14.9	nd	<2.3	2.6
Standard Deviation	n/a	2.29		0.59		n/a	0.19
CV (%)	n/a	12.0		3.9		n/a	7.1
<i>Outlier Test</i>							
Dixons outlier test was applied to the above data							
Data sorted		15.302		14.221	49.786		2.37871
		18.763		14.793	51.241		2.512712
		20.252		14.875	52.272		2.514725
		20.261		14.971	53.713		2.748532
		21.054		15.848	57.303		2.827703
Statistical test applied							
Dixons low end test		0.602		0.352	0.194		0.298
Outlier detected at 95%							
Dixons high end test		0.138		0.539	0.478		0.176
Outlier detected at 95%							
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>							
Summary of Results							
Mean (ng/cig)	<2.7	19.1	nd	14.9	nd	<2.3	2.6
Standard Deviation	n/a	2.29		0.59		n/a	0.19
CV (%)	n/a	12.0		3.9		n/a	7.1

Berkely Superkings

Brand	Arsenic	Cadmium	Chromium	Lead	Nickel	Selenium	Mercury
Berkely Superkings	<2.7	12.2	nd	15.8	nd	<2.3	2.1
Berkely Superkings	<2.7	17.6	nd	19.6	nd	<2.3	2.3
Berkely Superkings	<2.7	16.9	nd	18.4	nd	<2.3	2.2
Berkely Superkings	<2.7	16.3	nd	17.7	nd	<2.3	2.1
Berkely Superkings	<2.7	15.9	nd	18.0	nd	<2.3	2.1
Mean (ng/cig)	<2.7	15.8	nd	17.9	nd	<2.3	2.2
Standard Deviation	n/a	2.11		1.37		n/a	0.09
CV (%)	n/a	13.4		7.7		n/a	4.3
<i>Outlier Test</i>							
Dixons outlier test was applied to the above data							
Data sorted		12.176		15.794			2.062
		15.915		17.691			2.108
		16.320		17.977			2.113
		16.903		18.436			2.172
		17.594		19.558			2.301
Statistical test applied							
Dixons low end test		0.690		0.504			0.192
Outlier detected at 95%							
Dixons high end test		0.128		0.298			0.539
Outlier detected at 95%							
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>							
Summary of Results							
Mean (ng/cig)	<2.7	15.8	nd	17.9	nd	<2.3	2.2
Standard Deviation	n/a	2.11		1.37		n/a	0.09
CV (%)	n/a	13.4		7.7		n/a	4.3

Camel Ultra Lights

Brand	Arsenic	Cadmium	Chromium	Lead	Nickel	Selenium	Mercury
Camel Ultra Lights	nd	8.2	nd	2.9	nd	nd	0.9
Camel Ultra Lights	nd	7.8	nd	2.7	nd	nd	1.1
Camel Ultra Lights	nd	8.4	nd	2.9	nd	nd	1.0
Camel Ultra Lights	nd	11.8	nd	3.0	nd	nd	1.0
Camel Ultra Lights	nd	9.7	nd	2.5	nd	nd	0.9
Mean (ng/cig)	nd	9.2	nd	2.8	nd	nd	1.0
Standard Deviation		1.63		0.20			0.08
CV (%)		17.7		7.1			8.6
<i>Outlier Test</i>							
Dixons outlier test was applied to the above data							
Data sorted		7.835		2.493			0.859
		8.173		2.725			0.912
		8.379		2.904			0.990
		9.697		2.910			1.018
		11.797		2.996			1.068
Statistical test applied							
Dixons low end test		0.085		0.462			0.252
Outlier detected at 95%							
Dixons high end test		0.530		0.170			0.241
Outlier detected at 95%							
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>							
Summary of Results							
Mean (ng/cig)	nd	9.2	nd	2.8	nd	nd	1.0
Standard Deviation		1.63		0.20			0.08
CV (%)		17.7		7.1			8.6

Consulate Menthol

Brand	Arsenic	Cadmium	Chromium	Lead	Nickel	Selenium	Mercury
Consulate Menthol	<2.7	10.5	nd	8.6	nd	nd	1.6
Consulate Menthol	<2.7	10.0	nd	8.2	nd	nd	1.7
Consulate Menthol	<2.7	10.4	nd	8.3	nd	nd	1.5
Consulate Menthol	<2.7	9.7	nd	8.4	nd	nd	1.6
Consulate Menthol	<2.7	14.0	nd	10.8	nd	nd	1.6
Mean (ng/cig)	<2.7	10.9	nd	8.9	nd	nd	1.6
Standard Deviation	n/a	1.76		1.09			0.08
CV (%)	n/a	16.1		12.3			5.1
<i>Outlier Test</i>							
Dixons outlier test was applied to the above data							
Data sorted		9.697		8.214	37.548		1.534
		10.013		8.265	38.100		1.581
		10.378		8.442	43.988		1.594
		10.518		8.639	44.929		1.598
		14.030		10.799	45.920		1.750
Statistical test applied							
Dixons low end test		0.073		0.020	0.066		0.217
Outlier detected at 95%							
Dixons high end test		0.811		0.836	0.118		0.702
Outlier detected at 95%		95%		95%			
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>							
Summary of Results							
Mean (ng/cig)	<2.7	10.2	nd	8.4	nd	nd	1.6
Standard Deviation	n/a	0.37		0.19			0.08
CV (%)	n/a	3.6		2.3			5.1

