

CONFIDENTIAL

UK SMOKE CONSTITUENTS STUDY

Part 10: Determination of Mono and Dihydroxy Phenol Yields in Cigarette Smoke

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UK SMOKE CONSTITUENTS TESTING STUDY PROTOCOL

Determination of Mono and Dihydroxy Phenols 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, 'phenols' 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 mono and dihydroxy phenols ('phenols'): phenol, m-cresol & p-cresol (3 & 4 methyl phenol), o-cresol (2-methyl phenol), catechol (o-hydroxy phenol), hydroquinone (p-hydroxy phenol), resorcinol (m-hydroxy phenol).

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 20 channel linear smoking machines.

5 cigarettes were sub-sampled from packets chosen on a random basis and smoked to determine the yields of 'phenols' 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 channels on different smoking runs.

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 ‘phenols’ in mainstream tobacco smoke by HPLC and fluorescence detection. For each sample, five conditioned cigarettes are smoked on a linear 20 channel smoking machine. The mainstream smoke is collected on a Cambridge filter pad. Each pad is transferred to a conical flask and extracted with an acetic acid/methanol mixture. An aliquot of each sample solution is filtered through a $0.45\mu\text{m}$ filter into an autosampler vial, which is then sealed.

Analysis is with an HPLC equipped with a reversed phase column and a fluorescence detector. Compounds are eluted from the column using a gradient system to increase the methanol fraction in the methanol/water mobile phase. Mono and dihydroxy phenols are well separated except for m-cresol and p-cresol, which co-elute. Therefore, a combined value is reported for m+p-cresol.

The full method is given in an Annexe to this report.

The method is in current use and has been validated. The validation data used to show that the method is 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 6). Linear least squares regression analysis has been carried out for each ‘phenols’ yield versus carbon monoxide (Page 7 to 12) and each ‘phenols’ yield versus NFDPM (Page 13 to 18) for the twenty five cigarette brands (excluding 1R4F and 1R5F).

A reporting limit has been used based on the limit of quantitation for the method (0.72 to $0.32 \mu\text{g cig}^{-1}$ depending on the analyte – see validation report).

7. Outlier Test

It was agreed as part of the study protocol that Dixon’s outlier test would be performed on each set of 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 'phenols' 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.

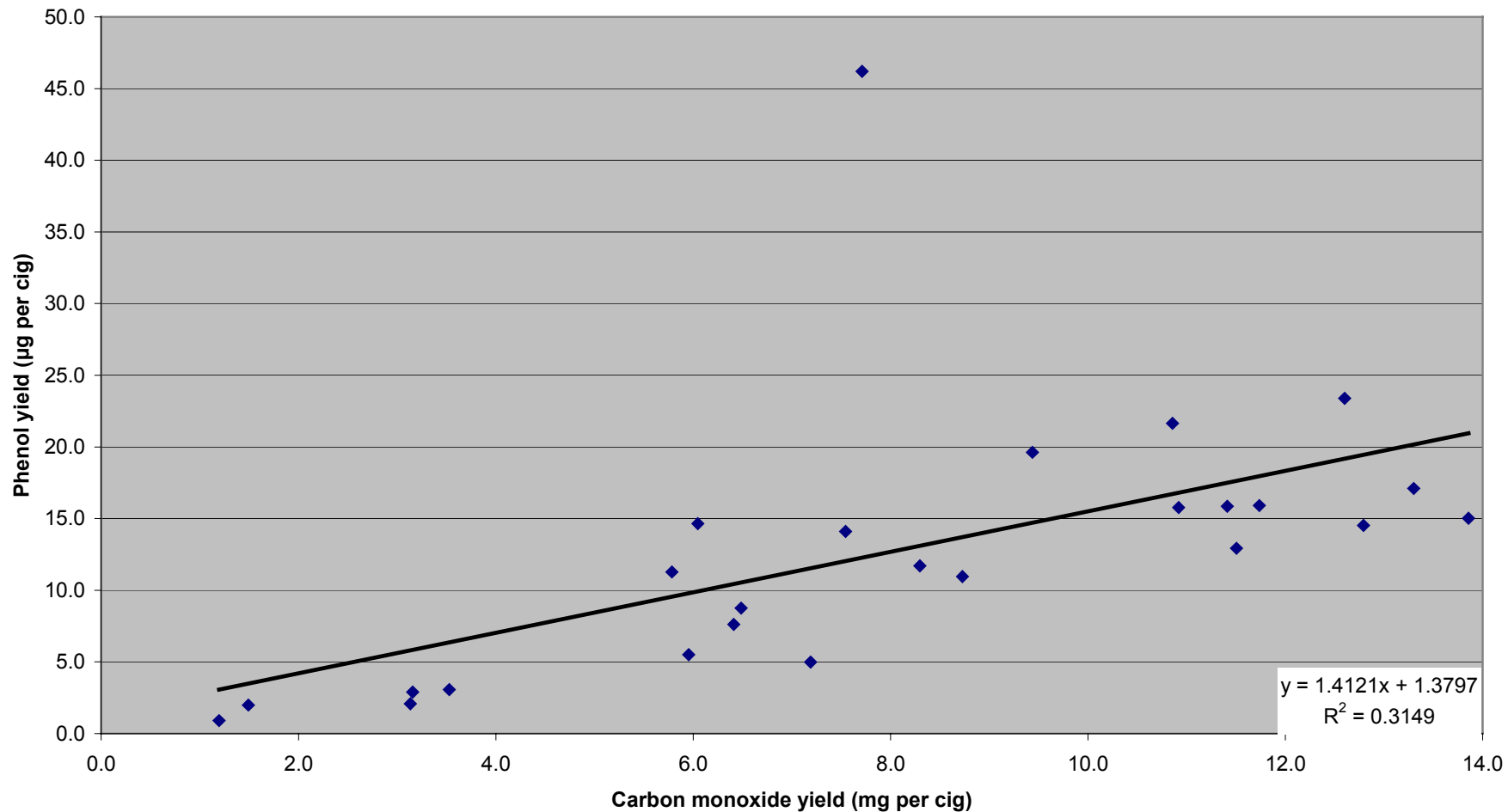
Tables

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

	Phenol	m + p-cresol	o-cresol	Catechol	Hydroquinone	Resorcinol	NFDPM	Carbon Monoxide
	µg/cig	µg/cig	µg/cig	µg/cig	µg/cig	µg/cig	mg/cig	mg/cig
1R4F	7.54	5.88	2.31	38.0	34.2	0.64	9.06	12.26
1R5F	<0.72	0.67	<0.41	8.42	6.66	<0.33	1.92	3.36
Benson & Hedges King Size	15.9	10.0	4.02	57.8	52.9	1.18	10.30	11.74
Berkely Superkings	12.9	8.53	3.48	55.1	43.7	1.06	9.69	11.50
Camel Ultra Lights	2.08	1.81	0.69	19.7	17.3	0.38	3.09	3.13
Consulate Menthol	11.7	7.35	3.03	48.7	42.1	0.90	7.06	8.30
Gitanes Caporal Filter	23.4	15.6	6.50	43.9	35.8	0.77	12.00	12.60
Lambert & Butler King Size	17.1	10.2	4.27	67.6	60.7	1.47	11.93	13.30
Lambert & Butler Lights King Size	8.75	5.57	2.27	38.1	32.6	0.71	5.24	6.48
Lambert & Butler Ultra Lights	1.98	1.50	0.61	14.0	11.3	<0.33	1.61	1.49
Marlboro King Size	14.5	9.67	3.83	50.2	47.2	1.24	12.69	12.79
Marlboro Lights King Size	5.00	3.88	1.37	31.6	31.5	0.77	6.10	7.19
Mayfair Lights King Size	11.0	7.42	3.09	40.4	33.9	0.77	7.23	8.73
Mayfair Menthol King Size	5.51	4.07	1.56	31.1	25.4	0.52	4.65	5.95
Red Band Lights King Size	7.61	5.10	1.78	44.2	35.7	0.73	5.55	6.41
Regal Filter	15.8	9.11	3.83	55.2	50.1	1.14	10.65	10.92
Regal King Size	15.0	9.08	3.69	67.6	62.7	1.46	11.96	13.86
Rothman Royals 120s	19.6	11.2	4.60	66.7	62.4	1.32	10.39	9.44
Rothman Royals King Size	21.6	11.7	4.84	70.7	61.8	1.41	11.00	10.86
Senior Service	46.2	21.7	10.0	70.6	58.6	1.18	11.92	7.71
Silk Cut Extra Mild	2.89	2.21	0.87	19.9	17.0	<0.33	2.67	3.16
Silk Cut King Size	11.3	6.97	2.89	37.3	32.3	0.59	5.62	5.78
Silk Cut Ultra King Size	0.91	0.78	<0.41	10.1	8.46	<0.33	1.01	1.20
Superkings	15.9	10.2	4.15	69.3	63.2	1.46	10.71	11.41
Superkings Lights	14.1	8.94	3.68	57.6	48.5	1.02	8.09	7.54
Superkings Ultra Lights	3.07	2.49	0.96	21.0	22.0	0.42	3.08	3.53
Vogue Superslims	14.7	8.42	3.25	38.6	30.9	0.93	7.38	6.05

Regression analysis of phenol versus carbon monoxide

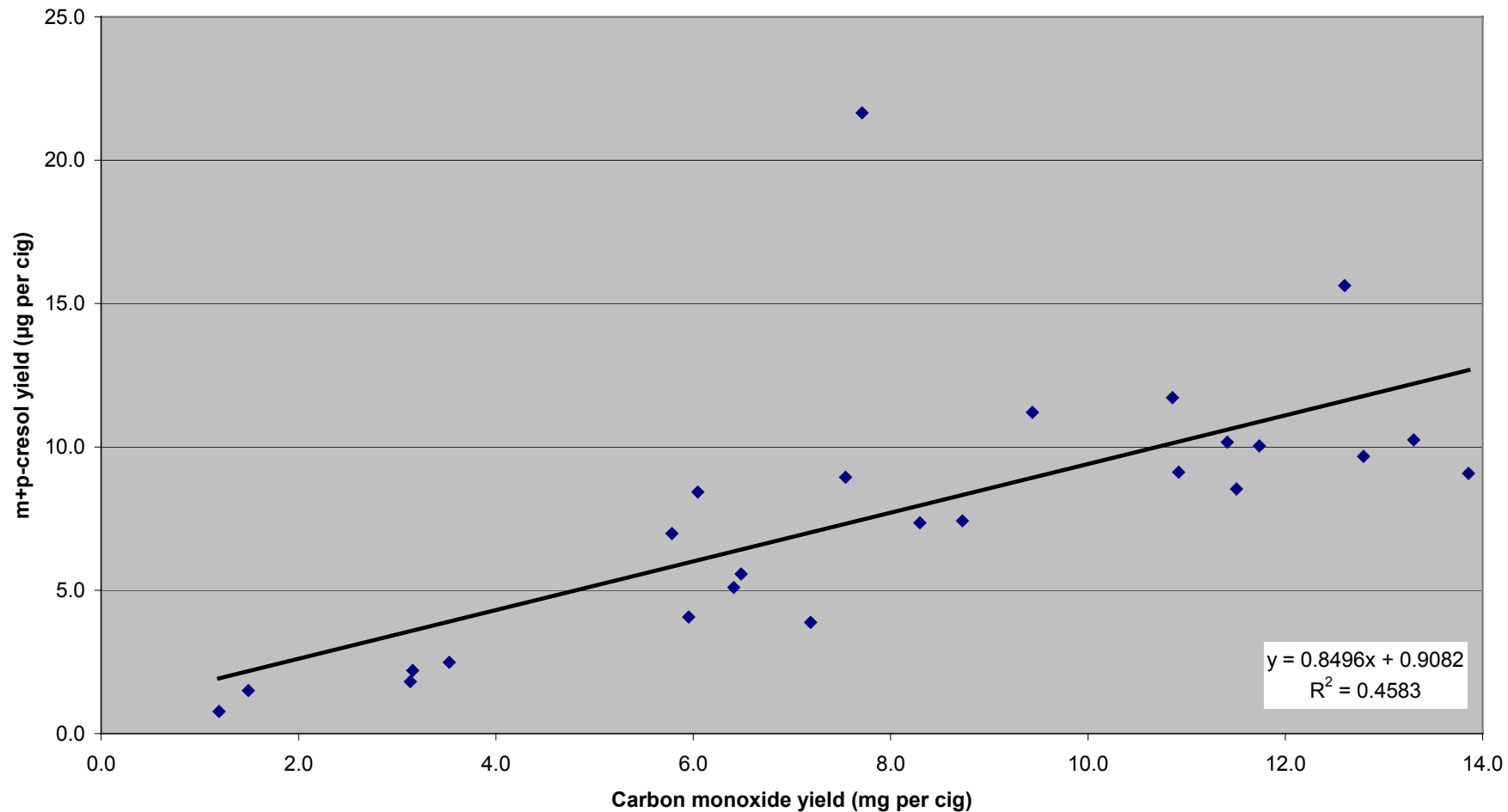
Regression analysis of phenol versus carbon monoxide for 25 cigarette brands



