Cigarettes sold in China: design, emissions and metals

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ABSTRACT

Background China is the home to the world's largest cigarette maker, China National Tobacco Company (CNTC), yet little is known publicly about the design and emissions of Chinese cigarettes. CNTC is currently in the process of consolidating its brands and has ambitions to export its cigarettes. Machine-measured tar yields of many of its cigarette brands have also been reduced, similar to what occurred in Western countries from the 1970s through the 1990s with so-called 'low-tar' cigarettes introduced to address consumer concerns about health risks from smoking.

Method The current study examines the design and physical characteristics, labelled smoke emissions and tobacco metals content of leading brands of Chinese cigarettes from seven cities purchased in 2005–6 and in 2007.

Results Findings suggest that similar to most countries, tar levels of Chinese cigarettes are predicted primarily by tobacco weight and filter ventilation. Ventilation explained approximately 50% of variation observed in tar and 60% variation in carbon monoxide yields. We found little significant change in key design features of cigarettes purchased in both rounds. We observed significant levels of various metals, averaging 0.82 µg/g arsenic (range 0.3–3.3), 3.21 µg/g cadmium (range 2.0–5.4) and 2.65 µg/g lead (range 1.2–6.5) in a subsample of 13 brands in 2005–6, substantially higher than contemporary Canadian products.

Conclusion Results suggest that cigarettes in China increasingly resemble those sold in Western countries, but with tobacco containing higher levels of heavy metals. As CNTC looks to export its product around the world, independent surveillance of tobacco product characteristics, including tobacco blend characteristics, will become increasingly important.

INTRODUCTION

Approximately 57% of adult males and 3% of adult females in China smoke.[1] The WHO estimates tobacco-related diseases currently kill one million Chinese smokers each year,[2] with substantial increases expected in the coming years. China is increasingly a target market for multinational tobacco companies given its large population and high smoking rates.[3] *Tobacco Journal International* recently pointed to China as '… the only area of the world that the industry can look on with any degree of optimism.'[4] However, multinational brands have yet to gain substantial market share within China. China's domestic market is instead dominated by a state monopoly, and the world's largest tobacco company (by sales volume), the China National Tobacco Company (CNTC), which is overseen by the State Tobacco Monopoly Administration (STMA). Thirty-one independent cigarette factories operate in China under the direction of CNTC and STMA.[5] STMA has undertaken a plan of modernisation, which includes brand and manufacturing consolidation, aiming to create about 10 large tobacco manufacturing enterprises under CNTC. As part of this modernisation, the number of cigarette brands in China has dropped from 1181 in 2000 to 173 in 2007,[4] further dropping to 154 as of October 2008.[6] The goal is to create larger brand families with national and potentially international markets as opposed to locally popular varieties.[4 5]

As part of the CNTC modernisation strategy, efforts are under way to reduce tar levels under machine testing. In April 2006, a cap of 15 mg of tar was implemented, with a reported national average machine yield of 13.2 mg, as measured by the ISO method.[4] Lower tar (<10 mg) varieties account for about 2% of the market,[4] probably due to a lack of demand and limited competition from foreign brands.[7] However, the publicly stated goal of the tar level reduction is to reduce harm caused by smoking,[8 9] which raises the spectre of the low-tar cigarette debacle experienced by Western countries from the 1970s to the 1990s.

Reductions in tar levels to meet the newly adopted 15 mg tar yield ceiling have primarily been achieved through design modification, most prominently increasing filter ventilation, which has the effect of reducing the amount of smoke collected using the ISO machine smoking protocol. It is well established that the ISO regimen is not representative of human smoking patterns and that values obtained from smoking machines cannot be used to distinguish health risks associated with different brands.[10–14] Nevertheless, tar, nicotine and carbon monoxide emission from the ISO test are required by law to be printed on packs in China. It is increasingly recognised that these numbers are not valid indicators of health risk and can actively mislead consumers.[11–13] Indeed, Article 11 of the WHO Framework Convention on Tobacco Control (FCTC) has recommended the removal of tar and nicotine numbers from packages.[15]

There are few published reports on the design characteristics of cigarettes sold in China. Chen and colleagues reviewed news reports about herbal-tobacco cigarettes in China, which claimed health benefits but for which supporting data were difficult to locate.[16] Akpan and colleagues[17] reported the levels of polycyclic aromatic hydrocarbon levels in Chinese cigarettes purchased in 2003–4 when smoked under the ISO regimen. Tar yields ranged from 6.3 mg/cigarette to 17.4 mg/cigarette, and benzo[a]pyrene (BaP) levels from 5.8 mg/cigarette to 14.2 ng/cigarette. The reported BaP levels were 2–7 times higher than contemporary cigarettes from the European Union. But the authors did not report physical characteristics or design features of the tested cigarettes, such as tobacco weight or filter ventilation, which would have a strong influence on observed BaP levels. Such measurements are critically important for understanding variability in TNCO yields across brands; in particular, filter ventilation can explain virtually all of the inter-brand variability in tar levels.[18 19]

In order to better understand the emerging epidemic of tobacco-caused illness in China and globally, given CNTC's role as the largest producer of cigarettes in the world, data on the changing design and emission characteristics of Chinese cigarettes are needed (eg, Geoffrey T, Fong, Yuan Jiang, *et al*. Introduction to the International Tobacco Control Policy Evaluation Project in China (ITC China Project). Tobacco Control, unpublished). This paper presents data on the physical characteristics, tobacco contents and selected smoke emissions of popular cigarette brands manufactured and sold in seven cities in China during 2005–6 and 2007. We addressed two main research questions: (1) how do the design and emission characteristics of Chinese cigarettes compare to those of established international brands; and (2) to what extent did the design and emission characteristics of Chinese cigarettes change between 2005–6 and 2007, if at all?

METHODS

Data for this study come from cigarettes purchased in China initially from December 2005 to March 2006 (2005–6), and again in October–December 2007 (2007). Cigarettes were purchased at typical retail locations in seven cities in China (Beijing, Changsha, Guangzhou, Shanghai, Shenyang, Yinchuan, Zhengzhou). In each city, a list of target brands was created and one carton of each brand was purchased at each of three distinct retail locations. In 2006, 65 target domestic brands were identified from local investigator knowledge of popular brands available at retail. In 2007, 28 leading domestic brands were identified by self-report data obtained from Wave 1 of the ITC China Survey.[20] While some imported varieties were also purchased (eg, Marlboro, State Express 555, Mild Seven), the current discussion focuses on domestic cigarette varieties. The tested brand varieties are listed in table 1. All cigarettes were shipped to the Tobacco Research Laboratory at Roswell Park Cancer Institute (RPCI) via overnight courier and stored unopened at −20°C until analysis.

Characteristics

Cigarette physical and design characteristics were assessed on all products using methods described previously.[18 19] Prior to analysis, the cigarettes tested were stored in a freezer at −20°C. The packs were conditioned for a minimum of 48 hours at 22°C±2.0°C and 60%±2.0% relative humidity in an environmental chamber per ISO. For a single brand, five cigarettes were randomly selected for each assay and the data averaged together. Physical measures were taken using digital callipers, including cigarette length and diameter, filter length, length of the tipping paper, distance to any areas of filter ventilation and the length of the tobacco rod. Filter weight measurements were made using a Mettler-Toledo analytical balance. The moisture and weight of tobacco was then analysed using an HR83 Moisture Analyser (Mettler-Toledo, Ohio, USA). The moisture content was determined as the percentage change in weight after heating the tobacco from five cigarettes with a halogen bulb at 125°C until an asymptote was reached. Weight is reported as the average of tobacco from five cigarettes prior to drying. The level of permeability of each cigarette paper was also examined using a PPM1000M paper porosity device (Cerulean, Milton-Keynes, UK) using the vacuum method. Lastly, the measurements of the cigarette filter ventilation and pressure drop were taken using a KC3 combined dilution/pressure drop instrument (Borgwaldt-KC, Richmond, Virginia, USA). For consistency, all products were tested contemporaneously and laboratory analysis was completed in April 2009.

Emissions

Values of tar, nicotine and CO (where available) as reported on packs were recorded for all products. These are ostensibly measured using the ISO testing regimen (ISO 3308),[i] in which 35 ml puffs of 2-second duration are drawn from the cigarette every 60 seconds until a fixed butt length is reached.