Gitanes Caporal Filter

Brand	Arsenic	Cadmium	Chromium	Lead	Nickel	Selenium	Mercury
Gitanes Caporal Filter	4.2	70.7	nd	20.8	nd	8.5	2.7
Gitanes Caporal Filter	4.5	95.7	nd	24.4	nd	10.2	2.8
Gitanes Caporal Filter	4.4	96.3	nd	23.4	nd	10.4	2.7
Gitanes Caporal Filter	4.6	97.8	nd	25.0	nd	12.2	2.7
Gitanes Caporal Filter	4.7	91.2	nd	22.1	nd	10.0	3.1
Mean (ng/cig)	4.5	90.3	nd	23.1	nd	10.3	2.8
Standard Deviation	0.20	11.2		1.72		1.31	0.15
CV (%)	4.5	12.4		7.4		12.8	5.5
<i>Outlier Test</i>							
Dixons outlier test was applied to the above data							
Data sorted	4.218	70.701		20.771		8.513	2.687
	4.448	91.243		22.100		10.159	2.704
	4.465	95.686		23.368		10.420	2.737
	4.643	96.261		24.350		12.191	2.795
	4.740	97.807		25.027		10.025	3.059
Statistical test applied							
Dixons low end test	0.440	0.758		0.312		1.089	0.044
Outlier detected at 95%		95%				95%	
Dixons high end test	0.185	0.057		0.159		-1.433	0.710
Outlier detected at 95%							95%
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>							
Summary of Results							
Mean (ng/cig)	4.5	95.2	nd	23.1	nd	10.7	2.7
Standard Deviation	0.20	2.82		1.72		1.01	0.05
CV (%)	4.5	3.0		7.4		9.4	1.7

Lambert & Butler King Size

Brand	Arsenic	Cadmium	Chromium	Lead	Nickel	Selenium	Mercury
Lambert & Butler King Size	<2.7	28.5	nd	28.5	nd	<2.3	2.4
Lambert & Butler King Size	<2.7	30.2	nd	28.6	nd	nd	2.5
Lambert & Butler King Size	2.7	39.5	nd	34.4	nd	<2.3	2.8
Lambert & Butler King Size	<2.7	36.8	nd	30.0	nd	nd	2.8
Lambert & Butler King Size	<2.7	37.8	nd	33.6	nd	<2.3	2.7
Mean (ng/cig)	<2.7	34.5	nd	31.0	nd	<2.3	2.7
Standard Deviation	n/a	4.89		2.82		n/a	0.17
CV (%)	n/a	14.2		9.1		n/a	6.3
<i>Outlier Test</i>							
Dixons outlier test was applied to the above data							
Data sorted		28.510		28.481			2.422
		30.153		28.559			2.534
		36.784		29.990			2.736
		37.774		33.606			2.756
		39.510		34.430			2.816
Statistical test applied							
Dixons low end test		0.149		0.013			0.284
Outlier detected at 95%							
Dixons high end test		0.158		0.139			0.153
Outlier detected at 95%							
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>							
Summary of Results							
Mean (ng/cig)	<2.7	34.5	nd	31.0	nd	<2.3	2.7
Standard Deviation	n/a	4.89		2.82		n/a	0.17
CV (%)	n/a	14.2		9.1		n/a	6.3

Lambert & Butler Lights King Size

Brand	Arsenic	Cadmium	Chromium	Lead	Nickel	Selenium	Mercury
Lambert & Butler Lights King Size	nd	6.9	nd	7.9	nd	nd	1.3
Lambert & Butler Lights King Size	nd	7.1	nd	7.5	nd	nd	1.2
Lambert & Butler Lights King Size	nd	9.5	nd	8.8	nd	nd	1.2
Lambert & Butler Lights King Size	nd	9.7	nd	8.0	nd	nd	1.3
Lambert & Butler Lights King Size	nd	10.8	nd	9.5	nd	nd	1.3
Mean (ng/cig)	nd	8.8	nd	8.3	nd	nd	1.3
Standard Deviation		1.70		0.80			0.04
CV (%)		19.3		9.5			3.4
<i>Outlier Test</i>							
Dixons outlier test was applied to the above data							
Data sorted		6.939		7.482			1.197
		7.115		7.910			1.247
		9.462		8.037			1.263
		9.702		8.816			1.298
		10.812		9.479			1.302
Statistical test applied							
Dixons low end test		0.046		0.214			0.481
Outlier detected at 95%							
Dixons high end test		0.287		0.332			0.034
Outlier detected at 95%							
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>							
Summary of Results							
Mean (ng/cig)	nd	8.8	nd	8.3	nd	nd	1.3
Standard Deviation		1.70		0.80			0.04
CV (%)		19.3		9.5			3.4

Lambert & Butler Ultra Lights

Brand	Arsenic	Cadmium	Chromium	Lead	Nickel	Selenium	Mercury
Lambert & Butler Ultra Lights	nd	1.4	nd	<2.0	nd	nd	<0.25
Lambert & Butler Ultra Lights	nd	1.7	nd	<2.0	nd	nd	<0.25
Lambert & Butler Ultra Lights	nd	1.7	nd	<2.0	nd	nd	0.3
Lambert & Butler Ultra Lights	nd	1.6	nd	<2.0	nd	nd	0.3
Lambert & Butler Ultra Lights	nd	1.3	nd	<2.0	nd	nd	0.3
Mean (ng/cig)	nd	1.5	nd	<2.0	nd	nd	<0.25
Standard Deviation		0.16		n/a			n/a
CV (%)		10.4		n/a			n/a
<i>Outlier Test</i>							
Dixons outlier test was applied to the above data							
Data sorted		1.335					0.259
		1.420					0.268
		1.622					0.287
		1.676					0.000
		1.692					0.000
Statistical test applied							
Dixons low end test		0.238					
Outlier detected at 95%							
Dixons high end test		0.045					
Outlier detected at 95%							
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>							
Summary of Results							
Mean (ng/cig)	nd	1.5	nd	<2.0	nd	nd	<0.25
Standard Deviation		0.16		n/a			n/a
CV (%)		10.4		n/a			n/a