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

Regression analysis of m+p-cresol versus carbon monoxide

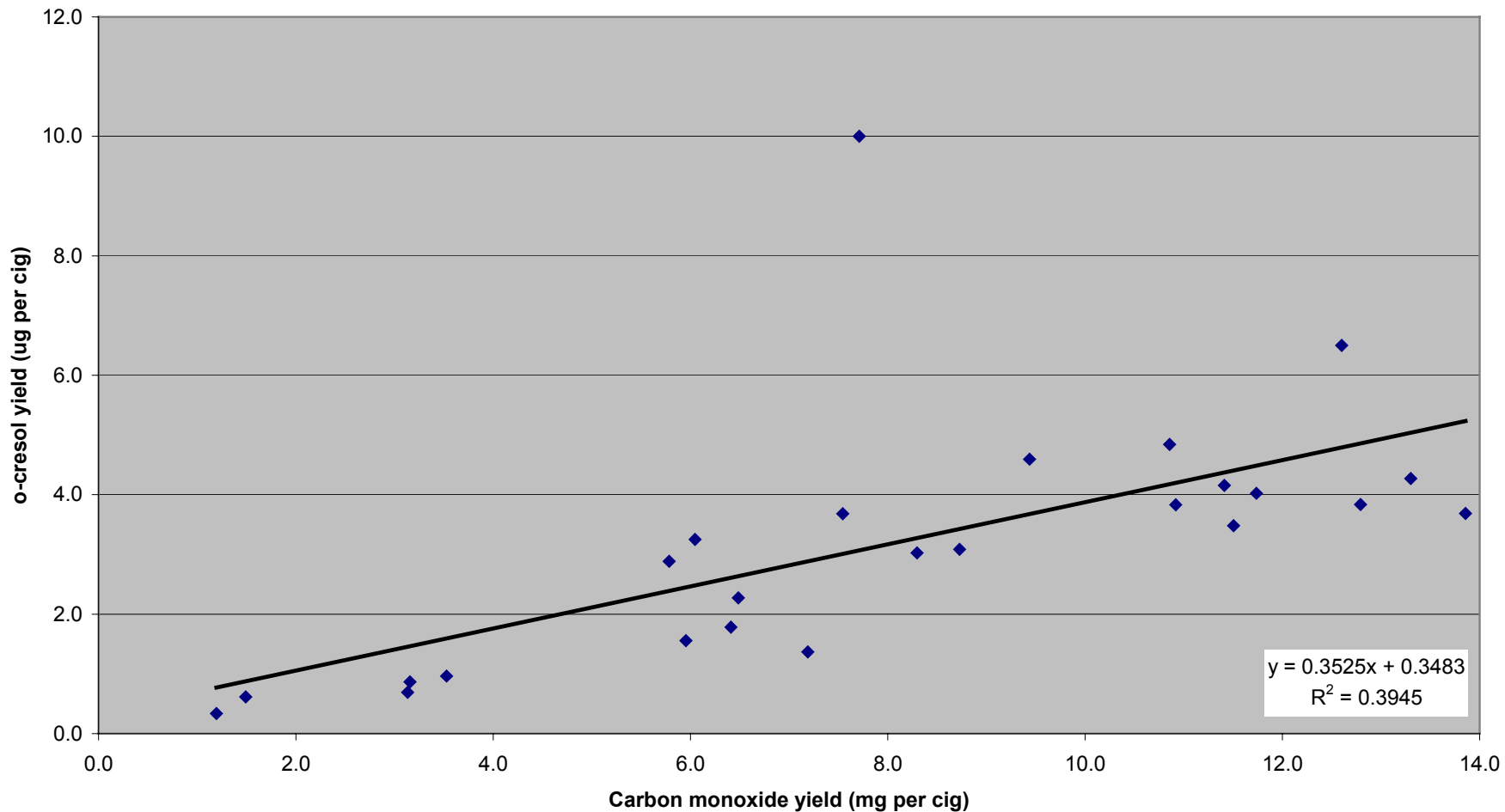
Regression analysis of m+p-cresol versus carbon monoxide for 25 cigarette brands



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

Regression analysis of o-cresol versus carbon monoxide

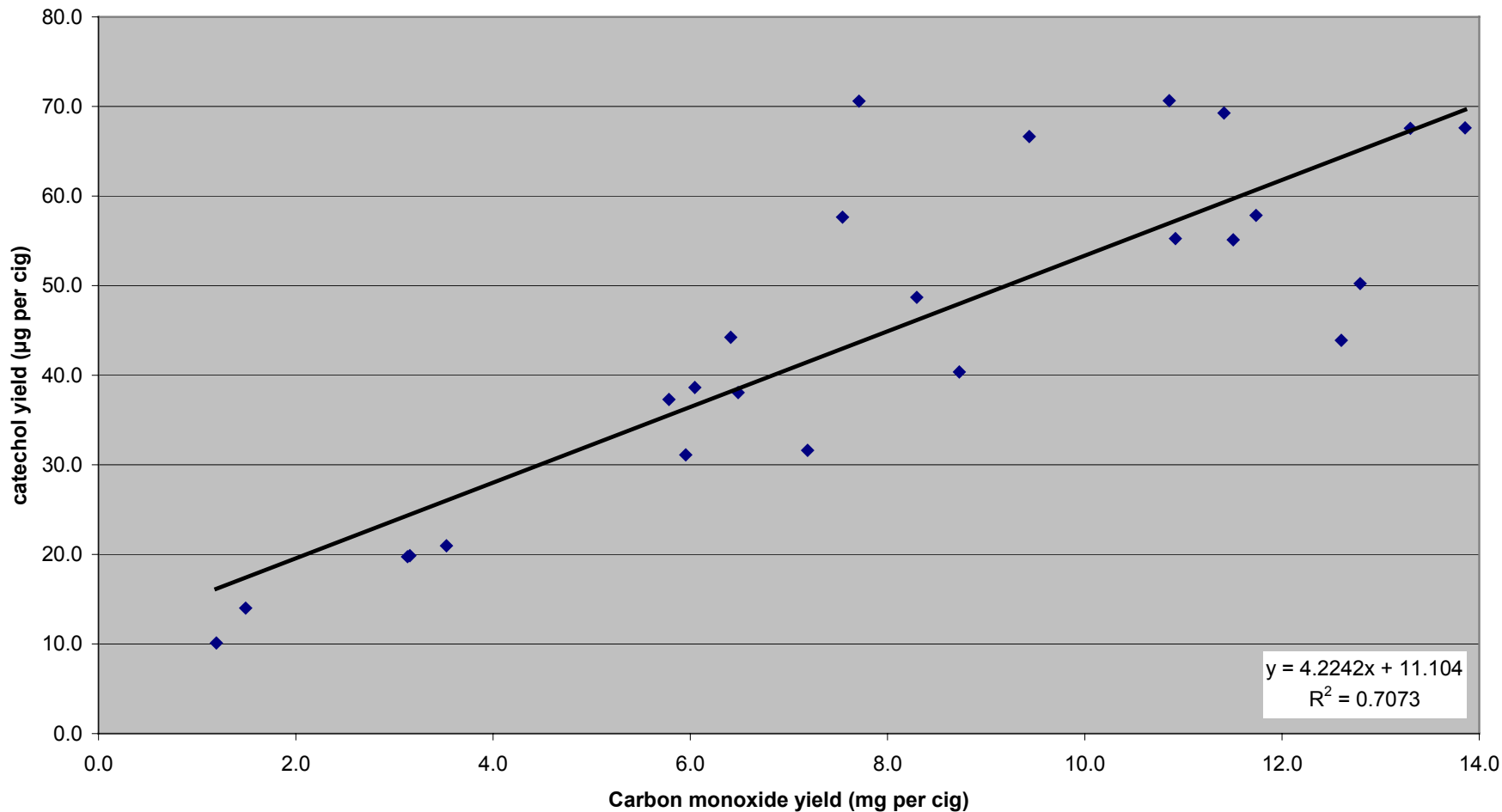
Regression analysis of o-cresol versus carbon monoxide for 25 cigarette brands



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

Regression analysis of catechol versus carbon monoxide

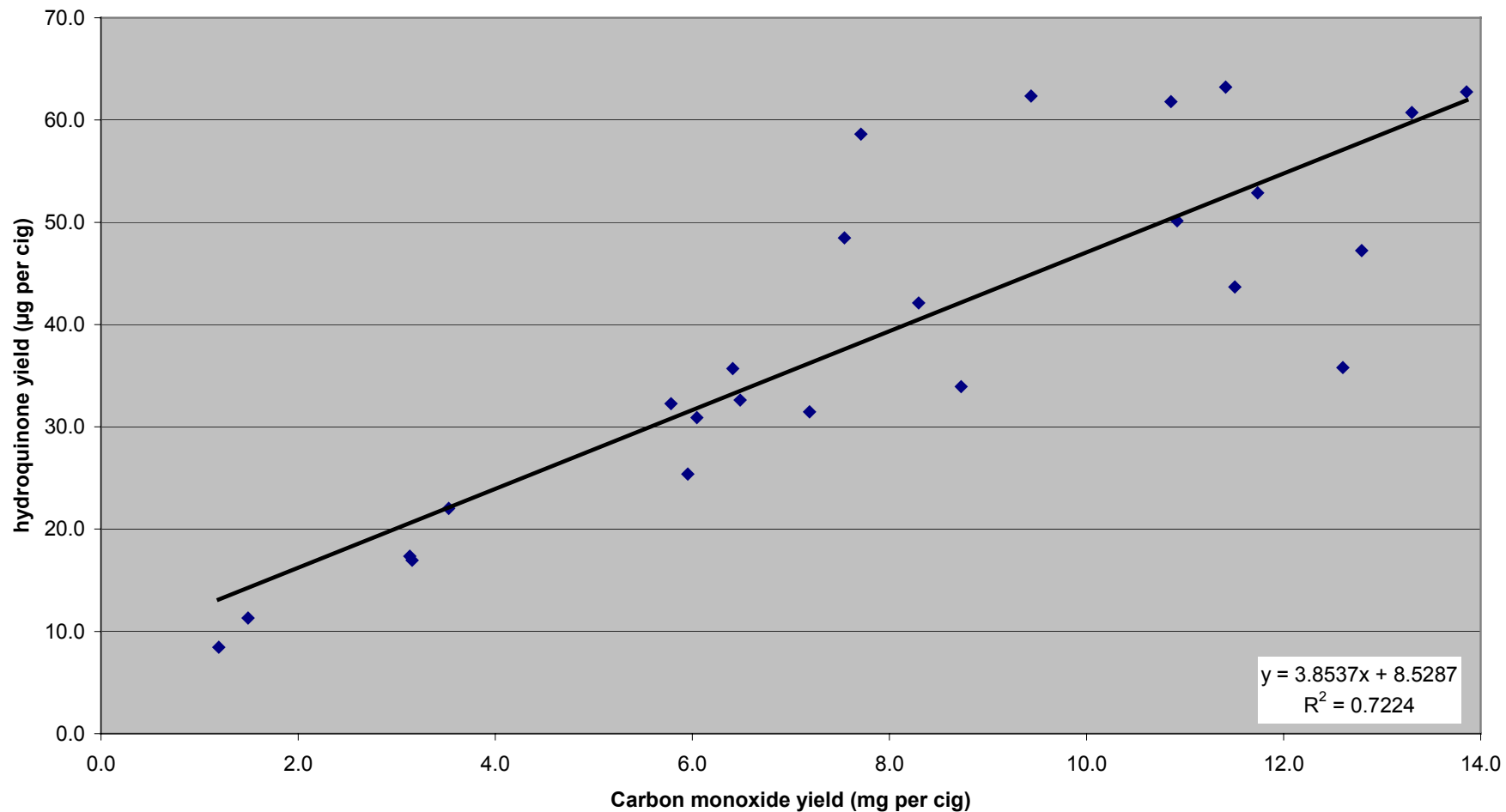
Regression analysis of catechol versus carbon monoxide for 25 cigarette brands