Metals concentration

A randomly selected subsample of 2006 brands (n=13) was tested for trace metals in unburned tobacco using polarised energy dispersive x-ray fluorescence[21] at St Andrews University in October–November 2007. In brief, tobacco extracted from about 20 cigarettes was dried and powdered. Two pressed pellets, each of about 6 g, were analysed quantitatively for several heavy metals and other trace elements on a Spectro XLAB using calibrations based on a wide range of reference standards including foliage materials. A more complete description with data on detection limits, etc, is published elsewhere.[22]

Statistical analysis

Analysis of data was conducted using SPSS 14.0. Brands that were not repeatedly sampled in each year were compared by Mann-Whitney U tests to account for differences in variance between samples. Repeatedly sampled brands (n=15) were compared via Wilcoxon signed rank tests. Averages of tested Chinese brands were compared to previously published data using t tests based on means and standard deviations. Relations between measured physical and design parameters and TNCO emissions were examined via stepwise linear regression, with an indicator variable for year of purchase was forced first into the model. Stepwise entry of other potential predictors used p value criteria of 0.10 and 0.15 for entry and removal, respectively, to be inclusive of features that might have small overall roles.

RESULTS

Product characteristics

Table 1 presents the per-brand values for ventilation, paper permeability, tobacco weight and rod and filter densities. Mean values for the products purchased in each year are presented in table 2. Comparing those brands purchased at both rounds (n=15) very few significant differences are evident. The 2007 versions of these products were slightly longer (apparently mostly attributed to longer tobacco rods), and had slightly higher packing density, but slightly lower moisture content.

Table 3 presents comparisons of the Chinese market cigarettes (combining both sets, but including only the 2007 purchase of repeated brands) to two published sources of cigarette characteristics data. The study by O'Connor and colleagues[19]

[i] http://www.iso.org/iso/iso_catalogue/catalogue_ics/catalogue_detail_ics.htm?csnumber=28325.

Table 1 Chinese brands examined in the current study with selected physical and design characteristics reported, 2005—7

Brand	Descriptor	UPC	Tobacco weight (mg)	Filter density (mg/ml)	Rod density (mg/ml)	Paper permeability (CORESTA)	Ventilation (%)
Baisha	Blue	191098	660.4	109.2	251.5	53.6	0.0
Baisha	Combination	191838	693.4	116.9	258.5	52.0	0.0
Baisha	Environmental protection	191432	681.4	114.3	258.2	49.0	0.3
Baisha	Red, soft, treasure	192545	693.4	116.7	263.3	50.8	0.0
Baisha	Silver lid	191500	690.6	111.8	240.2	52.0	0.0
Baisha	White lid	191029	714.2	113.8	244.9	34.9	0.0
Changzheng	Red hard pack	038638	678.2	115.7	241.6	53.9	2.5
Chunghwa	Lights red	075794	751.2	114.0	246.7	52.0	20.9
Cocopalm	Blue	002097	693.2	114.9	235.6	47.9	2.0
Cocopalm	Green	002752	676.4	116.4	229.7	47.1	0.1
Cocopalm	Red	002233	715.0	114.0	255.4	78.5	2.5
Daqianmen	Soft pack	075916	728.6	117.2	248.0	55.8	3.9
Derby	King size, tan	132268	676.8	118.9	236.5	57.2	22.1
Derby	White, soft pack	126021	669.2	117.8	256.7	45.9	0.0
Diaoyutai	Soft	326391	681.2	114.5	246.1	26.5	11.9
Dihao	Golden hard	170765	687.2	120.4	240.2	46.8	0.5
Double happiness	Elite	075602	752.8	113.3	255.9	27.4	21.9
Double happiness	Lights green	075978	703.2	106.3	246.2	54.9	17.0
Double happiness	Low tar	075824	726.8	107.1	250.1	52.8	20.7
Double happiness	Regular	075800	737.8	117.9	243.1	51.6	2.8
Double happiness	Soft	075817	730.4	113.1	237.9	57.3	3.6
Double happiness	Super aromatic	75831	633.0	114.3	230.4	57.4	23.5
Furong Xiangyan	Soft, gold	199414	699.6	121.0	244.9	38.1	2.2
Furongwang	Masterwork	193856	660.4	84.3	255.6	52.2	0.1
Furongwang	Yellow, lid	193498	729.0	122.3	248.8	52.6	0.9
Golden leaf	Light of the century	161145	693.8	112.2	239.8	43.2	0.1
Good fortune	Light red	050371	634.2	112.8	237.1	51.5	0.3
Happiness	King size, red	050678	698.6	119.5	246.9	54.5	1.7
Hatamen	Aromatic	149358	666.8	106.9	244.8	68.6	3.4
Honghe	Lid	055048	637.4	114.9	240.8	52.6	0.2
Honghe	Soft	055024	640.0	115.0	252.0	57.9	0.6
Hongjinlong	Dance of the fire	180177	657.4	112.7	239.3	58.5	0.7
Hongjinlong	Hard	179416	695.6	113.9	237.9	57.2	0.9
Hongmei	Red super aromatic	317610	679.8	114.2	248.5	38.8	19.5
Hongmei	White	315098	640.6	119.4	241.5	61.0	0.4
Hongmei	Yellow lid	314145	690.2	111.4	256.6	57.0	0.1
Hongmei	Yellow soft	048125	689.2	111.9	254.0	52.7	0.2
Hongqiqu	Gold elite	164511	661.4	109.5	248.4	64.8	0.8
Hongqiqu	Light of the milkyway	164542	645.4	118.2	246.4	55.1	14.2
Hongqiqu	Silver, special 1st class	164375	639.8	111.8	239.2	64.3	0.9
Hongtashan	Gold	314015	676.6	117.1	246.7	37.5	32.6
Hongtashan	Red platinum	317450	688.2	111.9	247.4	59.6	18.5
Hongtashan	Regular, red	316156	666.8	110.9	242.7	38.3	13.3
Hongtashan	Yellow	048231	687.2	113.8	253.6	37.2	29.3
Houwang	Hard	058032	668.4	114.1	252.3	57.1	1.0
Jinmanggou	Green	166041	661.6	116.9	252.3	67.5	0.0
Jinxuchang	Yellow soft	162012	685.4	110.3	227.4	46.5	1.2
LanLing	Green	091794	670.8	118.4	257.7	40.5	0.2
LanLing	Yellow	091176	691.8	112.8	248.2	54.1	1.5
Lesser Panda	Black soft	337168	720.6	112.4	245.7	53.5	16.6
Liqun	Hard	118170	711.4	119.2	252.9	56.4	2.8
Liqun	Long filter	118811	583.4	111.1	225.9	45.8	0.0
Mellow Furong	Yellow	193818	684.2	113.6	233.3	39.1	0.0
Peony	Filter kings- red	075855	665.6	112.2	225.5	56.7	5.8
Peony	Red	075589	698.6	115.6	229.1	61.7	0.4
Peony	Red, soft pack	075862	710.2	119.2	261.8	61.1	4.0
Peony	White	076012	714.6	117.9	242.2	58.0	4.3
Pingtan	Red	069427	655.2	113.1	238.7	53.7	0.1
Pingtanxian Gyan	White	069205	700.2	120.2	259.7	62.0	0.5
Pride	Black, multi-coloured print	025577	729.4	104.9	258.2	56.9	0.4
Sanhua	Blue	160018	668.6	111.0	218.2	39.9	1.0
Shanghai		075848	748.6	116.7	247.3	57.4	4.6

Continued

Table 1 Continued

Brand	Descriptor	UPC	Tobacco weight (mg)	Filter density (mg/ml)	Rod density (mg/ml)	Paper permeability (CORESTA)	Ventilation (%)
Shuangxi	Classic hard pack	000642	690.6	117.9	239.3	41.9	0.5
Shuangxi	Soft pack	001489	698.2	114.9	228.2	48.7	1.1
State Guests	Black, lights	052504	719.2	113.0	250.3	55.3	0.3
Stone Forest	White	050883	656.2	120.3	235.1	48.8	1.3
The Scarlet Camellia	Purple	310192	738.0	122.3	257.3	74.6	0.3
The Scarlet Camellia	Red	045605	728.6	125.3	256.0	63.0	0.7
Yizhibi	Hard	149396	688.0	102.6	248.0	62.5	0.9
Yun Yan	Regular (purple)	046886	647.6	119.2	243.2	58.4	0.6
Yun Yan	Regular (white)	045636	649.2	117.2	236.5	68.4	1.1
Yun Yan	Regular, red	045575	705.8	113.7	239.0	67.4	1.6
Yun Yan	Treasure	045902	713.6	114.6	238.1	61.1	0.2
Zhongnanhai	Herb Blend Regular[10]	071284	648.4	109.9	210.8	60.0	27.8
Zhongnanhai	Herb Blend- Regular[8]	071499	600.0	114.9	218.8	56.4	26.5
Zhongnanhai	Red, regular, hard	072038	722.0	114.2	238.9	52.2	11.8
Zhongnanhai	White, hard[3]	071673	591.2	117.8	216.8	58.3	59.2
Zhongnanhai	White, hard, colourful[8]	071765	577.2	109.9	208.5	57.0	25.0

examined characteristics of cigarettes sold in the USA, UK, Canada and Australia in 2005, while the study by Counts and colleagues[23] reported limited design information on Philip Morris international brands in 2004. As one can see the Chinese cigarettes are substantially different on a number of parameters, most notably filter ventilation, but also rod length, tobacco weight, rod and filter density, and paper permeability.