Marlboro King Size

Brand	Arsenic	Cadmium	Chromium	Lead	Nickel	Selenium	Mercury
Marlboro King Size	4.4	35.6	nd	16.9	nd	<2.3	2.3
Marlboro King Size	4.5	45.2	nd	18.3	nd	<2.3	2.8
Marlboro King Size	4.5	54.2	nd	19.2	nd	<2.3	2.6
Marlboro King Size	5.0	53.6	nd	21.2	nd	<2.3	2.6
Marlboro King Size	3.8	45.9	nd	18.4	nd	<2.3	2.5
Mean (ng/cig)	4.4	46.9	nd	18.8	nd	<2.3	2.6
Standard Deviation	0.42	7.60		1.57		n/a	0.16
CV (%)	9.6	16.2		8.4		n/a	6.2
<i>Outlier Test</i>							
Dixons outlier test was applied to the above data							
Data sorted	3.816	35.567		16.932			2.320
	4.430	45.208		18.274			2.514
	4.456	45.875		18.362			2.588
	4.457	53.610		19.175			2.606
	5.016	54.221		21.204			2.751
Statistical test applied							
Dixons low end test	0.512	0.517		0.314			0.450
Outlier detected at 95%							
Dixons high end test	0.465	0.033		0.475			0.337
Outlier detected at 95%							
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>							
Summary of Results							
Mean (ng/cig)	4.4	46.9	nd	18.8	nd	<2.3	2.6
Standard Deviation	0.42	7.60		1.57		n/a	0.16
CV (%)	9.6	16.2		8.4		n/a	6.2

Marlboro Lights King Size

Brand	Arsenic	Cadmium	Chromium	Lead	Nickel	Selenium	Mercury
Marlboro Lights King Size	<2.7	16.4	nd	7.6	nd	nd	1.9
Marlboro Lights King Size	<2.7	24.5	nd	8.5	nd	nd	1.6
Marlboro Lights King Size	<2.7	22.0	nd	8.0	nd	nd	1.6
Marlboro Lights King Size	<2.7	20.9	nd	7.9	nd	nd	1.6
Marlboro Lights King Size	<2.7	22.3	nd	8.4	nd	nd	1.6
Mean (ng/cig)	<2.7	21.2	nd	8.1	nd	nd	1.7
Standard Deviation	n/a	3.02		0.38			0.15
CV (%)	n/a	14.2		4.7			9.0
<i>Outlier Test</i>							
Dixons outlier test was applied to the above data							
Data sorted		16.351		7.555			1.553
		20.871		7.911			1.558
		22.017		7.998			1.611
		22.316		8.436			1.625
		24.499		8.455			1.912
Statistical test applied							
Dixons low end test		0.555		0.396			0.012
Outlier detected at 95%							
Dixons high end test		0.268		0.021			0.802
Outlier detected at 95%							95%
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>							
Summary of Results							
Mean (ng/cig)	<2.7	21.2	nd	8.1	nd	nd	1.6
Standard Deviation	n/a	3.02		0.38			0.04
CV (%)	n/a	14.2		4.7			2.3

Mayfair Lights King Size

Brand	Arsenic	Cadmium	Chromium	Lead	Nickel	Selenium	Mercury
Mayfair Lights King Size	<2.7	11.3	nd	14.4	nd	<2.3	1.6
Mayfair Lights King Size	<2.7	13.0	nd	14.6	nd	<2.3	1.9
Mayfair Lights King Size	<2.7	13.5	nd	15.1	nd	nd	2.2
Mayfair Lights King Size	<2.7	11.5	nd	12.3	nd	nd	1.8
Mayfair Lights King Size	<2.7	11.9	nd	13.5	nd	nd	1.7
Mean (ng/cig)	<2.7	12.3	nd	14.0	nd	<2.3	1.8
Standard Deviation	n/a	0.96		1.09		n/a	0.21
CV (%)	n/a	7.8		7.8		n/a	11.2
<i>Outlier Test</i>							
Dixons outlier test was applied to the above data							
Data sorted		11.335		12.321			1.632
		11.545		13.544			1.737
		11.892		14.412			1.790
		13.024		14.628			1.878
		13.511		15.059			2.178
Statistical test applied							
Dixons low end test		0.096		0.447			0.192
Outlier detected at 95%							
Dixons high end test		0.224		0.157			0.550
Outlier detected at 95%							
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>							
Summary of Results							
Mean (ng/cig)	<2.7	12.3	nd	14.0	nd	<2.3	1.8
Standard Deviation	n/a	0.96		1.09		n/a	0.21
CV (%)	n/a	7.8		7.8		n/a	11.2