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

Regression analysis of hydroquinone versus carbon monoxide

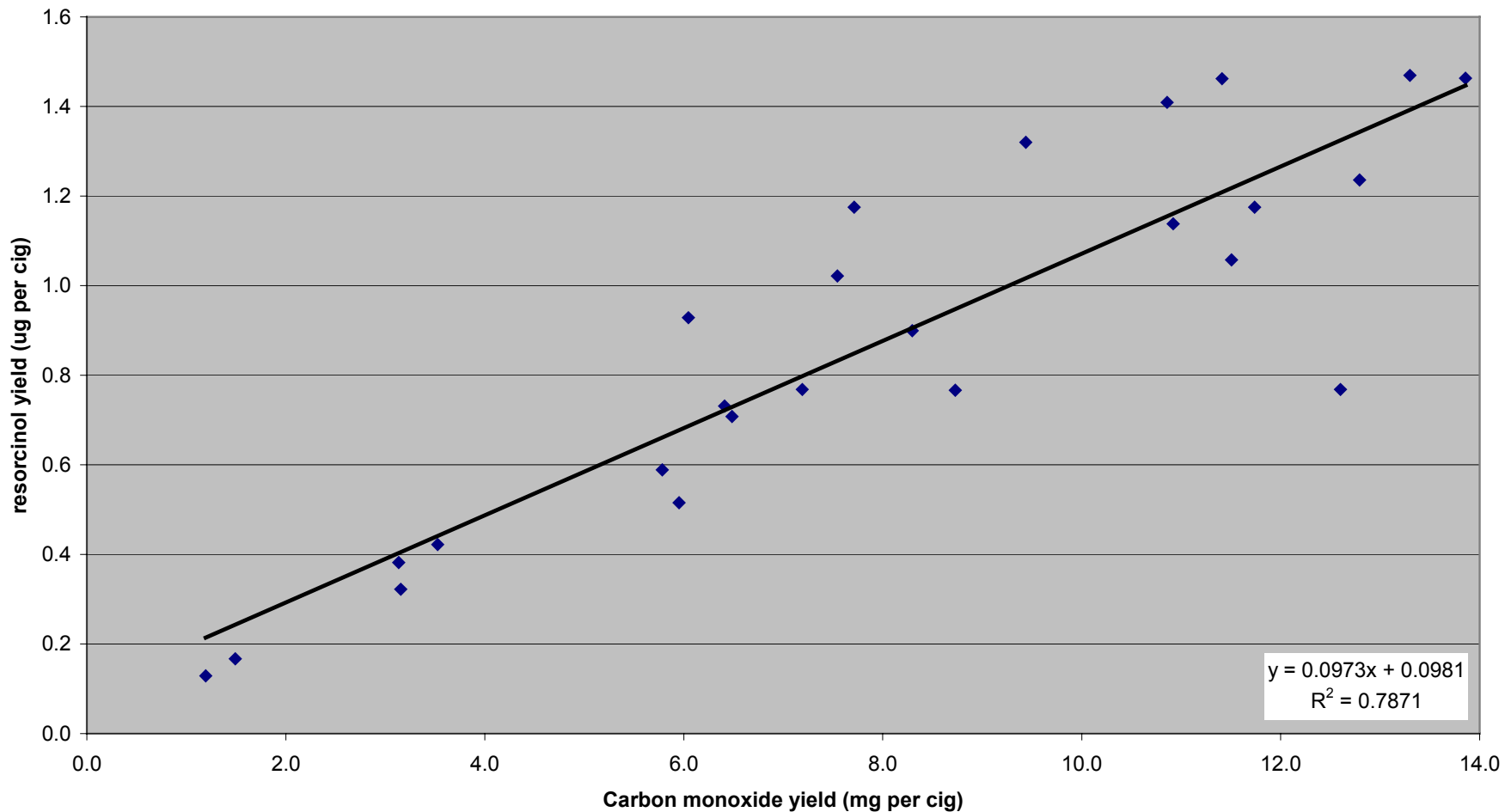
Regression analysis of hydroquinone versus carbon monoxide for 25 cigarette brands



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

Regression analysis of resorcinol versus carbon monoxide

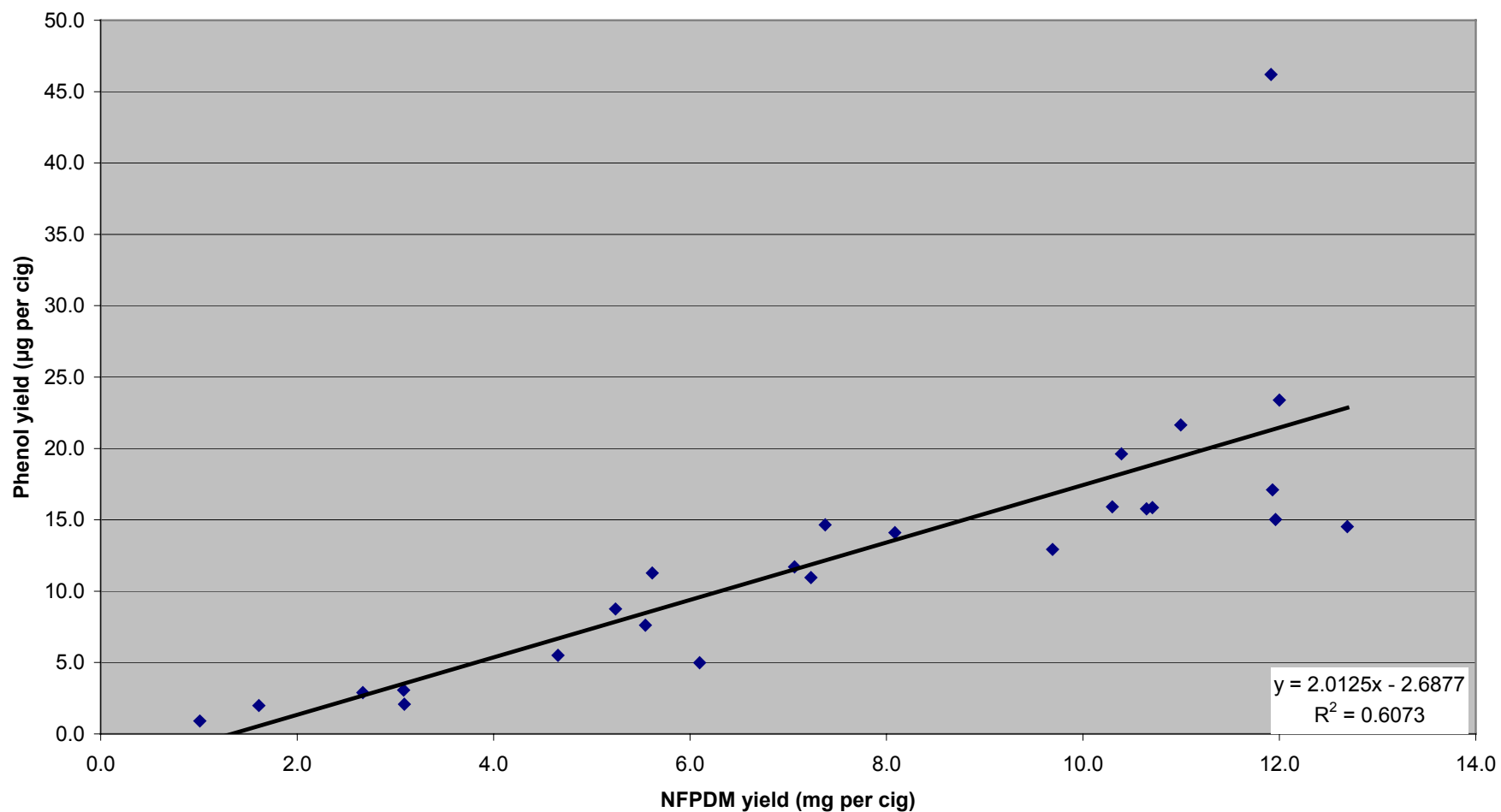
Regression analysis of resorcinol versus carbon monoxide for 25 cigarette brands



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

Regression analysis of phenol versus NFDPM

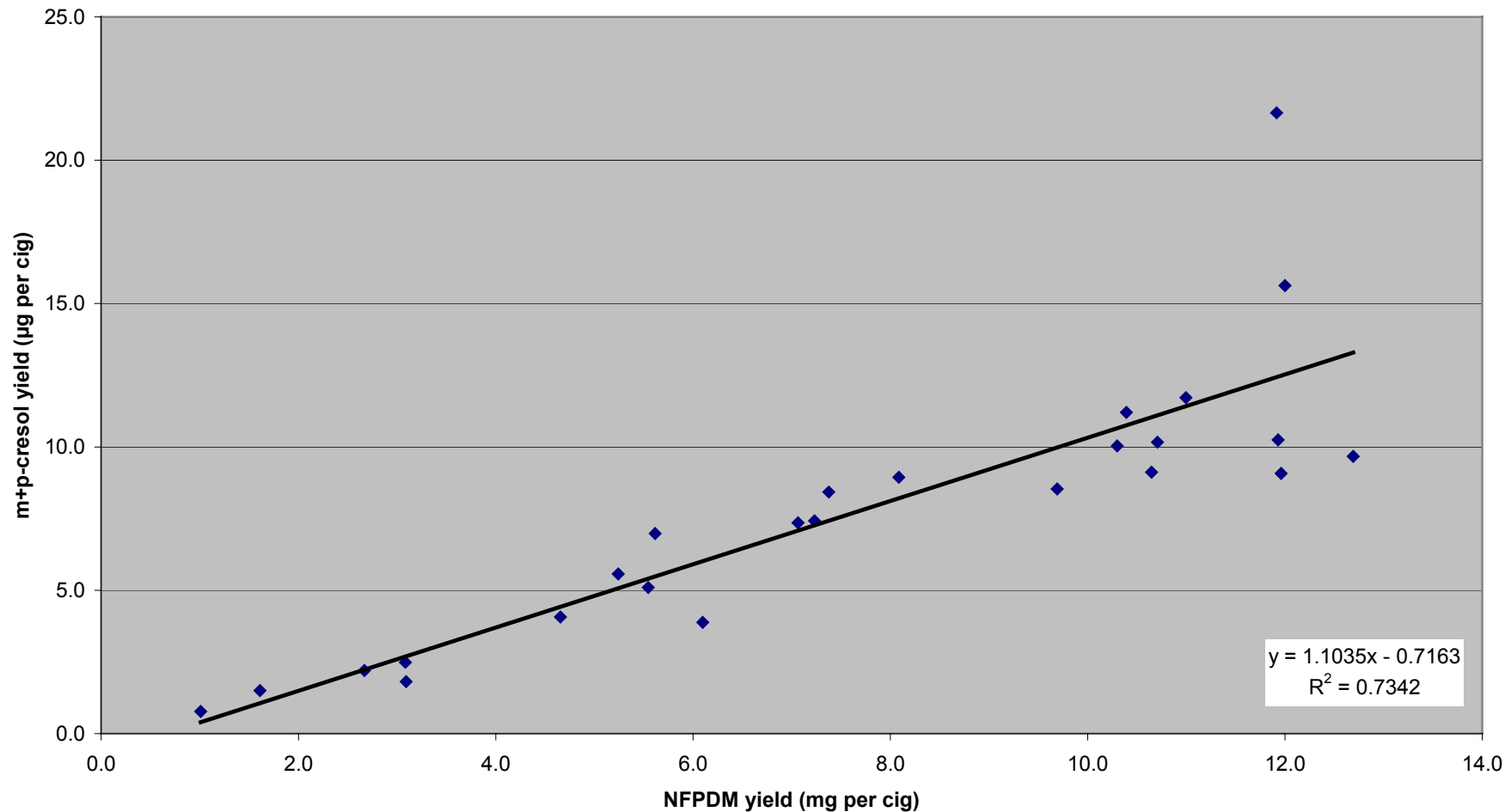
Regression analysis of phenol versus NFDPM for 25 cigarette brands