TNCO emissions and design

We examined the relation of the measured design features to labelled emissions of tar, nicotine and CO in the 78 unique varieties of Chinese cigarettes using stepwise linear regression. Results are shown in table 4. Prediction of tar yields involved a number of parameters, with ventilation making the largest single contribution to variation in yields (over 57% of variance), and parameters such as filter weight and paper permeability making minor contributions. The total model had an adjusted R^2 of 0.721, suggesting that the majority of variation in tar could be explained by the included parameters. Nicotine yielded a less complex model, with ventilation again serving as the largest predictor (40% of variance), with tobacco weight and filter length serving as significant contributors. However, the overall adjusted R^2 for this model was 0.472, suggesting that half the variation in nicotine yields could be explained by unmeasured parameters. Finally, for CO, the major contributors were ventilation and paper permeability, together explaining 49.3% of variation in CO yields. Design features not listed did not contribute significantly to the respective prediction model (p values >0.20).

Metals in unburned tobacco

Overall, as depicted in figure 1, the levels of metals of health concern (Cr, As, Cd, Pb) varied considerably among brands. The tested Chinese brands averaged 0.55 μg/g Cr (range 0.0–1.0), 0.78 μg/g As (range 0.3–3.3), 3.24 μg/g Cd (range 2.0–5.4) and 2.54 μg/g Pb (range 1.2–6.5). figure 2 presents comparison data from the Canadian market in 2004 (see Hammond and O'Connor for more details[24]) indicating that levels of Cr are comparable to Canadian brands (though statistically significantly different, p values <0.02 by t test), but that levels of As, Cd and Pb are substantially (2–3-fold) higher (p values <0.0001).

Table 2 Mean physical characteristics of Chinese brands tested in both 2005–6 and 2007

	Independent samples		Repeat samples (n=15)	
	Mean (SE)		Mean (SE)	
	2005–6 (n=50)	2007 (n=13)	2005–6	2007
Labelled tar (mg/cigarette)	13.9 (0.31)	12.9* (0.57)	13.5 (0.5)	12.9‡ (0.5)
Labelled nicotine (mg/cigarette)	1.13 (0.02)	1.12 (0.04)	1.07 (0.04)	1.08 (0.04)
Labelled CO‡ (mg/cigarette)	13.4 (0.55)	13.8 (0.55)	12.9 (0.5)	12.9 (0.4)
Cigarette length (mm)	83.8 (0.02)	83.7 (0.04)	83.6 (0.06)	83.9‡ (0.03)
Rod diameter (mm)	7.6 (0.02)	7.6 (0.03)	7.6 (0.05)	7.6 (0.03)
Tipping paper length (mm)	29.4 (0.40)	28.5 (0.58)	28.2 (0.65)	28.4 (0.67)
Tobacco rod length (mm)	61.4 (0.40)	62.3 (0.62)	61.4 (0.66)	62.4‡ (0.63)
Filter length (mm)	22.0 (0.54)	20.2* (1.1)	22.0 (0.64)	21.8 (0.67)
Filter weight (mg)	115.8 (2.68)	107.3 (6.2)	114.6 (4.7)	114.6 (3.1)
Paper permeability (CORESTA units)	52.7 (1.40)	52.3 (1.88)	49.5 (0.70)	52.9 (0.90)
Pressure drop (mmwg)	107.0 (1.61)	115.9*(2.74)	119.0 (3.2)	112.9 (2.6)
Ventilation (%)	7.3 (1.67)	4.9 (2.74)	5.9 (2.0)	4.6 (1.8)
Tobacco weight (mg)	684.2 (5.57)	675.2 (9.19)	680.0 (7.9)	687.1 (8.4)
Filter density (mg/ml)	113.9 (0.84)	116.3 (1.01)	113.1 (1.19)	113.7 (1.10)
Rod density (mg/ml)	244.6 (1.62)	239.2 (4.03)	239.1 (2.14)	242.0†(2.32)
Moisture (%)	19.1 (0.16)	18.3 (0.45)	19.0 (0.21)	18.3‡ (0.30)

*p<0.05 by Mann-Whitney test.
†p<0.05 by Wilcoxon signed rank test.
‡p<0.01 by Wilcoxon signed rank test.

Table 3 Mean (SD) of physical characteristics of cigarettes from different studies

	China (current study)		O'Connor *et al* (2008)[18]		Counts *et al* (2005)[22]	
Parameter	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
No tested	78		172		48	
Pressure drop	109.6*	11.4	98.6	15.3	NR	
Ventilation	6.4* †	10.7	37.8	21.6	37.3	22.1
Tobacco rod length	61.7*	2.6	59.9	3.3	NR	
Tipping paper length	28.9	2.6	28.2	3.1	NR	
Tobacco weight	683.3*	36.9	640.0	79.1	679.0	86.8
Rod density	243.2*	11.7	229.1	23.7	NR	
Filter density	114.2*	5.3	122.2	10.9	NR	
Paper permeability	53.3†	9.6	NR		45.0	16.5

*significantly different from O'Connor *et al*[18] at $p<0.0001$ by t test.
†significantly different from Counts *et al*[22] at $p<0.001$ by t test.
NR, not reported.

DISCUSSION

The current paper examined the variation in design features in contemporary Chinese cigarettes and their relation to reported ISO emissions, as well as tobacco metal contents in a subsample of popular cigarette brands purchased in seven cities in China in 2005–6 and 2007. The physical and design characteristics of Chinese domestic cigarettes were broadly similar to manufactured cigarettes examined in international samples.[19 23 25] However, they did show significant differences in specific parameters such as ventilation, tobacco weight and paper permeability. Mass-manufactured cigarettes have relatively tight parameters for features such as overall length and diameter, such that there is little variation among brands or across countries within a product class (eg, king size filter tipped). Most observed brand-to-brand variation occurs in tobacco and filter weight, filter length, paper permeability and filter ventilation. Consistent with data from other countries, filter ventilation emerged as the most important predictor of labelled tar, nicotine and CO yields, though the relation was not as strong as observed in other studies, where R^2 values of 0.90 and greater are seen.[18 19] Differences in predicted yields from previous studies probably reflect the restricted range of yields examined in China since very few brands purchased had tar yields lower than 10 mg, in contrast to many Western markets where 50% or more of tar yields fall below 10 mg. The predictive model for nicotine was weakest, suggesting that engineering features may not be the primary drivers of nicotine yield in China, especially considering the very narrow range of yields observed. The findings overall underscore the influence of ventilation, even at relatively low levels, in manipulating the emission levels of products when tested under the standard ISO regimen, which remains the basis for reporting in much of the world. The fact that few brands on the Chinese market currently have yields below 10 mg suggests a potential marketing opportunity for CNTC as Chinese smokers become increasingly educated about the health risks of smoking. Indeed, evidence from the ITC Survey suggests that many Chinese smokers believe 'light'/'low tar' cigarettes are less harmful.[25]