Mayfair Menthol King Size

Brand	Arsenic	Cadmium	Chromium	Lead	Nickel	Selenium	Mercury
Mayfair Menthol King Size	<2.7	6.4	nd	7.2	nd	nd	1.2
Mayfair Menthol King Size	<2.7	7.7	nd	8.2	nd	nd	1.1
Mayfair Menthol King Size	<2.7	8.4	nd	8.4	nd	nd	1.5
Mayfair Menthol King Size	<2.7	7.6	nd	7.2	nd	nd	1.3
Mayfair Menthol King Size	<2.7	8.1	nd	8.5	nd	nd	1.3
Mean (ng/cig)	<2.7	7.6	nd	7.9	nd	nd	1.3
Standard Deviation	n/a	0.75		0.64			0.14
CV (%)	n/a	9.8		8.1			11.3
<i>Outlier Test</i>							
Dixons outlier test was applied to the above data							
Data sorted		6.398		7.180			1.116
		7.625		7.191			1.182
		7.698		8.170			1.252
		8.072		8.360			1.278
		8.364		8.471			1.493
Statistical test applied							
Dixons low end test		0.624		0.009			0.174
Outlier detected at 95%							
Dixons high end test		0.149		0.086			0.570
Outlier detected at 95%							
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>							
Summary of Results							
Mean (ng/cig)	<2.7	7.6	nd	7.9	nd	nd	1.3
Standard Deviation	n/a	0.75		0.64			0.14
CV (%)	n/a	9.8		8.1			11.3

Red Band Lights King Size

Brand	Arsenic	Cadmium	Chromium	Lead	Nickel	Selenium	Mercury
Red Band Lights King Size	<2.7	22.6	nd	8.0	nd	<2.3	2.5
Red Band Lights King Size	<2.7	25.8	nd	8.3	nd	<2.3	2.5
Red Band Lights King Size	<2.7	22.4	nd	7.4	nd	<2.3	2.4
Red Band Lights King Size	<2.7	23.3	nd	7.9	nd	<2.3	2.6
Red Band Lights King Size	<2.7	24.4	nd	8.4	nd	<2.3	2.8
Mean (µg/cig)	<2.7	23.7	nd	8.0	nd	<2.3	2.6
Standard Deviation	n/a	1.42		0.40		n/a	0.17
CV (%)	n/a	6.0		4.9		n/a	6.6
<i>Outlier Test</i>							
Dixons outlier test was applied to the above data							
Data sorted		22.410		7.378			2.386
		22.640		7.939			2.471
		23.281		8.010			2.550
		24.445		8.326			2.638
		25.837		8.358			2.828
Statistical test applied							
Dixons low end test		0.067		0.572			0.192
Outlier detected at 95%							
Dixons high end test		0.406		0.032			0.429
Outlier detected at 95%							
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>							
Summary of Results							
Mean (µg/cig)	<2.7	23.7	nd	8.0	nd	<2.3	2.6
Standard Deviation	n/a	1.42		0.40		n/a	0.17
CV (%)	n/a	6.0		4.9		n/a	6.6

Regal Filter

Brand	Arsenic	Cadmium	Chromium	Lead	Nickel	Selenium	Mercury
Regal Filter	<2.7	12.2	nd	13.8	nd	nd	1.6
Regal Filter	<2.7	13.6	nd	13.6	nd	nd	1.7
Regal Filter	<2.7	16.4	nd	15.6	nd	nd	1.5
Regal Filter	<2.7	17.5	nd	16.2	nd	nd	1.8
Regal Filter	<2.7	17.8	nd	16.5	nd	nd	1.8
Mean (ng/cig)	<2.7	15.5	nd	15.1	nd	nd	1.7
Standard Deviation	n/a	2.48		1.34			0.11
CV (%)	n/a	16.0		8.8			6.3
<i>Outlier Test</i>							
Dixons outlier test was applied to the above data							
Data sorted		12.168		13.638			1.534
		13.642		13.803			1.594
		16.423		15.567			1.702
		17.468		16.178			1.763
		17.807		16.507			1.777
Statistical test applied							
Dixons low end test		0.261		0.057			0.248
Outlier detected at 95%							
Dixons high end test		0.060		0.115			0.057
Outlier detected at 95%							
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>							
Summary of Results							
Mean (ng/cig)	<2.7	15.5	nd	15.1	nd	nd	1.7
Standard Deviation	n/a	2.48		1.34			0.11
CV (%)	n/a	16.0		8.8			6.3

Regal King Size

Brand	Arsenic	Cadmium	Chromium	Lead	Nickel	Selenium	Mercury
Regal King Size	<2.7	17.8	nd	17.3	nd	<2.3	2.1
Regal King Size	<2.7	16.9	nd	15.9	nd	nd	2.1
Regal King Size	<2.7	23.7	nd	20.4	nd	<2.3	2.2
Regal King Size	<2.7	25.3	nd	20.2	nd	nd	2.4
Regal King Size	<2.7	25.6	nd	22.6	nd	<2.3	2.1
Mean (ng/cig)	<2.7	21.9	nd	19.3	nd	<2.3	2.2
Standard Deviation	n/a	4.19		2.68		n/a	0.13
CV (%)	n/a	19.2		13.9		n/a	5.9
<i>Outlier Test</i>							
Dixons outlier test was applied to the above data							
Data sorted		16.908		15.887			2.090
		17.802		17.335			2.110
		23.737		20.239			2.138
		25.280		20.429			2.249
		25.594		22.631			2.401
Statistical test applied							
Dixons low end test		0.103		0.215			0.064
Outlier detected at 95%							
Dixons high end test		0.036		0.327			0.490
Outlier detected at 95%							
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>							
Summary of Results							
Mean (ng/cig)	<2.7	21.9	nd	19.3	nd	<2.3	2.2
Standard Deviation	n/a	4.19		2.68		n/a	0.13
CV (%)	n/a	19.2		13.9		n/a	5.9