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

Regression analysis of m+p-cresol versus NFDPM

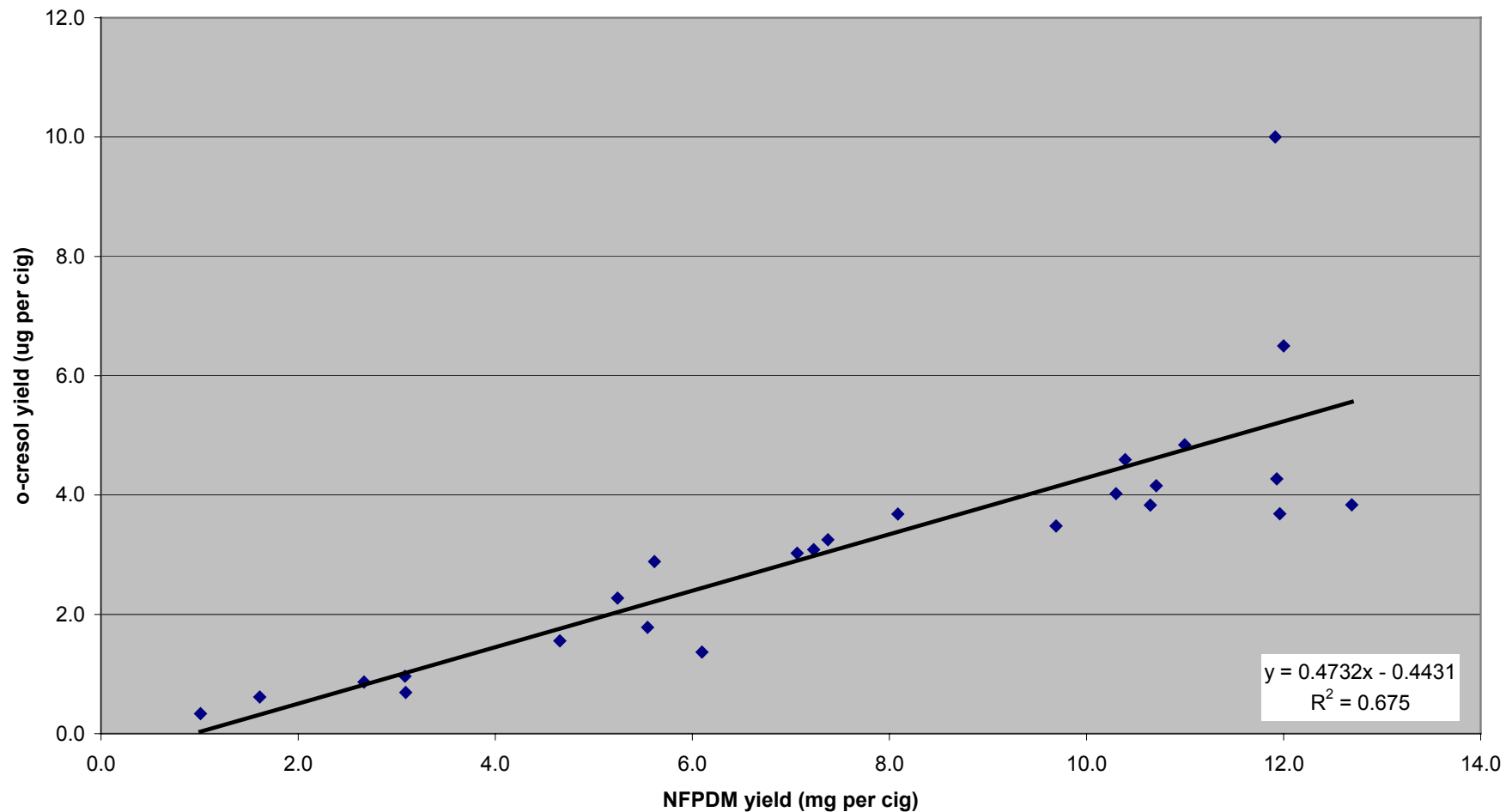
Regression analysis of m+p-cresol versus NFDPM for 25 cigarette brands



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

Regression analysis of o-cresol versus NFDPM

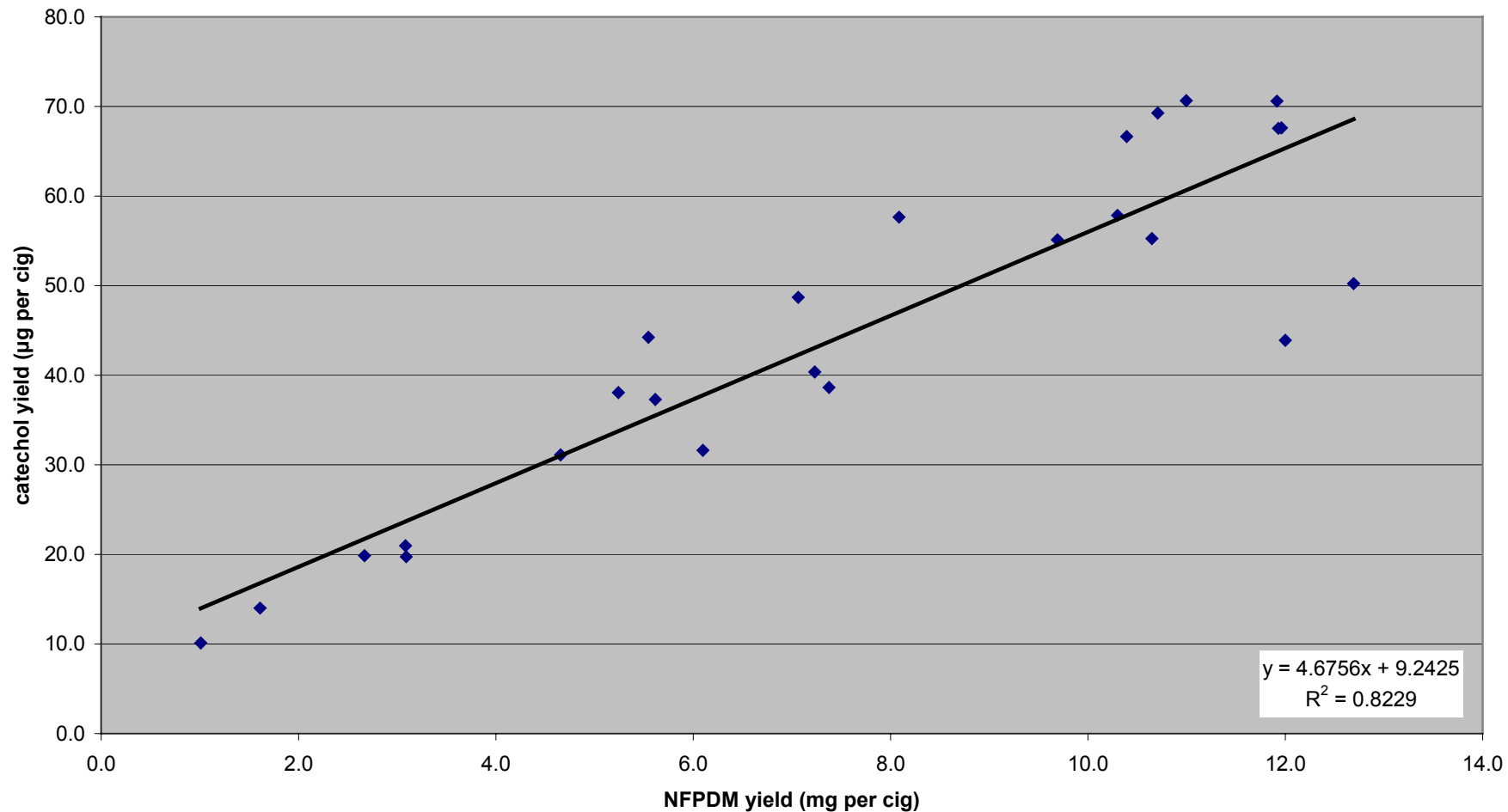
Regression analysis of o-cresol versus NFDPM for 25 cigarette brands



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

Regression analysis of catechol versus NFDPM

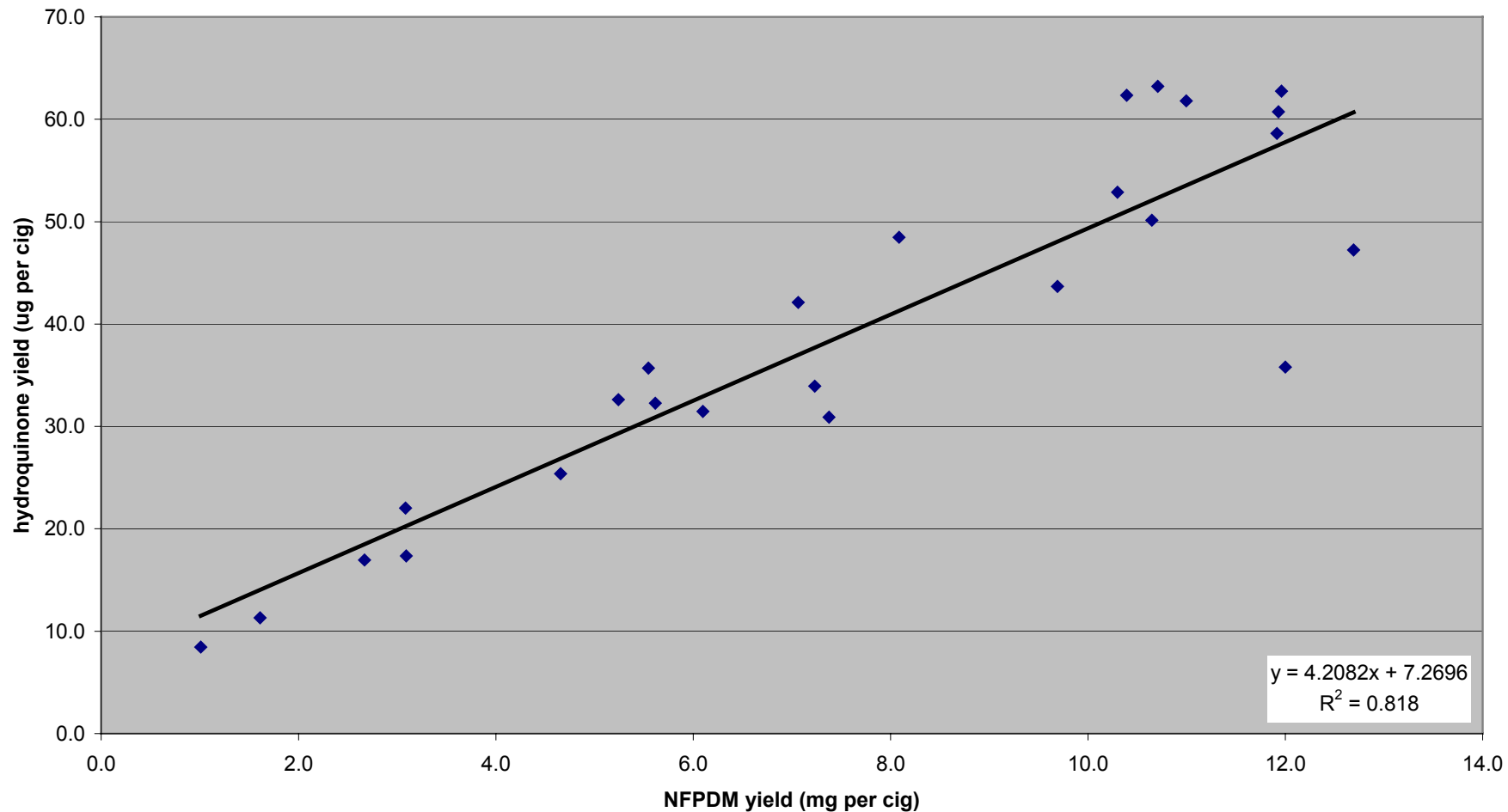
Regression analysis of catechol versus NFDPM for 25 cigarette brands