We found relatively high levels of arsenic, lead and cadmium in the tobacco of domestic Chinese cigarettes, substantially higher than cigarettes from Canada.[26] This is consistent with existing literature on metals in counterfeit cigarettes, the majority of which appear to originate in China.[21] Metal content in tobacco leaf primarily is driven by the metal content of the soil in which it is grown, rather than resulting from processing.[27] Various investigations using different methodologies consistently indicate that cadmium (an IARC Type 1 carcinogen) transfers linearly from tobacco into smoke emissions.[24 28 29] Galazyn-Sidorczuk *et al*[28] have shown that this correlation extends to blood cadmium levels. Recent work also suggests that cadmium and lead levels are higher in lung tissues of current and former smoking lung cancer patients relative to non-smokers.[30] Furthermore, large increases in transference factors are observed using the Canadian intense smoking protocol compared with the ISO protocol (factors of 2.9 and 2.4 respectively for Cd and Pb; 25), meaning transfer increases with increasing smoking intensity. Thus cadmium and lead concentrations in tobacco can be taken as first order indicators of relative exposure to different products. While the relative health burden of metal exposure from tobacco is still unclear, some studies suggest that they might be at least as important in carcinogenesis as polycyclic aromatic hydrocarbons (PAHs) and N-nitrosamines.[31]

The higher yields of cadmium and lead in cigarettes manufactured in China are worrisome given current smoking prevalence in China and CNTC's export ambitions. Health and regulatory officials around the world should be concerned about the potential for export of cigarettes (or processed tobacco) with manifold higher contents of known toxicants from China into international markets. From a regulatory perspective, precluding import of tobacco and tobacco products with high arsenic, cadmium, and/or lead content, using relatively simple leaf and filler analysis as screening tools, could have substantial impacts on the international tobacco trade and, potentially, public health. Regulatory limits on metal contamination would not be unprecedented. Australia and New Zealand, for example, have maximal limits for arsenic (1 mg/kg[ii] in cereals), cadmium (0.1 mg/kg in leafy vegetables) and lead (0.1 mg/kg in

Table 4 Stepwise linear regression results for tar, nicotine, and carbon monoxide on cigarettes purchases in China, 2005–7 (n=78)

Variable	ΔR^2	B	Beta	t	p Value
Tar					
Intercept		−4.183		−0.796	0.429
Year	0.049	−1.274	−0.283	−4.455	<0.001
Ventilation	0.577	−0.118	−0.584	−7.675	<0.001
Tobacco weight	0.047	8.785	0.149	1.615	0.111
Filter weight	0.044	39.023	0.332	3.522	0.001
Paper permeability	0.016	−0.25	−0.112	−1.791	0.078
Rod length	0.010	0.160	0.192	1.683	0.097
Final model	0.721				
Nicotine					
Intercept		0.095		0.299	0.766
Year	0.008	−0.033	−0.098	−1.142	0.257
Ventilation	0.402	−0.007	−0.441	−4.351	<0.001
Tobacco weight	0.037	1.195	0.275	3.064	0.003
Filter length	0.053	0.012	0.277	2.778	0.007
Final model	0.472				
CO (N=40)					
Intercept		16.571		14.669	<0.001
Year	0.004	−0.183	−0.049	−0.429	0.67
Ventilation	0.477	−0.142	−0.713	−6.244	<0.001
Paper permeability	0.050	−0.040	−0.224	−1.988	0.054
Final model	0.493				

B, unstandardised regression weight.
Beta, standardised regression weight.

[ii] 1 mg/kg = 1 ug/g.

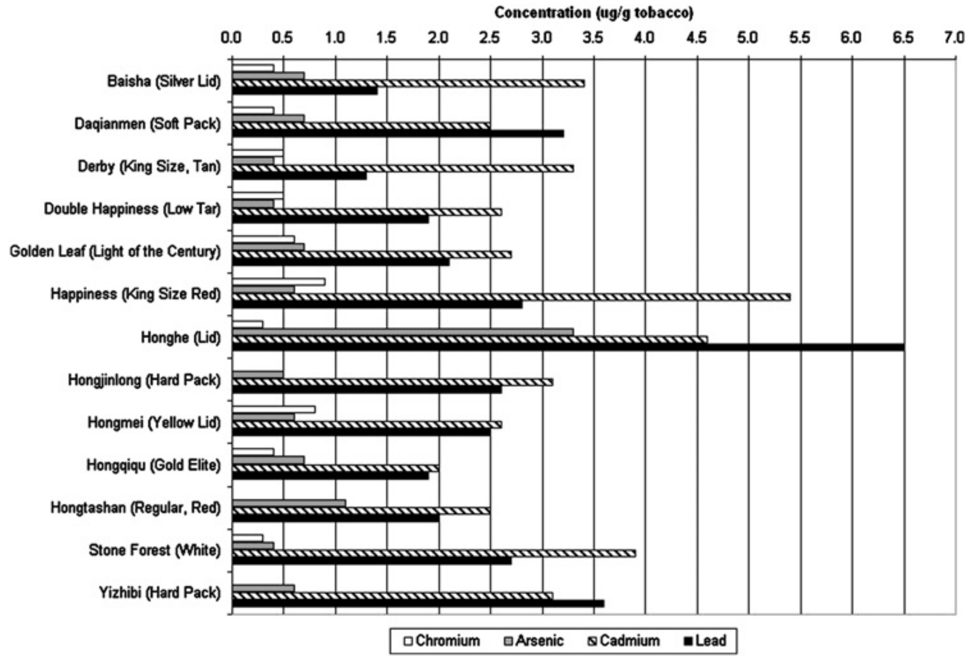

Figure 1 Distribution of metal content of unburned tobacco in 13 Chinese cigarette varieties, 2005–6.

vegetables) in plant products intended as foods.[32] Cigarette tobacco (even those in Canada) generally exceeds these levels.

A limitation of the current study is the reliance on labelled values for tar, nicotine and CO for regression analyses rather than direct testing of emissions. In addition, metals were only tested for a subset of brands. Another limitation is that brands for this study were not selected strictly on the basis of market share or to represent a broad range of tar yields, but rather were a convenience sample. Future research should replicate these findings across a market-based sample.

China is a party to the FCTC and is moving to implement regulations to meet its treaty obligations. Simultaneously, it owns the world's largest tobacco company. Chinese tobacco scientists appear to be active in research and development of new products and emission reduction technologies, which speaks to the growing sophistication of the Chinese industry.[33] These reports are consistent with STMA's moves to modernise factories and adopt manufacturing and quality control technologies from the major international companies. It is also possible, then, that product-level regulations such as chemical-specific emissions limits[12] could be implemented in China with emerging production technologies. Particular attention should be paid to eliminating heavy metals from tobacco.

Overall, the findings from this study suggest that Chinese cigarettes differ in substantive ways from cigarettes sold in Western markets, though they follow similar patterns in determining tar and nicotine yields under standard testing conditions. But the presence of high levels of heavy metals in Chinese cigarettes may constitute a potential global public health problem as exports of Chinese cigarettes continue to increase.

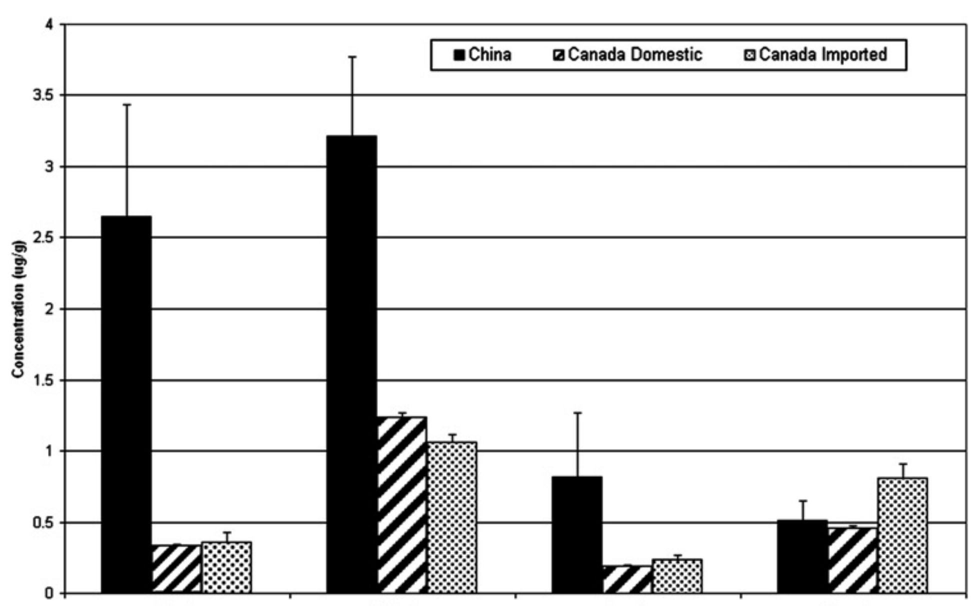

Figure 2 Comparisons of average metal contents for Chinese and Canadian cigarettes. Error bars represent 95% CIs.