Rothman Royals 120s

Brand	Arsenic	Cadmium	Chromium	Lead	Nickel	Selenium	Mercury
Rothman Royals 120s	2.7	18.3	nd	14.8	nd	<2.3	1.8
Rothman Royals 120s	3.0	22.6	nd	16.7	nd	<2.3	1.9
Rothman Royals 120s	3.0	24.0	nd	16.5	nd	<2.3	2.1
Rothman Royals 120s	3.0	27.0	nd	19.2	nd	<2.3	2.2
Rothman Royals 120s	2.7	26.2	nd	18.4	nd	<2.3	2.2
Mean (ng/cig)	2.9	23.6	nd	17.1	nd	<2.3	2.0
Standard Deviation	0.16	3.43		1.71		n/a	0.18
CV (%)	5.7	14.5		10.0		n/a	9.0
<i>Outlier Test</i>							
Dixons outlier test was applied to the above data							
Data sorted	2.665	18.346		14.833			1.837
	2.685	22.562		16.508			1.860
	2.972	24.005		16.724			2.129
	2.973	26.222		18.432			2.188
	2.973	26.959		19.180			2.218
Statistical test applied							
Dixons low end test	0.066	0.489		0.385			0.062
Outlier detected at 95%							
Dixons high end test	0.002	0.086		0.172			0.080
Outlier detected at 95%							
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>							
Summary of Results							
Mean (ng/cig)	2.9	23.6	nd	17.1	nd	<2.3	2.0
Standard Deviation	0.16	3.43		1.71		n/a	0.18
CV (%)	5.7	14.5		10.0		n/a	9.0

Rothman Royals King Size

Brand	Arsenic	Cadmium	Chromium	Lead	Nickel	Selenium	Mercury
Rothman Royals King Size	<2.7	18.4	nd	15.6	nd	<2.3	2.0
Rothman Royals King Size	<2.7	21.1	nd	17.0	nd	<2.3	1.9
Rothman Royals King Size	<2.7	26.3	nd	17.3	nd	nd	2.1
Rothman Royals King Size	<2.7	26.7	nd	17.4	nd	nd	2.1
Rothman Royals King Size	<2.7	27.8	nd	19.4	nd	<2.3	2.0
Mean (ng/cig)	<2.7	24.1	nd	17.4	nd	<2.3	2.0
Standard Deviation	n/a	4.09		1.36		n/a	0.07
CV (%)	n/a	17.0		7.9		n/a	3.5
<i>Outlier Test</i>							
Dixons outlier test was applied to the above data							
Data sorted		18.404		15.639			1.938
		21.068		16.980			1.988
		26.289		17.324			2.035
		26.733		17.398			2.096
		27.763		19.442			2.102
Statistical test applied							
Dixons low end test		0.285		0.353			0.303
Outlier detected at 95%							
Dixons high end test		0.110		0.537			0.038
Outlier detected at 95%							
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>							
Summary of Results							
Mean (ng/cig)	<2.7	24.1	nd	17.4	nd	<2.3	2.0
Standard Deviation	n/a	4.09		1.36		n/a	0.07
CV (%)	n/a	17.0		7.9		n/a	3.5

Senior Service

Brand	Arsenic	Cadmium	Chromium	Lead	Nickel	Selenium	Mercury
Senior Service	<2.7	11.2	nd	11.1	nd	<2.3	1.6
Senior Service	<2.7	12.8	nd	11.5	nd	<2.3	1.8
Senior Service	<2.7	12.2	nd	11.1	nd	<2.3	1.7
Senior Service	<2.7	12.3	nd	11.5	nd	<2.3	1.9
Senior Service	<2.7	10.9	nd	10.2	nd	<2.3	1.8
Mean (ng/cig)	<2.7	11.9	nd	11.1	nd	<2.3	1.8
Standard Deviation	n/a	0.79		0.54		n/a	0.13
CV (%)	n/a	6.6		4.8		n/a	7.3
<i>Outlier Test</i>							
Dixons outlier test was applied to the above data							
Data sorted		10.935		10.198			1.559
		11.228		11.119			1.719
		12.235		11.149			1.835
		12.289		11.494			1.846
		12.825		11.524			1.865
Statistical test applied							
Dixons low end test		0.155		0.694			0.522
Outlier detected at 95%							
Dixons high end test		0.283		0.023			0.064
Outlier detected at 95%							
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>							
Summary of Results							
Mean (ng/cig)	<2.7	11.9	nd	11.1	nd	<2.3	1.8
Standard Deviation	n/a	0.79		0.54		n/a	0.13
CV (%)	n/a	6.6		4.8		n/a	7.3

Silk Cut Extra Mild

Brand	Arsenic	Cadmium	Chromium	Lead	Nickel	Selenium	Mercury
Silk Cut Extra Mild	nd	2.4	nd	2.4	nd	nd	0.8
Silk Cut Extra Mild	nd	2.5	nd	2.5	nd	nd	0.9
Silk Cut Extra Mild	nd	3.4	nd	2.8	nd	nd	0.9
Silk Cut Extra Mild	nd	3.6	nd	2.5	nd	nd	0.8
Silk Cut Extra Mild	nd	3.7	nd	2.5	nd	nd	0.8
Mean (ng/cig)	nd	3.1	nd	2.5	nd	nd	0.8
Standard Deviation		0.64		0.16			0.05
CV (%)		20.3		6.3			5.9
<i>Outlier Test</i>							
Dixons outlier test was applied to the above data							
Data sorted		2.423		2.375			0.751
		2.453		2.458			0.786
		3.433		2.505			0.790
		3.637		2.544			0.855
		3.688		2.796			0.860
Statistical test applied							
Dixons low end test		0.024		0.197			0.324
Outlier detected at 95%							
Dixons high end test		0.041		0.600			0.049
Outlier detected at 95%							
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>							
Summary of Results							
Mean (ng/cig)	nd	3.1	nd	2.5	nd	nd	0.8
Standard Deviation		0.64		0.16			0.05
CV (%)		20.3		6.3			5.9