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

Regression analysis of hydroquinone versus NFDPM

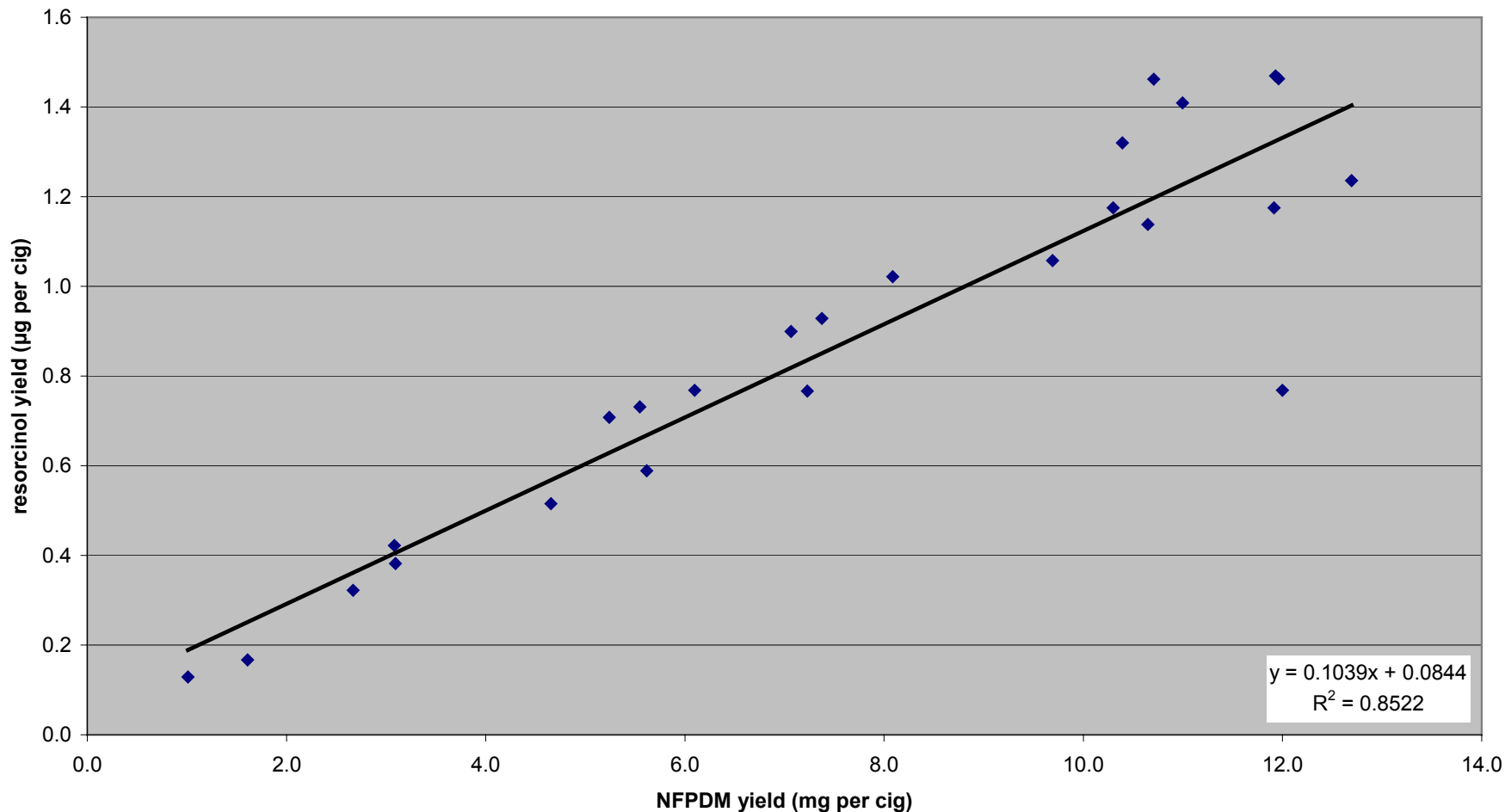
Regression analysis of hydroquinone versus NFDPM for 25 cigarette brands



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

Regression analysis of resorcinol versus NFDPM

Regression analysis of resorcinol 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	Phenol	m + p-cresol	o-cresol	Catechol	Hydroquinone	Resorcinol
1R4F	7.88	5.98	2.35	38.4	34.2	0.64
1R4F	6.62	5.30	2.03	34.6	31.2	0.58
1R4F	6.71	5.29	2.10	36.4	33.9	0.64
1R4F	8.71	6.71	2.63	41.8	37.7	0.73
1R4F	7.76	6.13	2.42	38.7	33.7	0.62
Mean (µg/cig)	7.54	5.88	2.31	38.0	34.2	0.64
Standard Deviation	0.88	0.60	0.25	2.68	2.32	0.06
CV (%)	11.6	10.2	10.6	7.1	6.8	8.9

Outlier Test

Dixons outlier test was applied to the above data

Data sorted	6.620	5.291	2.033	34.619	31.240	0.578
	6.707	5.295	2.099	36.402	33.730	0.621
	7.760	5.981	2.355	38.420	33.930	0.638
	7.880	6.126	2.423	38.697	34.206	0.641
	8.711	6.713	2.635	41.765	37.742	0.734

Statistical test applied

Dixons low end test 0.041 0.003 0.110 0.250 0.383 0.279

Outlier detected at 95%

Dixons high end test 0.397 0.413 0.351 0.429 0.544 0.595

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 (µg/cig)	7.54	5.88	2.31	38.0	34.2	0.64
Standard Deviation	0.88	0.60	0.25	2.68	2.32	0.06
CV (%)	11.6	10.2	10.6	7.1	6.8	8.9

1R5F

Brand	Phenol	m + p-cresol	o-cresol	Catechol	Hydroquinone	Resorcinol
1R5F	<0.72	0.60	<0.41	8.20	6.85	<0.33
1R5F	<0.72	0.66	<0.41	8.67	7.04	<0.33
1R5F	<0.72	0.83	<0.41	9.18	7.48	<0.33
1R5F	<0.72	0.63	<0.41	8.14	6.27	<0.33
1R5F	<0.72	0.64	<0.41	7.92	5.65	<0.33
Mean (µg/cig)	<0.72	0.67	<0.41	8.42	6.66	<0.33
Standard Deviation	n/a	0.09	n/a	0.50	0.71	n/a
CV (%)	n/a	13.0	n/a	6.0	10.7	n/a
<i>Outlier Test</i>						
Dixons outlier test was applied to the above data						
Data sorted	0.398	0.603	0.213	7.924	5.654	0.122
	0.430	0.634	0.216	8.143	6.266	0.132
	0.438	0.644	0.219	8.200	6.854	0.132
	0.486	0.663	0.229	8.670	7.040	0.133
	0.704	0.827	0.299	9.180	7.476	0.141
Statistical test applied						
Dixons low end test	0.102	0.139	0.042	0.175	0.336	0.527
Outlier detected at 95%						
Dixons high end test	0.714	0.732	0.807	0.406	0.240	0.397
Outlier detected at 95%						
	n/a	95%	n/a			
<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)	<0.72	0.64	<0.41	8.42	6.66	<0.33
Standard Deviation	n/a	0.02	n/a	0.50	0.71	n/a
CV (%)	n/a	3.9	n/a	6.0	10.7	n/a

Benson & Hedges King Size

Brand	Phenol	m + p-cresol	o-cresol	Catechol	Hydroquinone	Resorcinol
Benson & Hedges King Size	15.2	9.61	3.87	55.3	51.2	1.13
Benson & Hedges King Size	15.1	9.61	3.85	56.1	52.3	1.18
Benson & Hedges King Size	14.2	9.13	3.65	54.3	49.8	1.15
Benson & Hedges King Size	18.3	11.4	4.56	62.7	57.3	1.21
Benson & Hedges King Size	16.7	10.5	4.19	60.8	53.7	1.21
Mean (µg/cig)	15.9	10.0	4.02	57.8	52.9	1.18
Standard Deviation	1.60	0.88	0.36	3.69	2.87	0.04
CV (%)	10.1	8.8	8.9	6.4	5.4	3.0

Outlier Test

Dixons outlier test was applied to the above data

Data sorted	14.237	9.129	3.646	54.266	49.786	1.129
	15.142	9.612	3.850	55.290	51.241	1.149
	15.173	9.614	3.867	56.109	52.272	1.179
	16.674	10.459	4.194	60.812	53.713	1.209
	18.303	11.352	4.563	62.674	57.303	1.209
Statistical test applied						
Dixons low end test	0.223	0.217	0.223	0.122	0.194	0.243
Outlier detected at 95%						
Dixons high end test	0.401	0.402	0.402	0.221	0.478	0.006
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 (µg/cig)	15.9	10.0	4.02	57.8	52.9	1.18
Standard Deviation	1.60	0.88	0.36	3.69	2.87	0.04
CV (%)	10.1	8.8	8.9	6.4	5.4	3.0

Berkely Superkings

Brand	Phenol	m + p-cresol	o-cresol	Catechol	Hydroquinone	Resorcinol
Berkely Superkings	12.0	8.03	3.24	53.1	43.1	1.01
Berkely Superkings	12.3	8.18	3.29	53.7	43.8	1.07
Berkely Superkings	13.6	8.85	3.63	55.5	43.2	1.03
Berkely Superkings	13.5	8.80	3.58	56.8	43.6	1.11
Berkely Superkings	13.3	8.80	3.66	56.5	44.7	1.07
Mean (µg/cig)	12.9	8.53	3.48	55.1	43.7	1.06
Standard Deviation	0.72	0.39	0.20	1.67	0.61	0.04
CV (%)	5.6	4.6	5.7	3.0	1.4	3.6

Outlier Test

Dixons outlier test was applied to the above data

Data sorted	12.003	8.028	3.239	53.079	43.110	1.010
	12.312	8.177	3.293	53.672	43.219	1.027
	13.301	8.798	3.579	55.476	43.625	1.070
	13.475	8.799	3.634	56.494	43.779	1.073
	13.556	8.849	3.656	56.823	44.658	1.106
Statistical test applied						
Dixons low end test	0.199	0.181	0.128	0.158	0.071	0.181
Outlier detected at 95%						
Dixons high end test	0.052	0.061	0.053	0.088	0.568	0.338
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 (µg/cig)	12.9	8.53	3.48	55.1	43.7	1.06
Standard Deviation	0.72	0.39	0.20	1.67	0.61	0.04
CV (%)	5.6	4.6	5.7	3.0	1.4	3.6

Camel Ultra Lights

Brand	Phenol	m + p-cresol	o-cresol	Catechol	Hydroquinone	Resorcinol
Camel Ultra Lights	2.43	2.06	0.78	19.8	16.6	0.37
Camel Ultra Lights	2.05	1.81	0.68	18.8	16.4	0.37
Camel Ultra Lights	2.11	1.84	0.68	18.7	15.6	0.36
Camel Ultra Lights	1.87	1.73	0.66	19.4	17.5	0.39
Camel Ultra Lights	1.93	1.62	0.66	22.0	20.7	0.42
Mean (µg/cig)	2.08	1.81	0.69	19.7	17.3	0.38
Standard Deviation	0.22	0.16	0.05	1.36	1.98	0.03
CV (%)	10.5	8.9	7.0	6.9	11.4	7.1

Outlier Test

Dixons outlier test was applied to the above data

Data sorted	1.874	1.618	0.660	18.694	15.577	0.356
	1.926	1.733	0.663	18.806	16.353	0.367
	2.055	1.807	0.678	19.363	16.616	0.370
	2.110	1.836	0.682	19.762	17.478	0.391
	2.429	2.055	0.776	22.035	20.674	0.425
Statistical test applied						
Dixons low end test	0.092	0.262	0.026	0.034	0.152	0.151
Outlier detected at 95%						
Dixons high end test	0.575	0.502	0.814	0.680	0.627	0.489
Outlier detected at 95%			95%			

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

Summary of Results						
Mean (µg/cig)	2.08	1.81	0.67	19.7	17.3	0.38
Standard Deviation	0.22	0.16	0.01	1.36	1.98	0.03
CV (%)	10.5	8.9	1.6	6.9	11.4	7.1

Consulate Menthol

Brand	Phenol	m + p-cresol	o-cresol	Catechol	Hydroquinone	Resorcinol
Consulate Menthol	14.5	8.75	3.56	53.4	44.0	0.96
Consulate Menthol	13.8	8.48	3.55	50.9	45.9	0.98
Consulate Menthol	12.1	7.67	3.22	46.2	37.5	0.81
Consulate Menthol	9.57	6.38	2.57	45.3	38.1	0.81
Consulate Menthol	8.49	5.48	2.23	47.6	44.9	0.94
Mean (µg/cig)	11.7	7.35	3.03	48.7	42.1	0.90
Standard Deviation	2.61	1.39	0.60	3.37	3.96	0.08
CV (%)	22.3	19.0	19.8	6.9	9.4	9.3

Outlier Test

Dixons outlier test was applied to the above data

Data sorted	8.495	5.477	2.229	45.294	37.548	0.806
	9.565	6.377	2.573	46.214	38.100	0.813
	12.134	7.666	3.215	47.647	43.988	0.935
	13.777	8.480	3.551	50.905	44.929	0.965
	14.517	8.746	3.560	53.364	45.920	0.980
Statistical test applied						
Dixons low end test	0.178	0.275	0.258	0.114	0.066	0.041
Outlier detected at 95%						
Dixons high end test	0.123	0.081	0.007	0.305	0.118	0.086
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 (µg/cig)	11.7	7.35	3.03	48.7	42.1	0.90
Standard Deviation	2.61	1.39	0.60	3.37	3.96	0.08
CV (%)	22.3	19.0	19.8	6.9	9.4	9.3