What this paper adds

There is very limited public information about the design and emissions of Chinese cigarettes. In recent years the China National Tobacco Company (CNTC) has reduced the machine measured tar yields of many of its cigarette brands, similar to what occurred in Western countries from the 1970s through the 1990s with so-called 'low-tar' cigarettes introduced to address consumer concerns about health risks from smoking. Findings from this study suggest that, as in most countries, reported tar levels are predicted primarily by tobacco weight and filter ventilation. We found particularly high levels of cadmium and lead in Chinese cigarette tobacco, which is probably the result of soil conditions where tobacco is grown in China. The presence of high levels of these and other heavy metals may constitute a global health concern as China increases their cigarette exports.

Regulators should require disclosure of the source and growing conditions of tobacco used in all products and should consider product standards based on heavy metal content.

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中国卷烟：设计、释放物和金属成分

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摘要

背景：中国烟草总公司（CNTC）是全世界最大的卷烟生产商，然而对于中国卷烟的设计和释放物信息公开的还十分有限。CNTC目前正在进行品牌合并，并积极出口其卷烟产品。CNTC多种卷烟品牌都降低了其机检焦油释放量，这一做法同西方国家上世纪70年代到90年代所谓的"低焦"卷烟策略如出一辙，目的就是为了针对消费者对于吸烟健康风险的顾虑。

方法：本次研究考察了2005-6年、2007年从中国七个城市购买的主流国产品牌卷烟的设计和物理特性、盒标烟雾释放物成分和烟草金属含量。

结果：本研究结果显示同大多数国家一样，中国卷烟的焦油含量水平主要还是通过烟丝含量和过滤嘴通气能力两个因素进行预测。通气能力可以解释大约50%观察到的焦油释放变异和60%的一氧化碳（CO）释放变异。两轮购买的卷烟中在关键设计特点方面未发现显著的变化。我们在2005-6年收集的13种品牌的卷烟样本当中发现了相当高水平的各种金属成分，平均砷含量达0.82μg/g（范围：0.3-3.3），镉含量达3.21μg/g（范围：2.0-5.4），铅含量达2.65μg/g（范围：1.2-6.5），远高于当前的加拿大产品。

结论：本研究结果显示，中国卷烟正在越来越多地模仿西方国家产品，但是其中的重金属含量水平却更高。CNTC希望将其产品出口到世界各国，因此对烟草产品特性的独立监测，包括烟草成分特性的监测将变得越发重要。

前言

中国约有57%的成年男性和3%的成年女性吸烟。[1] 据WHO估计，中国目前每年死于烟草相关疾病的人数达100万，[2]且预计这一数字在未来几年内还会发生显著增长。由于有着巨大的人口基数和很高的吸烟率，中国正在越来越成为众多跨国烟草企业的目标市场。[3]《国际烟草杂志》近期将中国比为"……全世界唯一一个（烟草）产业界还可以带着一丝乐观关注的地区。"[4] 然而，跨国品牌在中国国内市场的份额尚小，这一块市场一直是由国家垄断机构控制着，这一机构也是全球（销售量）最大的烟草企业——中国烟草总公司（CNTC），下属于国家烟草专卖局（STMA）。在CNTC与STMA的领导下，全中国共有31家独立的卷烟生产厂家。[5] STMA采取了一项现代化计划，包括合并品牌和厂家，意图在CNTC下建立约10个大型烟草生产企业。

作为这一现代化举措的一部分，中国的卷烟品牌已经从2000年的1181种被压缩到了2007年的173种，[4]到2008年10月又进一步被减少到154种。[6] 其目的是为了建立针对全国乃至国际市场的更大型的品牌家族，减少仅在地方流行的品牌。[4 5] 采取措施，降低卷烟的机检焦油水平也是CNTC现代化战略的一部分。2006年4月，中国实施15mg焦油水平上限，并公布根据ISO方法测定的全国卷烟平均机检焦油释放量为13.2mg。[4] 目前焦油含量更低（<10mg）的品种约仅占中国市场份额的2%，[4]这可能是由于需求不足和来自外国品牌的竞争有限。[7] 不过，降低焦油含量这一举措公开宣称的目的是减少吸烟危害，[8 9]这让人不禁联想起上世纪70年代到90年代导致西方国家低焦烟泛滥的诡计。

降低焦油含量，达到新发布的15mg上限标准主要是通过调整设计得以实现的，其中最明显的就是提高了过滤嘴的通气性能，其效果就是减少了采用ISO机检吸烟程序中采集到的烟雾量。已有明确证据证实，ISO焦油检测方案对人类吸烟模式不具有代表性，吸烟机所测得到数值不能用于衡量不同品牌卷烟的健康风险。[10-14] 然而，中国法律要求必须在烟盒上印制通过ISO方法检测得出的焦油、尼古丁和CO释放数据。越来越多的人已经认识，这些数据并不是健康风险的有效指标，同时还会对消费者产生误导。[11-13] 事实上，WHO《烟草控制框架公约》（FCTC）第11条已经建议取缔烟草产品包装上的焦油和尼古丁含量的数字。[15]

目前关于中国销售卷烟的设计特点的报道还很少见。Chen与其同事回顾了关于中国中草药卷烟的新闻报道，该产品声称具有健康效益，但却很难找到相应的支持数据。[16] Akpan与其同事[17]报道了2003-2004年购买的中国卷烟按照ISO检测方案测定的多环芳烃水平，其中焦油释放量从6.3mg/支到17.4mg/支不等，苯并芘（BaP）水平从5.8mg/支到14.2mg/支不等。其报告BaP水平比同时期的欧盟卷烟产品高出2-7倍。但是该文作者没有报道测试卷烟的物理特性和设计特点，譬如烟丝含量和过滤嘴通气性等，这些特点对于BaP水平都有很大的影响。这些数据对于了解不同品牌间的焦油、尼古丁及一氧化碳（TNCO）释放变异具有十分重要的

意义，特别是过滤嘴通气性，这一特征可解释各品牌间的焦油含量水平的几乎全部变异。[18 19]

为了更好地理解中国和全球越来越严重的烟草相关疾病流行，鉴于CNTC作为全世界最大的烟草生产企业的地位，我们势必需要中国卷烟不断变化的设计和释放物特征数据。本文提供了关于2005-2006年和2007年在中国七城市生产和销售的畅销卷烟品牌的物理特性、烟丝成份和部分烟雾释放物数据。本研究针对的是两大研究问题：（1）与国际卷烟品牌相比，中国卷烟有哪些设计和释放物特点？（2）中国卷烟的设计和释放物特征在2005-2006年到2007年之间发生了多大程度的变化？

方法

本研究数据来自2005年12月到2006年3月（2005-6）和2007年10-12月（2007）在中国购买的卷烟，购买地点为中国七个城市（北京、长沙、广州、上海、沈阳、银川、郑州）的典型零售点。在每个城市首先制订一份目标品牌清单，然后分别从3个不同的零售点购买1条每种品牌的卷烟。2006年共根据当地调查人员对现有流行零售品牌的了解确定了65种目标国内品牌。2007年根据ITC中国调查第一轮自报数据确定了28个主流国内品牌。[20] 虽然调查同时也购买了部分进口品牌（如万宝路、State Express 555和Mild Seven），但此次讨论内容仅限于国产品牌。表1是测试的各种卷烟品牌列表。所有卷烟都通过快递寄往罗斯威尔帕克癌症研究所（RPCI）的烟草研究实验室，未开封置于-20℃低温下保存，直到分析为止。

卷烟特性

采用前面所描述的方法对上述13种卷烟的物理特性和设计特点进行评估。[18 19] 在分析前，待测卷烟均保存在-20℃冰柜中。测试前对烟盒按照ISO要求在温度22℃±2.0℃、湿度60%±2.0%的环境舱内放置至少48小时。对每一种品牌，每次实验随机选取5支卷烟，最后数据取平均值。采用数显游标卡尺测量物理指标，包括卷烟长度和直径、过滤嘴长度、接装纸长度、与任何过滤嘴通气区域的距离和烟杆长度。采用Mettler-Toledo分析天平测定过滤嘴重量数据。然后使用HR83湿度分析仪（Mettler-Toledo，Ohio，美国）测定烟丝重量和湿度。将5支卷烟放在一个125℃卤素灯下加热至渐近线水平，其重量变化百分比为卷烟含水率。烟丝含量使用5支卷烟干燥前的烟丝重量平均数表示。采用真空法使用PPM1000M纸张孔隙仪（Cerulean，Milton-Keynes，UK）检测每张卷烟纸的透气性水平。最后，采用KC3综合稀释/压差仪（Borgwaldt-KC，Richmond，Virginia，美国）测定卷烟过滤嘴的通气能力和压差数据。为确保一致性，所有产品均在同一时期进行检测，实验室分析完成时间在2009年4月。