Silk Cut King Size

Brand	Arsenic	Cadmium	Chromium	Lead	Nickel	Selenium	Mercury
Silk Cut King Size	<2.7	5.7	nd	5.4	nd	nd	1.4
Silk Cut King Size	<2.7	5.3	nd	5.4	nd	nd	1.4
Silk Cut King Size	<2.7	5.1	nd	5.5	nd	nd	1.5
Silk Cut King Size	<2.7	5.2	nd	5.7	nd	nd	1.4
Silk Cut King Size	<2.7	5.2	nd	5.5	nd	nd	1.6
Mean (ng/cig)	<2.7	5.3	nd	5.5	nd	nd	1.4
Standard Deviation	n/a	0.26		0.11			0.09
CV (%)	n/a	4.9		2.1			6.2
<i>Outlier Test</i>							
Dixons outlier test was applied to the above data							
Data sorted		5.070		5.422			1.361
		5.178		5.434			1.371
		5.202		5.467			1.431
		5.287		5.505			1.472
		5.744		5.702			1.583
Statistical test applied							
Dixons low end test		0.160		0.044			0.044
Outlier detected at 95%							
Dixons high end test		0.678		0.703			0.499
Outlier detected at 95%							
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>							
Summary of Results							
Mean (ng/cig)	<2.7	5.3	nd	5.5	nd	nd	1.4
Standard Deviation	n/a	0.26		0.11			0.09
CV (%)	n/a	4.9		2.1			6.2

Silk Cut Ultra King Size

Brand	Arsenic	Cadmium	Chromium	Lead	Nickel	Selenium	Mercury
Silk Cut Ultra King Size	nd	<1.2	nd	nd	nd	nd	0.25
Silk Cut Ultra King Size	nd	<1.2	nd	nd	nd	nd	0.27
Silk Cut Ultra King Size	nd	<1.2	nd	nd	nd	nd	0.35
Silk Cut Ultra King Size	nd	<1.2	nd	nd	nd	nd	0.35
Silk Cut Ultra King Size	nd	<1.2	nd	nd	nd	nd	0.36
Mean (ng/cig)	nd	<1.2	nd	nd	nd	nd	0.3
Standard Deviation							0.05
CV (%)							15.9
<i>Outlier Test</i>							
Dixons outlier test was applied to the above data							
Data sorted							0.253
							0.270
							0.351
							0.352
							0.355
Statistical test applied							
Dixons low end test							0.161
Outlier detected at 95%							
Dixons high end test							0.033
Outlier detected at 95%							
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>							
Summary of Results							
Mean (ug/cig)	nd	<1.2	nd	nd	nd	nd	0.3
Standard Deviation		n/a					0.05
CV (%)		n/a					15.9

Superkings

Brand	Arsenic	Cadmium	Chromium	Lead	Nickel	Selenium	Mercury
Superkings	<2.7	1.8	nd	<2.0	nd	<2.3	2.0
Superkings	<2.7	1.7	nd	2.0	nd	<2.3	2.1
Superkings	<2.7	1.5	nd	<2.0	nd	<2.3	2.2
Superkings	<2.7	1.5	nd	<2.0	nd	<2.3	2.1
Superkings	<2.7	1.7	nd	<2.0	nd	<2.3	2.1
Mean (ng/cig)	<2.7	1.6	nd	<2.0	nd	<2.3	2.1
Standard Deviation	n/a	0.13		n/a		n/a	0.10
CV (%)	n/a	7.7		n/a		n/a	4.7
<i>Outlier Test</i>							
Dixons outlier test was applied to the above data							
Data sorted		1.478					1.959
		1.543					2.051
		1.677					2.116
		1.731					2.136
		1.779					2.221
Statistical test applied							
Dixons low end test		0.217					0.351
Outlier detected at 95%							
Dixons high end test		0.161					0.323
Outlier detected at 95%							
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>							
Summary of Results							
Mean (ng/cig)	<2.7	1.6	nd	<2.0	nd	<2.3	2.1
Standard Deviation	n/a	0.13		n/a		n/a	0.10
CV (%)	n/a	7.7		n/a		n/a	4.7

Superkings Lights

Brand	Arsenic	Cadmium	Chromium	Lead	Nickel	Selenium	Mercury
Superkings Lights	<2.7	12.3	nd	12.6	nd	<2.3	1.4
Superkings Lights	nd	10.9	nd	12.0	nd	<2.3	1.4
Superkings Lights	nd	9.88	nd	11.8	nd	<2.3	1.4
Superkings Lights	nd	10.2	nd	13.5	nd	<2.3	1.5
Superkings Lights	nd	9.99	nd	10.8	nd	<2.3	1.4
Mean (ng/cig)	<2.7	10.7	nd	12.1	nd	<2.3	1.4
Standard Deviation	n/a	1.01		1.00		n/a	0.03
CV (%)	n/a	9.5		8.2		n/a	2.3
<i>Outlier Test</i>							
Dixons outlier test was applied to the above data							
Data sorted		9.877		10.840			1.374
		9.995		11.771			1.383
		10.205		11.963			1.393
		10.937		12.610			1.402
		12.317		13.524			1.456
Statistical test applied							
Dixons low end test		0.049		0.347			0.113
Outlier detected at 95%							
Dixons high end test		0.566		0.341			0.659
Outlier detected at 95%							
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>							
Summary of Results							
Mean (ng/cig)	<2.7	10.7	nd	12.1	nd	<2.3	1.4
Standard Deviation	n/a	1.01		1.00			0.03
CV (%)	n/a	9.5		8.2			2.3