Gitanes Caporal Filter

Brand	Phenol	m + p-cresol	o-cresol	Catechol	Hydroquinone	Resorcinol
Gitanes Caporal Filter	22.4	15.1	6.32	42.9	37.8	0.77
Gitanes Caporal Filter	22.6	15.7	6.56	41.7	34.0	0.73
Gitanes Caporal Filter	23.9	16.4	6.75	44.0	35.6	0.74
Gitanes Caporal Filter	25.3	17.3	7.30	46.9	37.4	0.81
Gitanes Caporal Filter	22.7	13.6	5.56	44.1	34.4	0.79
Mean (µg/cig)	23.4	15.6	6.50	43.9	35.8	0.77
Standard Deviation	1.25	1.37	0.64	1.93	1.71	0.03
CV (%)	5.3	8.8	9.8	4.4	4.8	4.1

Outlier Test

Dixons outlier test was applied to the above data

Data sorted	22.377	13.643	5.555	41.659	33.952	0.732
	22.631	15.116	6.318	42.866	34.387	0.743
	22.655	15.685	6.558	43.989	35.567	0.769
	23.929	16.402	6.752	44.061	37.356	0.788
	25.341	17.280	7.302	46.856	37.764	0.809
Statistical test applied						
Dixons low end test	0.086	0.405	0.436	0.232	0.114	0.145
Outlier detected at 95%						
Dixons high end test	0.476	0.241	0.315	0.538	0.107	0.265
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 (µg/cig)	23.4	15.6	6.50	43.9	35.8	0.77
Standard Deviation	1.25	1.37	0.64	1.93	1.71	0.03
CV (%)	5.3	8.8	9.8	4.4	4.8	4.1

Lambert & Butler King Size

Brand	Phenol	m + p-cresol	o-cresol	Catechol	Hydroquinone	Resorcinol
Lambert & Butler King Size	15.8	9.74	4.05	70.4	61.9	1.51
Lambert & Butler King Size	19.8	11.8	4.83	74.4	67.2	1.64
Lambert & Butler King Size	16.6	9.72	4.06	66.4	59.6	1.43
Lambert & Butler King Size	15.9	9.74	4.09	61.7	55.3	1.34
Lambert & Butler King Size	17.4	10.3	4.31	65.0	59.6	1.44
Mean (µg/cig)	17.1	10.2	4.27	67.6	60.7	1.47
Standard Deviation	1.63	0.88	0.33	4.93	4.33	0.11
CV (%)	9.5	8.6	7.8	7.3	7.1	7.5
<i>Outlier Test</i>						
Dixons outlier test was applied to the above data						
Data sorted	15.752	9.722	4.054	61.663	55.308	1.337
	15.935	9.736	4.065	64.983	59.576	1.428
	16.584	9.743	4.089	66.368	59.627	1.439
	17.418	10.251	4.310	70.428	61.899	1.507
	19.767	11.757	4.834	74.356	67.187	1.635
Statistical test applied						
Dixons low end test	0.046	0.007	0.014	0.262	0.359	0.307
Outlier detected at 95%						
Dixons high end test	0.585	0.740	0.672	0.310	0.445	0.430
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 (µg/cig)	17.1	9.86	4.27	67.6	60.7	1.47
Standard Deviation	1.63	0.26	0.33	4.93	4.33	0.11
CV (%)	9.5	2.6	7.8	7.3	7.1	7.5

Lambert & Butler Lights King Size

Brand	Phenol	m + p-cresol	o-cresol	Catechol	Hydroquinone	Resorcinol
Lambert & Butler Lights King Size	10.9	6.58	2.67	45.2	38.6	0.89
Lambert & Butler Lights King Size	9.85	6.30	2.61	42.6	36.9	0.77
Lambert & Butler Lights King Size	7.92	5.01	2.08	33.6	27.8	0.61
Lambert & Butler Lights King Size	7.34	4.80	1.92	33.3	29.1	0.61
Lambert & Butler Lights King Size	7.73	5.16	2.08	35.7	30.7	0.66
Mean (µg/cig)	8.75	5.57	2.27	38.1	32.6	0.71
Standard Deviation	1.54	0.81	0.34	5.48	4.85	0.12
CV (%)	17.7	14.6	15.0	14.4	14.9	17.0
<i>Outlier Test</i>						
Dixons outlier test was applied to the above data						
Data sorted	7.336	4.799	1.925	33.287	27.756	0.605
	7.733	5.005	2.078	33.602	29.066	0.612
	7.921	5.161	2.082	35.683	30.718	0.662
	9.853	6.296	2.612	42.585	36.946	0.774
	10.897	6.584	2.667	45.228	38.586	0.886
Statistical test applied						
Dixons low end test	0.112	0.116	0.207	0.026	0.121	0.024
Outlier detected at 95%						
Dixons high end test	0.293	0.161	0.074	0.221	0.151	0.401
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)	8.75	5.57	2.27	38.1	32.6	0.71
Standard Deviation	1.54	0.81	0.34	5.48	4.85	0.12
CV (%)	17.7	14.6	15.0	14.4	14.9	17.0

Lambert & Butler Ultra Lights

Brand	Phenol	m + p-cresol	o-cresol	Catechol	Hydroquinone	Resorcinol
Lambert & Butler Ultra Lights	1.45	1.15	0.46	12.0	9.63	<0.33
Lambert & Butler Ultra Lights	1.94	1.50	0.61	14.6	11.8	<0.33
Lambert & Butler Ultra Lights	2.10	1.60	0.65	14.5	11.8	<0.33
Lambert & Butler Ultra Lights	2.14	1.63	0.66	14.5	11.6	<0.33
Lambert & Butler Ultra Lights	2.29	1.64	0.67	14.5	11.7	<0.33
Mean (µg/cig)	1.98	1.50	0.61	14.0	11.3	<0.33
Standard Deviation	0.33	0.21	0.09	1.14	0.94	n/a
CV (%)	16.4	13.7	14.2	8.1	8.3	n/a

Outlier Test

Dixons outlier test was applied to the above data

Data sorted	1.445	1.150	0.461	11.969	9.630	0.142
	1.936	1.495	0.614	14.491	11.605	0.171
	2.097	1.601	0.652	14.499	11.726	0.171
	2.145	1.631	0.664	14.528	11.777	0.172
	2.287	1.641	0.669	14.552	11.818	0.179
Statistical test applied						
Dixons low end test	0.583	0.704	0.735	0.976	0.903	0.794
Outlier detected at 95%			95%	95%	95%	n/a
Dixons high end test	0.169	0.020	0.022	0.010	0.019	0.171
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 (µg/cig)	1.98	1.50	0.65	14.5	11.7	<0.33
Standard Deviation	0.33	0.21	0.02	0.03	0.09	n/a
CV (%)	16.4	13.7	3.8	0.2	0.8	n/a

Marlboro King Size

Brand	Phenol	m + p-cresol	o-cresol	Catechol	Hydroquinone	Resorcinol
Marlboro King Size	14.4	9.53	3.75	49.5	46.2	1.19
Marlboro King Size	13.9	8.85	3.47	49.9	46.2	1.20
Marlboro King Size	14.1	9.71	3.91	47.7	44.4	1.20
Marlboro King Size	15.2	10.1	3.98	52.2	50.1	1.30
Marlboro King Size	15.1	10.2	4.06	51.9	49.3	1.29
Mean (µg/cig)	14.5	9.67	3.83	50.2	47.2	1.24
Standard Deviation	0.58	0.53	0.23	1.86	2.37	0.05
CV (%)	4.0	5.5	6.1	3.7	5.0	4.2
<i>Outlier Test</i>						
Dixons outlier test was applied to the above data						
Data sorted	13.878	8.854	3.467	47.659	44.408	1.194
	14.112	9.533	3.752	49.493	46.164	1.198
	14.389	9.713	3.905	49.854	46.229	1.202
	15.108	10.053	3.981	51.861	49.308	1.286
	15.160	10.199	4.061	52.219	50.082	1.298
Statistical test applied						
Dixons low end test	0.183	0.505	0.481	0.402	0.309	0.036
Outlier detected at 95%						
Dixons high end test	0.041	0.109	0.135	0.078	0.136	0.117
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)	14.5	9.67	3.83	50.2	47.2	1.24
Standard Deviation	0.58	0.53	0.23	1.86	2.37	0.05
CV (%)	4.0	5.5	6.1	3.7	5.0	4.2

Marlboro Lights King Size

Brand	Phenol	m + p-cresol	o-cresol	Catechol	Hydroquinone	Resorcinol
Marlboro Lights King Size	5.22	4.02	1.44	32.1	31.4	0.78
Marlboro Lights King Size	4.91	3.82	1.35	30.8	30.7	0.76
Marlboro Lights King Size	5.82	4.36	1.55	33.7	33.8	0.81
Marlboro Lights King Size	4.42	3.53	1.23	31.0	31.3	0.74
Marlboro Lights King Size	4.60	3.65	1.28	30.5	30.0	0.75
Mean (µg/cig)	5.00	3.88	1.37	31.6	31.5	0.77
Standard Deviation	0.56	0.33	0.13	1.32	1.43	0.03
CV (%)	11.1	8.5	9.4	4.2	4.6	3.5

Outlier Test

Dixons outlier test was applied to the above data

Data sorted	4.416	3.531	1.227	30.451	30.040	0.740
	4.602	3.652	1.276	30.817	30.704	0.750
	4.914	3.818	1.354	30.986	31.321	0.763
	5.219	4.020	1.436	32.068	31.431	0.782
	5.824	4.364	1.551	33.705	33.825	0.808
Statistical test applied						
Dixons low end test	0.133	0.145	0.151	0.112	0.176	0.151
Outlier detected at 95%						
Dixons high end test	0.430	0.413	0.353	0.503	0.633	0.386
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 (µg/cig)	5.00	3.88	1.37	31.6	31.5	0.77
Standard Deviation	0.56	0.33	0.13	1.32	1.43	0.03
CV (%)	11.1	8.5	9.4	4.2	4.6	3.5

Mayfair Lights King Size

Brand	Phenol	m + p-cresol	o-cresol	Catechol	Hydroquinone	Resorcinol
Mayfair Lights King Size	10.9	7.27	3.00	38.8	33.1	0.80
Mayfair Lights King Size	9.57	6.76	2.79	38.0	32.7	0.74
Mayfair Lights King Size	11.2	7.48	3.15	41.0	34.3	0.75
Mayfair Lights King Size	12.8	8.56	3.58	43.0	35.7	0.79
Mayfair Lights King Size	10.3	7.03	2.91	41.2	33.9	0.75
Mean (µg/cig)	11.0	7.42	3.09	40.4	33.9	0.77
Standard Deviation	1.20	0.69	0.30	2.01	1.19	0.03
CV (%)	11.0	9.3	9.8	5.0	3.5	3.7
<i>Outlier Test</i>						
Dixons outlier test was applied to the above data						
Data sorted	9.570	6.762	2.794	37.963	32.699	0.743
	10.326	7.030	2.913	38.765	33.058	0.746
	10.930	7.273	3.004	40.958	33.852	0.749
	11.152	7.483	3.146	41.153	34.260	0.794
	12.809	8.558	3.576	42.968	35.728	0.800
Statistical test applied						
Dixons low end test	0.233	0.149	0.152	0.160	0.118	0.042
Outlier detected at 95%						
Dixons high end test	0.511	0.598	0.550	0.363	0.485	0.106
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)	11.0	7.42	3.09	40.4	33.9	0.77
Standard Deviation	1.20	0.69	0.30	2.01	1.19	0.03
CV (%)	11.0	9.3	9.8	5.0	3.5	3.7