释放物

记录所有产品烟盒标识上的焦油、尼古丁和CO（若有）值。这些指标采用ISO检测方案（ISO 3308）进行检测，其中对每支卷烟每隔60秒进行1次2秒长的35ml吸气，直到达到固定的烟蒂长度。

金属含量

从2006年品牌（n=13）当中随机选取一组亚样本，于2007年10-12月在圣安德鲁斯大学使用能量色散X射线荧光分析[21]测定未燃烧烟丝中的痕量金属成份。简要过程如下，首先抽取约20支卷烟的烟丝，然后将烟丝干燥后粉碎，然后采用Spectro XLAB光谱仪对2张样品粉末压片（每张约6g）的多种重金属和其它痕量元素进行定量分析，校准采用广泛的参考标准，其中包括植物物质参考标准。更为详尽、附有检测极限数据的描述可参见其它相关文献。[22]

统计学分析

使用SPSS 14.0软件进行数据分析。两次调查没有重复采样的品牌使用Mann-Whitney U检验进行比较，消除样本间变异。重复采样品牌（n=15）采用Wilcoxon符号秩次检验进行比较。将受检中国品牌的平均值按照均值、标准差与以往发表的数据进行t检验比较。采用逐步线性回归确定测得物理和设计参数与TNCO释放物之间的关系，其中购买年份指标变量被首先强制进入模型。其它潜在的预测因素按照p值0.10和0.15的水平决定进入或剔除，分别逐步代入模型，以纳入可能存在微小总体影响的因素。

结果

产品特性

表1是每种品牌的通气能力、纸张透气性、烟丝含量、烟杆和过滤嘴密度值。表2是各年份购买产品的均值。对两轮均购买的品牌（n=15）比较显示，二者几乎没有差异。相比之下，2007年购买的卷烟要稍微长一些（很明显主要是由于烟杆较长），装填密度略高，但含水率略低。

表3是对中国市场上的卷烟（两轮样本合并，但只包括2007年购买样本中重复的品牌）与两组已经发表的卷烟特性数据进行了比较。O'Connor及其同事的研究[19]探讨了美国、英国、加拿大和澳大利亚2005年销售的卷烟特性，Counts及其同事[23]报道了关于菲莫公司2004年国际品牌的部分设计信息。很容易看出，中国卷烟在一系列参数上都存在显著的差别，其中最明显的就是过滤嘴通气能力，此外还有烟杆长度、烟丝含量、烟杆与过滤嘴密度，以及纸张的透气性。

TNCO释放水平与设计

我们使用逐步线性回归方法对78个品种的中国卷烟盒标焦油、尼古丁和CO释放量数据与受测设计特点之间的关系进行了探讨，结果如表4。对焦油释放量的预测涉及一系列参数，其中通气能力对释放量变异的影响最大（超过变异的57%），相对而言过滤嘴重量和纸张透气性的影响较小。模型总体调整R^2值为0.721，说明大部分的焦油含量变异都可以通过模型中包括的参数来解释。尼古丁释放量的模型相对简单一些，其中最大的预测因素依然是通气能力（变异的40%），另外烟丝含量和过滤嘴长度也是重要的影响因素。不过，这一模型的总体调整R^2值为0.472，说明尼古丁释放量变异还有一半不能被模型中的变量解释。最后，对CO主要的影响因素包括通气能力和纸张通气性，总共可以解释CO释放量变异的49.3%。没有列出的设计特点对各种预测模型没有显著影响（p值>0.20）。

未燃烧烟丝中的金属成分

总体上讲，如图1所示，可引起健康问题的金属成份（铬、砷、镉、铅）水平在各品牌之间差异很大。受试中国品牌的金属成份平均含量如下：铬：0.55μg/g（范围：0.0-1.0）；

[i] http://www.iso.org/iso/iso_catalogue/catalogue_ics/catalogue_detail_ics.htm?csnumber=28325.

砷：0.78μg/g（范围：0.3-3.3）；镉：3.24μg/g（范围：2.0-5.4）；铅：2.54μg/g（范围：1.2-6.5）。图2是2004年加拿大市场的比较数据（更多信息请参见Hammond和O'Connor的文章[24]）。比较显示，中国品牌的铬含量水平与加拿大品牌接近（虽然差异有统计学意义，t检验p值<0.02），但是砷、镉和铅含量的水平都显著高于加拿大品牌（2-3倍，p值<0.0001）。

表1. 本研究考察的中国卷烟品牌的部分物理特性和设计特点：2005-7

品牌	品种	条码	烟丝含量	烟嘴密度	烟杆密度	纸张透气性	通气能力
白沙	蓝硬盒白沙	191098	660.4	109.2	251.5	53.6	0.0
白沙	综合型白沙	191838	693.4	116.9	258.5	52.0	0.0
白沙	环保型白沙	191432	681.4	114.3	258.2	49.0	0.3
白沙	红软珍品白沙	192545	693.4	116.7	263.3	50.8	0.0
白沙	银白沙	191500	690.6	111.8	240.2	52.0	0.0
白沙	硬盒白沙	191029	714.2	113.8	244.9	34.9	0.0
长征	红硬盒长征	038638	678.2	115.7	241.6	53.9	2.5
中华	红细中华	075794	751.2	114.0	246.7	52.0	20.9
椰树	蓝椰树	002097	693.2	114.9	235.6	47.9	2.0
椰树	绿椰树	002752	676.4	116.4	229.7	47.1	0.1
椰树	红椰树	002233	715.0	114.0	255.4	78.5	2.5
大前门	软盒大前门	075916	728.6	117.2	248.0	55.8	3.9
都宝	硬盒都宝	132268	676.8	118.9	236.5	57.2	22.1
都宝	白软都宝	126021	669.2	117.8	256.7	45.9	0.0
钓鱼台	软钓鱼台	326391	681.2	114.5	246.1	26.5	11.9
帝豪	金盒硬帝豪	170765	687.2	120.4	240.2	46.8	0.5
红双喜	精品双喜	075602	752.8	113.3	255.9	27.4	21.9
红双喜	绿双喜	075978	703.2	106.3	246.2	54.9	17.0
红双喜	低焦油双喜	075824	726.8	107.1	250.1	52.8	20.7
红双喜	普通双喜	075800	737.8	117.9	243.1	51.6	2.8
红双喜	软双喜	075817	730.4	113.1	237.9	57.3	3.6
红双喜	特醇双喜	075831	633.0	114.3	230.4	57.4	23.5
芙蓉	金软芙蓉	199414	699.6	121.0	244.9	38.1	2.2
芙蓉王	极品芙蓉王	193856	660.4	84.3	255.6	52.2	0.1
芙蓉王	黄盒硬芙蓉	193498	729.0	122.3	248.8	52.6	0.9
黄金叶	黄金叶（世纪之光）	161145	693.8	112.2	239.8	43.2	0.1
福烟	红软	050371	634.2	112.8	237.1	51.5	0.3
吉庆	软吉庆	050678	698.6	119.5	246.9	54.5	1.7
哈德门	精装哈德门	149358	666.8	106.9	244.8	68.6	3.4
红河	硬红河	055048	637.4	114.9	240.8	52.6	0.2
红河	软红河	055024	640.0	115.0	252.0	57.9	0.6
红金龙	火舞红金龙	180177	657.4	112.7	239.3	58.5	0.7
红金龙	硬红金龙	179416	695.6	113.9	237.9	57.2	0.9
红梅	特醇红梅	317610	679.8	114.2	248.5	38.8	19.5
红梅	白红梅	315098	640.6	119.4	241.5	61.0	0.4
红梅	黄硬红梅	314145	690.2	111.4	256.6	57.0	0.1
红梅	黄软红梅	048125	689.2	111.9	254.0	52.7	0.2
红旗渠	金红旗渠（精品）	164511	661.4	109.5	248.4	64.8	0.8
红旗渠	红旗渠（银河之光）	164542	645.4	118.2	246.4	55.1	14.2
红旗渠	银红旗渠（特制高级）	164375	639.8	111.8	239.2	64.3	0.9
红塔山	金红塔山	314015	676.6	117.1	246.7	37.5	32.6
红塔山	铂金红塔山	317450	688.2	111.9	247.4	59.6	18.5
红塔山	普通红塔山	316156	666.8	110.9	242.7	38.3	13.3
红塔山	黄色红塔山	048231	687.2	113.8	253.6	37.2	29.3