Superkings Ultra Lights

Brand	Arsenic	Cadmium	Chromium	Lead	Nickel	Selenium	Mercury
Superkings Ultra Lights	nd	4.7	nd	2.7	nd	nd	0.9
Superkings Ultra Lights	nd	5.1	nd	3.3	nd	nd	0.8
Superkings Ultra Lights	nd	5.2	nd	3.7	nd	nd	0.8
Superkings Ultra Lights	nd	4.8	nd	2.6	nd	nd	0.9
Superkings Ultra Lights	nd	5.2	nd	2.9	nd	nd	0.8
Mean (ng/cig)	nd	5.0	nd	3.0	nd	nd	0.8
Standard Deviation		0.24		0.47			0.02
CV (%)		4.7		15.5			1.9
<i>Outlier Test</i>							
Dixons outlier test was applied to the above data							
Data sorted		4.696		2.615			0.818
		4.757		2.686			0.836
		5.096		2.864			0.839
		5.178		3.253			0.854
		5.182		3.745			0.860
Statistical test applied							
Dixons low end test		0.126		0.063			0.429
Outlier detected at 95%							
Dixons high end test		0.006		0.435			0.133
Outlier detected at 95%							

If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier

Summary of Results							
Mean (ng/cig)	nd	5.0	nd	3.0	nd	nd	0.8
Standard Deviation		0.24		0.47			0.02
CV (%)		4.7		15.5			1.9

Vogue Superslims

Brand	Arsenic	Cadmium	Chromium	Lead	Nickel	Selenium	Mercury
Vogue Superslims	<2.7	15.3	nd	14.8	nd	nd	1.6
Vogue Superslims	<2.7	15.9	nd	15.5	nd	nd	1.7
Vogue Superslims	<2.7	17.7	nd	16.8	nd	nd	1.8
Vogue Superslims	<2.7	16.6	nd	14.4	nd	nd	1.8
Vogue Superslims	<2.7	16.2	nd	14.6	nd	nd	1.7
Mean (ng/cig)	<2.7	16.3	nd	15.2	nd	nd	1.7
Standard Deviation	n/a	0.89		0.96			0.07
CV (%)	n/a	5.4		6.3			4.3
<i>Outlier Test</i>							
Dixons outlier test was applied to the above data							
Data sorted		15.294		14.420			1.625
		15.859		14.612			1.717
		16.220		14.761			1.729
		16.584		15.514			1.778
		17.669		16.756			1.825
Statistical test applied							
Dixons low end test		0.238		0.082			0.460
Outlier detected at 95%							
Dixons high end test		0.457		0.531			0.234
Outlier detected at 95%							
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>							
Summary of Results							
Mean (ng/cig)	<2.7	16.3	nd	15.2	nd	nd	1.73
Standard Deviation	n/a	0.89		0.96			0.07
CV (%)	n/a	5.4		6.3			4.3

Appendix 1: Technical opinions and interpretations

The following comments are of a technical nature about the method, validation data and results obtained during the study. They are designed to help put the results in context.

Significant figures

Many of the yields reported were close to the limit of quantitation. It was therefore felt appropriate to report these low yields to 2 significant figures (e.g. 2.1) whereas 'higher' yields have been reported to 3 significant figures.

Limit of detection and limit of quantitation

Several yields for Arsenic and Selenium were below the limit of quantitation but above the limit of detection. The limit of detection is defined as is the lowest amount of an analyte in a sample which can be detected but not necessarily quantified as an exact value. The limit of quantitation is the lowest amount of an analyte in a sample which can be quantitatively determined with suitable uncertainty.

Therefore it was decided to distinguish between brands where nothing was found and those brands where analytes were identified but could not be reliably quantified. Low yields have either been reported as 'nd' (not detected) or e.g. arsenic $<2.7 \mu\text{g cig}^{-1}$ where the limit of quantitation for the analytical method for arsenic has been set at $2.7 \mu\text{g cig}^{-1}$. The limit of detection for arsenic is $1.0 \mu\text{g cig}^{-1}$ so it is probable that an arsenic yield reported as <2.7 will be somewhere in the range of 1 to $2.7 \mu\text{g cig}^{-1}$.

Trapping regime – sample homogeneity

It is easy to trap and measure carbon monoxide in cigarette smoke because it is a gas, easily separated from particulate matter and mixes readily with other gaseous components to form a homogenous sample. It is much more difficult to produce a homogenous sample for metals. Metals in the cigarette smoke may, e.g. be 'attached' to particles of tar, present as metal fume or as vapour (e.g. mercury). Therefore the trapping system used is likely to have a significant effect on the percentage of metals trapped. The metals that have been trapped then have to 'digested' to produce a homogenous sample solution containing metal ions, each metal ideally in the same oxidation state. In practice this is difficult to achieve reliably.