Mayfair Menthol King Size

Brand	Phenol	m + p-cresol	o-cresol	Catechol	Hydroquinone	Resorcinol
Mayfair Menthol King Size	5.30	3.97	1.51	30.0	24.9	0.50
Mayfair Menthol King Size	5.82	4.30	1.65	32.1	27.1	0.57
Mayfair Menthol King Size	5.39	3.99	1.53	30.8	24.2	0.49
Mayfair Menthol King Size	5.67	4.15	1.59	31.7	25.6	0.50
Mayfair Menthol King Size	5.35	3.93	1.50	31.0	25.1	0.51
Mean (µg/cig)	5.51	4.07	1.56	31.1	25.4	0.52
Standard Deviation	0.23	0.15	0.06	0.81	1.09	0.03
CV (%)	4.1	3.8	4.1	2.6	4.3	5.6
<i>Outlier Test</i>						
Dixons outlier test was applied to the above data						
Data sorted	5.298	3.930	1.504	30.027	24.202	0.491
	5.353	3.968	1.506	30.765	24.910	0.503
	5.389	3.995	1.533	30.989	25.096	0.504
	5.673	4.150	1.589	31.726	25.611	0.514
	5.816	4.298	1.654	32.088	27.118	0.565
Statistical test applied						
Dixons low end test	0.106	0.101	0.017	0.358	0.243	0.162
Outlier detected at 95%						
Dixons high end test	0.276	0.403	0.432	0.175	0.517	0.695
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)	5.51	4.07	1.56	31.1	25.4	0.52
Standard Deviation	0.23	0.15	0.06	0.81	1.09	0.03
CV (%)	4.1	3.8	4.1	2.6	4.3	5.6

Red Band Lights King Size

Brand	Phenol	m + p-cresol	o-cresol	Catechol	Hydroquinone	Resorcinol
Red Band Lights King Size	8.50	5.60	2.00	46.5	36.9	0.75
Red Band Lights King Size	7.92	5.14	1.83	41.5	33.5	0.68
Red Band Lights King Size	7.64	5.18	1.80	45.7	36.3	0.75
Red Band Lights King Size	7.43	5.01	1.73	44.5	35.7	0.74
Red Band Lights King Size	6.56	4.56	1.54	43.0	36.0	0.73
Mean (µg/cig)	7.61	5.10	1.78	44.2	35.7	0.73
Standard Deviation	0.71	0.37	0.17	2.02	1.30	0.03
CV (%)	9.3	7.3	9.3	4.6	3.6	4.0
<i>Outlier Test</i>						
Dixons outlier test was applied to the above data						
Data sorted	6.561	4.565	1.541	41.465	33.485	0.681
	7.432	5.012	1.735	42.979	35.734	0.733
	7.643	5.138	1.805	44.549	36.015	0.740
	7.924	5.181	1.833	45.656	36.312	0.747
	8.498	5.597	2.000	46.460	36.877	0.755
Statistical test applied						
Dixons low end test	0.450	0.433	0.422	0.303	0.663	0.710
Outlier detected at 95%						
Dixons high end test	0.296	0.403	0.364	0.161	0.167	0.098
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)	7.61	5.10	1.78	44.2	35.7	0.73
Standard Deviation	0.71	0.37	0.17	2.02	1.30	0.03
CV (%)	9.3	7.3	9.3	4.6	3.6	4.0

Regal Filter

Brand	Phenol	m + p-cresol	o-cresol	Catechol	Hydroquinone	Resorcinol
Regal Filter	15.7	9.13	3.92	54.4	50.3	1.14
Regal Filter	15.7	8.76	3.63	57.6	52.2	1.20
Regal Filter	15.4	9.25	3.89	53.7	48.4	1.13
Regal Filter	15.8	9.04	3.80	53.4	48.0	1.05
Regal Filter	16.3	9.39	3.91	57.1	51.9	1.17
Mean (µg/cig)	15.8	9.11	3.83	55.2	50.1	1.14
Standard Deviation	0.34	0.24	0.12	1.97	1.92	0.06
CV (%)	2.2	2.6	3.2	3.6	3.8	5.1

Outlier Test

Dixons outlier test was applied to the above data

Data sorted	15.389	8.764	3.627	53.399	48.034	1.046
	15.659	9.036	3.800	53.733	48.350	1.133
	15.660	9.135	3.894	54.355	50.296	1.143
	15.842	9.248	3.913	57.143	51.851	1.171
	16.304	9.389	3.917	57.586	52.182	1.199
Statistical test applied						
Dixons low end test	0.295	0.435	0.596	0.080	0.076	0.569
Outlier detected at 95%						
Dixons high end test	0.505	0.226	0.014	0.106	0.080	0.184
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 (µg/cig)	15.8	9.11	3.83	55.2	50.1	1.14
Standard Deviation	0.34	0.24	0.12	1.97	1.92	0.06
CV (%)	2.2	2.6	3.2	3.6	3.8	5.1

Regal King Size

Brand	Phenol	m + p-cresol	o-cresol	Catechol	Hydroquinone	Resorcinol
Regal King Size	15.6	9.53	3.93	70.6	64.3	1.51
Regal King Size	15.3	8.84	3.60	63.8	59.8	1.38
Regal King Size	15.1	9.37	3.83	70.3	65.8	1.48
Regal King Size	15.3	9.26	3.68	69.5	64.5	1.52
Regal King Size	13.8	8.39	3.39	63.8	59.2	1.43
Mean (µg/cig)	15.0	9.08	3.69	67.6	62.7	1.46
Standard Deviation	0.72	0.46	0.21	3.50	2.99	0.06
CV (%)	4.8	5.1	5.7	5.2	4.8	3.9
<i>Outlier Test</i>						
Dixons outlier test was applied to the above data						
Data sorted	13.770	8.390	3.393	63.760	59.219	1.383
	15.117	8.836	3.598	63.841	59.844	1.428
	15.324	9.256	3.675	69.536	64.291	1.481
	15.327	9.373	3.831	70.286	64.536	1.507
	15.586	9.530	3.931	70.643	65.790	1.518
Statistical test applied						
Dixons low end test	0.742	0.391	0.380	0.012	0.095	0.335
Outlier detected at 95%	95%					
Dixons high end test	0.143	0.138	0.186	0.052	0.191	0.079
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)	15.3	9.08	3.69	67.6	62.7	1.46
Standard Deviation	0.19	0.46	0.21	3.50	2.99	0.06
CV (%)	1.3	5.1	5.7	5.2	4.8	3.9

Rothman Royals 120s

Brand	Phenol	m + p-cresol	o-cresol	Catechol	Hydroquinone	Resorcinol
Rothman Royals 120s	22.0	12.4	5.16	74.2	69.4	1.45
Rothman Royals 120s	18.2	10.0	4.07	62.3	60.7	1.24
Rothman Royals 120s	19.2	10.6	4.33	64.5	59.9	1.28
Rothman Royals 120s	20.5	12.1	4.96	66.0	61.8	1.32
Rothman Royals 120s	18.2	11.0	4.47	66.1	60.0	1.31
Mean (µg/cig)	19.6	11.2	4.60	66.7	62.4	1.32
Standard Deviation	1.63	1.03	0.45	4.51	4.01	0.08
CV (%)	8.3	9.2	9.8	6.8	6.4	6.1

Outlier Test

Dixons outlier test was applied to the above data

Data sorted	18.202	9.987	4.070	62.330	59.876	1.238
	18.227	10.577	4.325	64.549	59.962	1.280
	19.189	10.956	4.468	66.047	60.737	1.308
	20.529	12.091	4.958	66.136	61.812	1.321
	21.992	12.426	5.156	74.237	69.385	1.453

Statistical test applied

Dixons low end test 0.007 0.242 0.235 0.186 0.009 0.194

Outlier detected at 95%

Dixons high end test 0.386 0.137 0.182 0.680 0.796 0.616

Outlier detected at 95% 95%

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

Summary of Results

Mean (µg/cig)	19.6	11.2	4.60	66.7	60.6	1.32
Standard Deviation	1.63	1.03	0.45	4.51	0.90	0.08
CV (%)	8.3	9.2	9.8	6.8	1.5	6.1

Rothman Royals King Size

Brand	Phenol	m + p-cresol	o-cresol	Catechol	Hydroquinone	Resorcinol
Rothman Royals King Size	22.0	12.1	5.10	74.1	64.5	1.43
Rothman Royals King Size	20.4	10.8	4.41	64.8	57.1	1.31
Rothman Royals King Size	22.5	11.8	4.89	70.0	59.4	1.35
Rothman Royals King Size	22.5	12.4	5.09	74.4	66.5	1.47
Rothman Royals King Size	20.8	11.4	4.72	70.0	61.4	1.48
Mean (µg/cig)	21.6	11.7	4.84	70.7	61.8	1.41
Standard Deviation	1.02	0.65	0.29	3.91	3.78	0.07
CV (%)	4.7	5.5	6.0	5.5	6.1	5.3

Outlier Test

Dixons outlier test was applied to the above data

Data sorted	20.364	10.778	4.409	64.785	57.144	1.313
	20.763	11.397	4.721	69.989	59.414	1.352
	22.035	11.847	4.892	70.030	61.441	1.427
	22.523	12.126	5.092	74.073	64.506	1.474
	22.548	12.436	5.097	74.400	66.523	1.479
Statistical test applied						
Dixons low end test	0.183	0.374	0.453	0.541	0.242	0.233
Outlier detected at 95%						
Dixons high end test	0.011	0.187	0.008	0.034	0.215	0.031
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 (µg/cig)	21.6	11.7	4.84	70.7	61.8	1.41
Standard Deviation	1.02	0.65	0.29	3.91	3.78	0.07
CV (%)	4.7	5.5	6.0	5.5	6.1	5.3

Senior Service

Brand	Phenol	m + p-cresol	o-cresol	Catechol	Hydroquinone	Resorcinol
Senior Service	52.9	24.5	11.4	74.0	60.3	1.18
Senior Service	46.7	22.1	10.2	69.6	56.4	1.12
Senior Service	42.5	20.1	9.20	68.8	57.1	1.14
Senior Service	41.5	19.8	9.13	66.7	56.8	1.14
Senior Service	47.3	21.8	10.1	74.0	62.5	1.29
Mean (µg/cig)	46.2	21.7	10.0	70.6	58.6	1.18
Standard Deviation	4.54	1.89	0.93	3.27	2.66	0.07
CV (%)	9.8	8.7	9.3	4.6	4.5	5.7

Outlier Test

Dixons outlier test was applied to the above data

Data sorted	41.481	19.759	9.126	66.660	56.351	1.120
	42.509	20.110	9.199	68.789	56.819	1.143
	46.737	21.796	10.080	69.566	57.076	1.143
	47.333	22.098	10.189	73.989	60.321	1.180
	52.918	24.509	11.407	73.996	62.452	1.290

Statistical test applied

Dixons low end test 0.090 0.074 0.032 0.290 0.077 0.133

Outlier detected at 95%

Dixons high end test 0.488 0.508 0.534 0.001 0.349 0.647

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 (µg/cig)	46.2	21.7	10.0	70.6	58.6	1.18
Standard Deviation	4.54	1.89	0.93	3.27	2.66	0.07
CV (%)	9.8	8.7	9.3	4.6	4.5	5.7

Silk Cut Extra Mild

Brand	Phenol	m + p-cresol	o-cresol	Catechol	Hydroquinone	Resorcinol
Silk Cut Extra Mild	2.85	2.14	0.84	19.5	17.0	<0.33
Silk Cut Extra Mild	3.20	2.39	0.93	21.0	17.8	0.34
Silk Cut Extra Mild	3.13	2.40	0.94	21.1	18.1	0.33
Silk Cut Extra Mild	2.48	1.98	0.77	19.1	16.0	<0.33
Silk Cut Extra Mild	2.79	2.12	0.85	18.6	16.0	<0.33
Mean (µg/cig)	2.89	2.21	0.87	19.9	17.0	<0.33
Standard Deviation	0.29	0.18	0.07	1.15	0.97	n/a
CV (%)	10.0	8.4	8.3	5.8	5.7	n/a

Outlier Test

Dixons outlier test was applied to the above data

Data sorted	2.480	1.978	0.771	18.558	15.966	0.295
	2.788	2.118	0.838	19.069	16.015	0.318
	2.850	2.137	0.846	19.525	16.981	0.322
	3.126	2.390	0.934	20.960	17.770	0.334
	3.204	2.402	0.945	21.150	18.078	0.340
Statistical test applied						
Dixons low end test	0.425	0.330	0.382	0.197	0.023	0.519
Outlier detected at 95%						
Dixons high end test	0.108	0.028	0.065	0.073	0.146	0.135
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 (µg/cig)	2.89	2.21	0.87	19.9	17.0	<0.33
Standard Deviation	0.29	0.18	0.07	1.15	0.97	n/a
CV (%)	10.0	8.4	8.3	5.8	5.7	n/a