表1（续）

品牌	品种	条码	烟丝含量	烟嘴密度	烟杆密度	纸张透气性	通气能力
猴王	硬猴王	058032	668.4	114.1	252.3	57.1	1.0
芒果	绿盒金芒果	166041	661.6	116.9	252.3	67.5	0.0
许昌	黄色软盒金许昌	162012	685.4	110.3	227.4	46.5	1.2
蓝翎	绿盒蓝翎	091794	670.8	118.4	257.7	40.5	0.2
蓝翎	黄盒蓝翎	091176	691.8	112.8	248.2	54.1	1.5
小熊猫	软盒小熊猫	337168	720.6	112.4	245.7	53.5	16.6
利群	硬利群	118170	711.4	119.2	252.9	56.4	2.8
利群	长嘴利群	118811	583.4	111.1	225.9	45.8	0.0
芙蓉	黄盖	193818	684.2	113.6	233.3	39.1	0.0
牡丹	长嘴牡丹	075855	665.6	112.2	225.5	56.7	5.8
牡丹	红牡丹（低焦油）	075589	698.6	115.6	229.1	61.7	0.4
牡丹	软盒牡丹	075862	710.2	119.2	261.8	61.1	4.0
牡丹	白盒牡丹	076012	714.6	117.9	242.2	58.0	4.3
乒坛	红乒坛	069427	655.2	113.1	238.7	53.7	0.1
乒坛	白乒坛	069205	700.2	120.2	259.7	62.0	0.5
娇子	黑色娇子	025577	729.4	104.9	258.2	56.9	0.4
散花	蓝散花	160018	668.6	111.0	218.2	39.9	1.0
上海		075848	748.6	116.7	247.3	57.4	4.6
双喜	经典硬盒双喜	000642	690.6	117.9	239.3	41.9	0.5
双喜	软盒双喜	001489	698.2	114.9	228.2	48.7	1.1
国宾	蓝硬国宾	052504	719.2	113.0	250.3	55.3	0.3
石林	白石林	050883	656.2	120.3	235.1	48.8	1.3
红山茶	紫色红山茶	310192	738.0	122.3	257.3	74.6	0.3
红山茶	红色红山茶	045605	728.6	125.3	256.0	63.0	0.7
壹枝笔	硬壹枝笔	149396	688.0	102.6	248.0	62.5	0.9
云烟	普通紫色云烟	046886	647.6	119.2	243.2	58.4	0.6
云烟	普通白色云烟	045636	649.2	117.2	236.5	68.4	1.1
云烟	普通红色云烟	045575	705.8	113.7	239.0	67.4	1.6
云烟	珍品云烟	045902	713.6	114.6	238.1	61.1	0.2
中南海	中南海薄荷(10mg)	071284	648.4	109.9	210.8	60.0	27.8
中南海	中南海薄荷(8mg)	071499	600.0	114.9	218.8	56.4	26.5
中南海	红色硬盒中南海	072038	722.0	114.2	238.9	52.2	11.8
中南海	白色硬中南海(3mg)	071673	591.2	117.8	216.8	58.3	59.2
中南海	白硬中南海（缤纷型）(8mg)	071765	577.2	109.9	208.5	57.0	25.0

讨论

本文讨论了当前中国卷烟的设计特点，这些特点与报道的ISO释放物水平之间的关系，以及2005-6和2007年在中国七城市购买的流行卷烟品牌的亚样本烟丝金属成份含量。中国国产卷烟的物理特性和设计特点与检测过的国际品牌卷烟具有普遍的相似性。[19 23 25] 然而，它们在一些具体参数上却存在显著的差异，如通气能力、烟丝含量和纸张透气性等。工业化大规模生产的卷烟在长度和直径等参数方面相对统一，因此在同一产品类别（如加长过滤嘴类型）下的不同品牌甚至不同国家之间都差异很小。品牌之间最常见的差异主要集中在烟丝和过滤嘴重量、过滤嘴长度、纸张透气性和过滤嘴通气能力方面。同其他国家的数据结论一样，过滤嘴通气能力是盒标焦油含量、尼古丁和CO释放量的最重要预测因素，虽然本次研究得出的联系不如其它一些研究的结果那么显著，譬如在其它研究当中就曾经出现过超过0.90的R^2值。[18 19] 既往研究中预测释放量的差异可能是因为中国卷烟释放物指标范围较窄，因为在中国购买的品牌中少有焦油释放量低于10mg的，而很多西方国家市场上50%以上的产品焦油度都已经降到10mg以下了。对尼古丁的预测模型是最弱的，提示工程特点可能并不是中国卷烟尼古丁释放量的主要决定因素，特别是考虑到我们检测到的释放量范围又很小。总体来讲，本研究的结果反映出，通气能力对ISO标准检验方案测试中释放物水平具有重要影响，虽然影响力相对较低。国际上大多数研究都是基于ISO标准。目前中国市场上还很少有卷烟品牌的释放量低于10mg，随着中国吸烟者越来越了解吸烟的健康危害，这一情况对于CNTC来说将是

表2：测试的2005-6和2007年中国卷烟品牌物理特性均值

	独立样本		重复样本 (N=15)	
	平均值 (SE)		平均值 (SE)	
	2005/06 (N=50)	2007 (N=13)	2005/06	2007
盒标焦油含量 (mg/支)	13.9 (0.31)	12.9* (0.57)	13.5 (0.5)	12.9‡ (0.5)
盒标尼古丁含量 (mg/支)	1.13 (0.02)	1.12 (0.04)	1.07 (0.04)	1.08 (0.04)
盒标CO含量 (mg/支)	13.4 (0.55)	13.8 (0.55)	12.9 (0.5)	12.9 (0.4)
长度 (mm)	83.8 (0.02)	83.7 (0.04)	83.6 (0.06)	83.9‡ (0.03)
烟杆直径 (mm)	7.6 (0.02)	7.6 (0.03)	7.6 (0.05)	7.6 (0.03)
接装纸长度 (mm)	29.4 (0.40)	28.5 (0.58)	28.2 (0.65)	28.4 (0.67)
烟丝杆长度 (mm)	61.4 (0.40)	62.3 (0.62)	61.4 (0.66)	62.4‡ (0.63)
过滤嘴长度 (mm)	22.0 (0.54)	20.2* (1.1)	22.0 (0.64)	21.8 (0.67)
过滤嘴重量 (mg)	115.8 (2.68)	107.3 (6.2)	114.6 (4.7)	114.6 (3.1)
纸张透气性 (CORESTA units)	52.7 (1.40)	52.3 (1.88)	49.5 (0.70)	52.9 (0.90)
压差 (mmwg)	107.0 (1.61)	115.9* (2.74)	119.0 (3.2)	112.9 (2.6)
通气能力 (%)	7.3 (1.67)	4.9 (2.74)	5.9 (2.0)	4.6 (1.8)
烟丝含量 (mg)	684.2 (5.57)	675.2 (9.19)	680.0 (7.9)	687.1 (8.4)
过滤嘴密度 (mg/cc)	113.9 (0.84)	116.3 (1.01)	113.1 (1.19)	113.7 (1.10)
烟杆密度 (mg/cc)	244.6 (1.62)	239.2 (4.03)	239.1 (2.14)	242.0† (2.32)
湿度 (%)	19.1 (0.16)	18.3 (0.45)	19.0 (0.21)	18.3‡ (0.30)

* p<.05 by Mann-Whitney检验；
† p<.05，Wilcoxon 符号秩检验;
‡ p<.01，Wilcoxon 符号秩检验。

个潜在的市场机遇。实际上，ITC调查结果已经显示，很多中国吸烟者都认为“淡味”/“低焦油”卷烟的危害更小。[25]