Analytical instrumentation

The ability to detect and quantify metal ions in solution accurately (i.e. reasonable precision & no bias) will depend on the analytical technique employed, the matrix of the solution and to a lesser extent the age of the equipment. Advances in analytical methodology and instrumentation means that it is now possible to measure low levels of metal ions in solution. However, the matrix of the solution (e.g. different acid concentrations) can effect the result but it is not practicable to produce identical matrices for each sample solution. Many instruments will be working close to their 'operating limit' to measure the metal ion concentrations and this will have an effect on the precision of the measurement. This is one factor in explaining why different laboratories using validated methods sometimes report a wide range of yields for 'metals' when smoking cigarette samples from the same production batch.

Alternative methodology

LGC Limited originally tried a method of trapping the cigarette smoke in a 'gas bottle' full of Raschel rings (large surface area) cooled with 'dry ice'. The metals were extracted at ambient temperature with dilute nitric acid and analysed by ICP-MS. The method was simple to set up and use but there were concerns over (a) extraction efficiency, (b) stability of metal ions in solution (a precipitate formed after a few hours) and (c) observable differences in the matrix, i.e. sample solutions, for low and high tar cigarettes which may effect the analysis by ICP-MS.

Appendix 2: Selected smoke constituents for UK study

Type	Specific analyte(s)
	Nicotine free dry particulate matter
	nicotine
	carbon monoxide
	ammonia
	hydrogen cyanide
	nitrogen monoxide
Aromatic amines	1-aminonaphthalene
	2-aminonaphthalene
	3-aminobiphenyl
	4-aminobiphenyl
Aldehydes & Ketones	formaldehyde
	acetaldehyde
	acetone
	acrolein
	propionaldehyde
	crotonaldehyde
	methyl ethyl ketone
	butyraldehyde
Nitrosamines	n-nitrosornicotine (nnn)
	n-nitrosoanatabine (nat)
	n-nitrosanabasine (nab)
	4-(N-Methyl-N-nitrosamino)-1-(3-pyridinyl)-1-butanone (nnk)
Phenols	phenol
	catechol
	hydroquinone
	resorcinol
	ortho-cresol
	meta-cresol &
	para-cresol
Polycyclic aromatic hydrocarbons	benzo[a]pyrene
Semi Volatile Compounds	pyridine
	quinoline
	styrene
Trace Metals	arsenic
	cadmium
	chromium
	lead
	mercury
	nickel
	selenium
Volatile Organic Compounds	benzene
	toluene
	1,3-butadiene
	isoprene
	acrylonitrile

Appendix 3: Selected abbreviations and terms used in this report

Term/Definition	Meaning
Channel	The channel of the smoking machine that the cigarette was smoked on
CO	Carbon Monoxide
CO(%v/v)	Percentage volume of carbon monoxide in the total volume of mainstream smoke corrected for any clearing puffs
Overwrap	The wrapper applied to the mouth end of the cigarette
Run	The smoking run that the cigarette was smoked in
TPM	Total Particulate Matter
Yield	The concentration of analyte measured in the smoke (normally per cigarette)
°C	Degree Celsius
ng	Nanogram
µg	Microgram
mg	Milligram
mL	Millilitre
L	Litre
mm	Millimetre
cig ⁻¹	per cigarette
‘metals’	Arsenic, Cadmium, Chromium, Lead, Nickel, Selenium and Mercury
As	Arsenic
Cd	Cadmium
Cr	Chromium
Pb	Lead
Ni	Nickel
Se	Selenium
Hg	Mercury
nd	Not detected
LoD	Limit of Detection
LoQ	Limit of Quantitation
CVAAS	Cold Vapour Atomic Absorption Spectroscopy
ICP-MS	Inductively Coupled Plasma – Mass Spectroscopy

Appendix 4: Description of brands (sold in the UK - Nov/Dec 2001) used in the benchmark study

Brand	Length (mm)	Butt length used for the study (mm)	Description
Benson & Hedges King Size	84	28	filter – typical UK blend
Berkeley Superkings	99	33	filter – typical UK blend
Camel Ultra Lights	84	35	filter – typical American blend
Consulate Menthol	84	35	filter – typical UK blend – menthol
Gitanes Caporal Filter	70	23	filter – dark air cured blend
Lambert & Butler King Size	84	30	filter – typical UK blend
Lambert & Butler Lights King Size	84	34 (overwrap + 3 mm)	filter – typical UK blend
Lambert & Butler Ultra Lights	84	34 (overwrap + 3 mm)	filter – typical UK blend
Marlboro King Size	84	29	filter – typical American blend
Marlboro Lights King Size	84	35	filter – typical American blend
Mayfair Lights King Size	84	28	filter – typical UK blend
Mayfair Menthol King Size	84	33	filter – typical UK blend – menthol
Red Band Lights King Size	84	33	filter – typical UK blend
Regal Filter	71	26	filter – typical UK blend
Regal King Size	84	30	filter – typical UK blend
Rothman Royals 120s	120	38	filter – typical UK blend
Rothman Royals King Size	84	30	filter – typical UK blend
Senior Service	69	23	plain - typical UK blend
Silk Cut Extra Mild	84	33	filter – typical UK blend
Silk Cut King Size	84	28	filter – typical UK blend
Silk Cut Ultra King Size	84	33 (overwrap + 3 mm)	filter – typical UK blend
Superkings	99	34	filter – typical UK blend
Superkings Lights	99	33	filter – typical UK blend
Superkings Ultra Lights	99	34	filter – typical UK blend
Vogue Superslims	99	38	filter – typical American blend