Silk Cut King Size

Brand	Phenol	m + p-cresol	o-cresol	Catechol	Hydroquinone	Resorcinol
Silk Cut King Size	14.4	8.36	3.51	40.0	33.8	0.61
Silk Cut King Size	10.6	6.66	2.76	35.6	30.8	0.56
Silk Cut King Size	10.5	6.68	2.72	36.6	31.6	0.57
Silk Cut King Size	10.3	6.61	2.72	37.3	31.9	0.60
Silk Cut King Size	10.5	6.56	2.72	37.0	33.1	0.60
Mean (µg/cig)	11.3	6.97	2.89	37.3	32.3	0.59
Standard Deviation	1.77	0.78	0.35	1.63	1.20	0.02
CV (%)	15.7	11.2	12.1	4.4	3.7	3.1
<i>Outlier Test</i>						
Dixons outlier test was applied to the above data						
Data sorted	10.346	6.560	2.718	35.590	30.841	0.565
	10.475	6.611	2.719	36.617	31.610	0.573
	10.529	6.660	2.723	37.011	31.906	0.597
	10.564	6.676	2.758	37.326	33.112	0.604
	14.428	8.365	3.507	39.974	33.843	0.605
Statistical test applied						
Dixons low end test	0.032	0.028	0.002	0.234	0.256	0.207
Outlier detected at 95%						
Dixons high end test	0.947	0.936	0.948	0.604	0.244	0.030
Outlier detected at 95%	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 (µg/cig)	10.5	6.63	2.73	37.3	32.3	0.59
Standard Deviation	0.10	0.05	0.02	1.63	1.20	0.02
CV (%)	0.9	0.8	0.7	4.4	3.7	3.1

Silk Cut Ultra King Size

Brand	Phenol	m + p-cresol	o-cresol	Catechol	Hydroquinone	Resorcinol
Silk Cut Ultra King Size	0.99	0.79	<0.41	9.70	7.69	<0.33
Silk Cut Ultra King Size	0.98	0.81	<0.41	9.89	7.96	<0.33
Silk Cut Ultra King Size	1.14	0.98	<0.41	10.7	9.38	<0.33
Silk Cut Ultra King Size	1.11	0.94	<0.41	10.9	8.90	<0.33
Silk Cut Ultra King Size	<0.34	0.36	nd	9.40	8.37	<0.33
Mean (µg/cig)	0.91	0.78	<0.41	10.1	8.46	<0.33
Standard Deviation	0.33	0.25	n/a	0.64	0.69	n/a
CV (%)	36.1	31.9	n/a	6.3	8.1	n/a
<i>Outlier Test</i>						
Dixons outlier test was applied to the above data						
Data sorted	0.337	0.357	0.000	9.404	7.688	0.116
	0.976	0.793	0.307	9.703	7.965	0.122
	0.987	0.808	0.309	9.887	8.368	0.125
	1.112	0.939	0.354	10.696	8.903	0.139
	1.140	0.979	0.370	10.872	9.380	0.142
Statistical test applied						
Dixons low end test	0.795	0.701	0.829	0.204	0.163	0.244
Outlier detected at 95%	95%		n/a			
Dixons high end test	0.035	0.064	0.042	0.120	0.282	0.122
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)	1.05	0.78	<0.41	10.1	8.46	<0.33
Standard Deviation	0.08	0.25	n/a	0.64	0.69	n/a
CV (%)	8.0	31.9	n/a	6.3	8.1	n/a

Superkings

Brand	Phenol	m + p-cresol	o-cresol	Catechol	Hydroquinone	Resorcinol
Superkings	18.4	11.2	4.69	69.0	61.7	1.47
Superkings	18.8	11.5	4.71	71.1	61.5	1.43
Superkings	14.9	9.73	3.89	65.6	60.6	1.36
Superkings	14.4	9.44	3.81	72.7	67.0	1.56
Superkings	12.9	8.89	3.68	68.0	65.3	1.49
Mean (µg/cig)	15.9	10.2	4.15	69.3	63.2	1.46
Standard Deviation	2.59	1.16	0.50	2.74	2.76	0.07
CV (%)	16.3	11.4	12.1	4.0	4.4	5.0
<i>Outlier Test</i>						
Dixons outlier test was applied to the above data						
Data sorted	12.896	8.889	3.679	65.626	60.585	1.359
	14.371	9.444	3.806	67.979	61.512	1.430
	14.853	9.733	3.886	68.982	61.715	1.474
	18.378	11.234	4.688	71.104	65.255	1.490
	18.755	11.545	4.708	72.685	66.984	1.557
Statistical test applied						
Dixons low end test	0.252	0.209	0.124	0.333	0.145	0.361
Outlier detected at 95%						
Dixons high end test	0.064	0.117	0.020	0.224	0.270	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 (µg/cig)	15.9	10.2	4.15	69.3	63.2	1.46
Standard Deviation	2.59	1.16	0.50	2.74	2.8	0.07
CV (%)	16.3	11.4	12.1	4.0	4.4	5.0

Superkings Lights

Brand	Phenol	m + p-cresol	o-cresol	Catechol	Hydroquinone	Resorcinol
Superkings Lights	15.5	9.61	3.97	60.3	51.0	1.06
Superkings Lights	16.7	10.2	4.25	60.1	49.6	1.04
Superkings Lights	13.3	8.60	3.54	57.6	48.7	0.99
Superkings Lights	12.5	8.12	3.31	54.7	45.3	1.02
Superkings Lights	12.5	8.16	3.34	55.3	47.8	0.99
Mean (µg/cig)	14.1	8.94	3.68	57.6	48.5	1.02
Standard Deviation	1.91	0.92	0.41	2.60	2.13	0.03
CV (%)	13.5	10.3	11.2	4.5	4.4	2.8

Outlier Test

Dixons outlier test was applied to the above data

Data sorted	12.475	8.123	3.306	54.744	45.288	0.991
	12.508	8.160	3.341	55.339	47.839	0.995
	13.321	8.601	3.544	57.625	48.694	1.020
	15.486	9.606	3.967	60.107	49.615	1.045
	16.713	10.198	4.254	60.343	50.959	1.056
Statistical test applied						
Dixons low end test	0.008	0.018	0.036	0.106	0.450	0.054
Outlier detected at 95%						
Dixons high end test	0.289	0.285	0.302	0.042	0.237	0.174
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 (µg/cig)	14.1	8.94	3.68	57.6	48.5	1.02
Standard Deviation	1.91	0.92	0.41	2.60	2.13	0.03
CV (%)	13.5	10.3	11.2	4.5	4.4	2.8

Superkings Ultra Lights

Brand	Phenol	m + p-cresol	o-cresol	Catechol	Hydroquinone	Resorcinol
Superkings Ultra Lights	3.19	2.56	1.01	21.4	21.7	0.42
Superkings Ultra Lights	3.04	2.52	0.97	19.8	21.0	0.41
Superkings Ultra Lights	3.49	2.66	1.02	21.7	23.6	0.44
Superkings Ultra Lights	3.29	2.64	1.03	22.8	23.7	0.45
Superkings Ultra Lights	2.34	2.05	0.78	19.1	20.1	0.38
Mean (µg/cig)	3.07	2.49	0.96	21.0	22.0	0.42
Standard Deviation	0.44	0.25	0.11	1.50	1.59	0.03
CV (%)	14.4	10.1	10.9	7.1	7.2	6.8

Outlier Test

Dixons outlier test was applied to the above data

Data sorted	2.339	2.047	0.779	19.142	20.113	0.381
	3.040	2.519	0.970	19.787	20.988	0.409
	3.187	2.558	1.008	21.397	21.693	0.424
	3.285	2.639	1.022	21.712	23.588	0.445
	3.495	2.664	1.033	22.841	23.710	0.453
Statistical test applied						
Dixons low end test	0.607	0.765	0.750	0.174	0.243	0.382
Outlier detected at 95%		95%	95%			
Dixons high end test	0.181	0.040	0.046	0.305	0.034	0.121
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 (µg/cig)	3.07	2.59	1.01	21.0	22.0	0.42
Standard Deviation	0.44	0.07	0.03	1.50	1.59	0.03
CV (%)	14.4	2.6	2.7	7.1	7.2	6.8

Vogue Superslims

Brand	Phenol	m + p-cresol	o-cresol	Catechol	Hydroquinone	Resorcinol
Vogue Superslims	16.0	8.83	3.42	40.6	30.9	0.94
Vogue Superslims	14.6	8.27	3.22	37.3	29.7	0.90
Vogue Superslims	15.7	8.97	3.48	38.0	29.9	0.87
Vogue Superslims	12.8	7.72	2.94	35.5	28.5	0.85
Vogue Superslims	14.1	8.32	3.19	41.8	35.5	1.08
Mean (µg/cig)	14.7	8.42	3.25	38.6	30.9	0.93
Standard Deviation	1.30	0.50	0.21	2.57	2.70	0.09
CV (%)	8.9	5.9	6.6	6.7	8.7	9.9

Outlier Test

Dixons outlier test was applied to the above data

Data sorted	Phenol	m + p-cresol	o-cresol	Catechol	Hydroquinone	Resorcinol
18.000	187.280	6.000	23.040	40.040	4.600	
18.440	196.880	6.440	23.120	41.160	4.880	
19.120	209.880	6.480	24.920	43.000	5.120	
19.280	210.200	6.560	25.080	44.080	5.360	
19.600	211.640	6.680	25.120	45.840	5.640	

Statistical test applied

Dixons low end test	0.275	0.394	0.647	0.038	0.193	0.269
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Outlier detected at 95%

Dixons high end test	0.200	0.059	0.176	0.019	0.303	0.269
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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 (µg/cig)	14.7	8.42	3.25	38.6	30.9	0.93
Standard Deviation	1.30	0.50	0.21	2.57	2.70	0.09
CV (%)	8.9	5.9	6.6	6.7	8.7	9.9

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.

Repeatability and Reproducibility

Originally it was intended to perform the analysis using a GC-MS technique. Validation data was obtained using a GC-MS method and acceptable repeatability was achieved. However, when the study was performed, it was found that poor repeatability between runs was achieved.* This could have been due to the ageing equipment used by LGC Limited, which broke down three times during the study and required the services of an engineer each time to repair.

Therefore, it was decided to repeat the whole study using a HPLC and fluorescence detection. Good repeatability was achieved throughout the study†. Consequently, the results obtained using the HPLC system have been reported and the results obtained by the GC-MS system discarded.

Comparing the results obtained from the study with those achieved but not reported using GC-MS showed that they were broadly similar but the CVs were higher. For example 1R4F gave

1R4F	hydroquinone	resorcinol	catechol	phenol	m+p-cresol	o-cresol
	$\mu\text{g cig}^{-1}$	$\mu\text{g cig}^{-1}$	$\mu\text{g cig}^{-1}$	$\mu\text{g cig}^{-1}$	$\mu\text{g cig}^{-1}$	$\mu\text{g cig}^{-1}$
by GC-MS	43.2	0.82	42.0	7.80	(1.50+4.75)	2.28
CV (%)	13.0	17.3	11.8	19.4	(68.7, 30.0)	43.0
by HPLC	34.2	0.64	38.0	7.54	5.88	2.31
CV (%)	6.8	8.9	7.1	11.6	10.2	10.6

It was also observed that the CVs obtained using the GC-MS were particularly high for low tar brands.

As a general point, good repeatability within laboratories does not necessarily result in good reproducibility between labs. In a recent inter comparison exercise, the mean results reported from six laboratories for m+p-cresol ranged from $6.4 \mu\text{g cig}^{-1}$ to $12.8 \mu\text{g cig}^{-1}$ for one brand. Each laboratory employing their own favoured technique and analysed five samples. All the laboratories reported excellent CoVs (<6%). For this brand and particular analyte there were no obvious outliers.

* GC-MS analysis was undertaken by LGC Limited

† After the first four analyses, the phenol and cresol yields for 2R4F were all on side of the mean though within 2 standard deviations whereas dihydroxy phenol yields remained randomly scattered around the mean. Historical data for 2R4F shows that this occurs from time to time but as yet no cause for this effect has been identified.

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
'phenols'	mono and dihydroxy phenols determined in the study (see below)
o	ortho
m	meta
p	para
2-methyl phenol	o-cresol
3-methyl phenol	m-cresol
4-methyl phenol	p-cresol
Catechol	o-dihydroxy benzene (o-hydroxy phenol)
Resorcinol	m-dihydroxy benzene (m-hydroxy phenol)
Hydroquinone	p-dihydroxy benzene (p-hydroxy phenol)
nd	Not detected

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