我们在中国国产卷烟的烟丝中发现了较高水平的砷、铅和镉，其含量远高于加拿大产品。[26] 这和目前关于假烟的文献数据是一致的，而假烟当中的大部分都可能来自中国。[21] 烟叶当中的金属成分主要取决于烟草生长的土壤中的金属成分，而不是加工过程。[27]各种采取不同方法的调查研究都一致表明，烟草中镉（IARC一类致癌物质）的含量与卷烟燃烧时释放的量成正比。[24 28 29] Galazyn-Sidorczuk等人研究发现，这一相互关系可以一直延伸到血镉水平层面。此外，最近的研究结果也显示，当前吸烟和既往吸烟的肺癌病人肺组织中的镉和铅水平都高于非吸烟者。[30] 此外，采用加拿大强化吸烟程序与ISO程序相比（镉和铅的因子分别为2.9和2.4；25），使用前者观察到转移因子大量增加，这也就意味着吸烟强度越大，转移作用也就越强。因此，烟草的镉浓度和铅浓度可以作为不同产品相对暴露水平的一级指标。虽然由于烟草造成的金属暴露相对健康负担尚不清楚，但已有一些研究结果显示，金属成份在致癌作用方面至少应该同多环芳烃化合物（PAH）和N-亚硝胺类物质被摆在同一级别上。[31]

表3：不同研究卷烟物理特性均值（SD）

	中国（本研究）		O'Connor 等人(2008)		Counts 等人(2005)	
参数	平均值	SD	平均值	SD	平均值	SD
测试数量	78		172		48	
压差	109.6*	11.4	98.6	15.3	NR	
通气能力	6.4*†	10.7	37.8	21.6	37.3	22.1
烟杆长度	61.7*	2.6	59.9	3.3	NR	
接装纸长度	28.9	2.6	28.2	3.1	NR	
烟丝含量	683.3*	36.9	640.0	79.1	679.0	86.8
烟杆密度	243.2*	11.7	229.1	23.7	NR	
过滤嘴密度	114.2*	5.3	122.2	10.9	NR	
纸张透气性	53.3†	9.6	NR		45.0	16.5

* t检验显示p<0.0001，与O'Connor等人研究存在显著差异。
† t检验显示p<0.001，与Counts等人研究存在显著差异。
NR =无报道

表4：中国购买卷烟焦油含量、尼古丁和一氧化碳逐步线性回归结果：2005-7 (n=78)

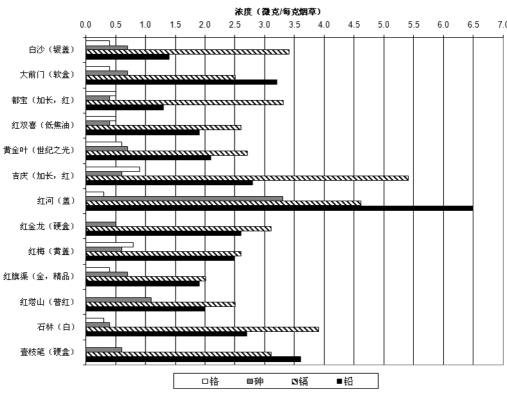
焦油含量	ΔR2	B	Beta	t	p
变量					
截距		-4.183		-0.796	.429
年份	0.049	-1.274	-0.283	-4.455	<.001
通气能力	0.577	-0.118	-0.584	-7.675	<.001
烟丝含量	0.047	8.785	0.149	1.615	.111
过滤嘴重量	0.044	39.023	0.332	3.522	.001
纸张透气性	0.016	-0.25	-0.112	-1.791	.078
烟杆长度	0.010	0.160	0.192	1.683	.097
最终模型	0.721				
尼古丁					
变量	ΔR2	B	Beta	t	p
截距		0.095		0.299	.766
年份	0.008	-0.033	-0.098	-1.142	.257
通气能力	0.402	-0.007	-0.441	-4.351	<.001
烟丝含量	0.037	1.195	0.275	3.064	.003
过滤嘴长度	0.053	0.012	0.277	2.778	.007
最终模型	0.472				
CO (N=40)					
变量	ΔR2	B	Beta	t	p
截距		16.571		14.669	<.001
年份	0.004	-0.183	-0.049	-0.429	0.67
通气能力	0.477	-0.142	-0.713	-6.244	<.001
纸张透气性	0.050	-0.040	-0.224	-1.988	0.054
最终模型	0.493				

B =非标准回归权重。Beta =标准回归权重。

鉴于中国现在的高吸烟率和CNTC的出口愿望，中国产卷烟当中的高镉、高铅水平让人担忧。世界各国卫生和管理人员应当注意中国出口的多种已知有毒物质含量超标的卷烟（或加工烟草）产品进入国际市场。从管理的角度来说，采用相对简单的烟叶和填充物分析作为筛查工具，排查进口的高砷、镉和/或铅含量的烟草和烟草产品，这种做法对于国际烟草贸易乃至公共卫生都会产生很大的影响。国际上对金属污染的管制限制是有先例的。以澳大利亚和新西兰为例，这两个国家都规定了食用植物产品当中的最高砷含量（谷物类：1mg/kg）、镉含量（绿叶蔬菜：0.1mg/kg）和铅含量（蔬菜：0.1mg/kg）限制。[32]但是，卷烟产品（即便是加拿大产品）也基本上超过了这些规定水平。

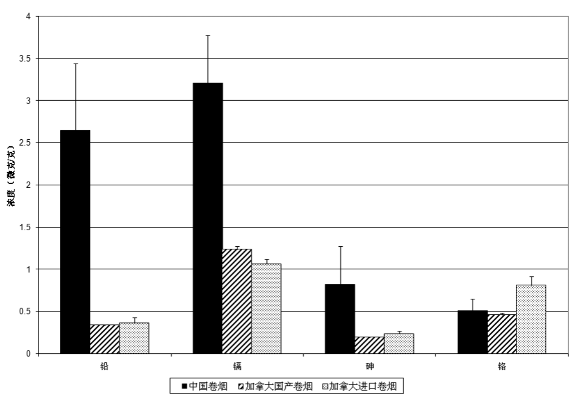
本研究的一个局限性在于，依赖盒标的焦油、尼古丁和CO数据进行回归分析，而不是采用直接的释放物测试结果。此外，研究仅针对部分品牌进行了金属检验。另一个局限性是，本研究采用的品牌不是根据其市场占有率严格挑选的，不能广泛代表焦油释放量水平，只是一个方便样本。今后的研究应当采取基于市场的样本，验证本研究的结果。

中国是FCTC成员国之一，正在逐步实施其中的规定，履行自己的公约义务。同时，中国又拥有世界上最大的烟草企业。中国烟草科学家在新产品和释放物减少技术的研发



方面显得十分积极，这也进一步增加了中国烟草产业的复杂性。[33] 这些报道同STMA对于生产厂家的现代化举措以及从主要国际企业吸收加工和质控技术的做法是一致的。那么，随着新生产技术的出现，在产品管制层面，譬如具体化学释放物限制[ii]的措施在中国实施也是可能的。这其中尤其需要重视的就是消除烟草当中的重金属成份。

总体上讲，本研究的结果显示，尽管都是在标准条件下，依照同样的方法来确定其焦油和尼古丁释放水平，中国卷烟同西方市场的卷烟产品之间依然存在很大的差别。不过，随着中国卷烟出口量不断增加，中国卷烟当中的高重金属含量可能最终变成一个全球性的公共卫生问题。管理部门应当要求公布所有烟草产品的原料来源和种植条件，要考虑产品的重金属含量标准。



研究贡献

目前，关于中国卷烟设计和释放物水平的公开信息十分有限。近年来，中国国家烟草公司（CNTC）已经降低了其下很多品牌卷烟的的机检焦油含量，这一做法同上世纪70年代到90年代西方国家的做法如出一辙——推出所谓的“低焦”卷烟，以迎合消费者对吸烟健康风险的关切。本研究结果指出，正如大多数国家一样，中国卷烟产品的报告焦油含量水平主要通过烟丝含量和过滤嘴通气能力两个因素进行预测。我们在中国卷烟的烟丝内发现了相当高的镉和铅含量，这可能是由于中国烟草种植的土壤条件导致。这两种重金属和其它重金属的高含量可能随着中国卷烟产品出口量增加，成为一个全球性的健康问题。

[ii] 1 mg/kg = 1 ug/g.

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患者同意：已取得。

来源及同行评价：未开展；经外部同行评价。

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