The Cadmium, Nickel and Lead Content of Tobacco and Cigarette Smoke*

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INTRODUCTION

There have been various references in the literature to the levels of trace metals in natural products (1, 2, 3). There have also been references to the level of cadmium found in tobacco smoke (4). We have, in the past, accepted the published data of other workers in this field (5, 6) but recently we have made our own evaluation of the level of cadmium, nickel and lead in tobacco and cigarette smoke. The work described in this paper had two objectives: firstly to determine, using recognized and unambiguous analytical procedures, the cadmium, nickel and lead content of tobacco types obtained from different sources and secondly to measure the amount of these metals found in cigarette smoke and the effect of commercial cigarette filters upon their transfer to the smoke from the tobacco. Traditionally, cadmium and other heavy metals in biological and organic samples have been analysed by somewhat complex extractions and spectrophotometric procedures after wet or dry ashing of samples. A recent paper by Nickless (7) confirmed our view that the least ambiguous analytical procedure for our purposes would be to use atomic absorption detection.

EXPERIMENTAL

All samples were conditioned, prior to analysis, for at least 48 hours at 70° F and 60% relative humidity.

Smoke Sample Preparation

The initial approach was to determine the metal content in whole smoke collected by cold trapping techniques. This approach produced several practical problems associated with the trapping of relatively large amounts of smoke and the subsequent quantitative extraction and transfer of the sample for digestion. Similar problems were experienced with the use of liquid absorption trapping techniques. Therefore the particulate and vapour phase samples were collected and analysed individually.

Particulate phase smoke samples were prepared by collecting the smoke from 5 cigarettes on a Cambridge filter pad which was then extracted with 20 ml of 5N

nitric acid by shaking for thirty minutes. This suspension was then filtered through a sintered funnel and washed with 2 aliquots of 5 ml of 5N nitric acid. The entire filtrate, including washings, from two Cambridge filter pads was transferred to a Kjeldahl flask and heated until the volume was reduced to 2 ml. The remaining solution was transferred to a 25 ml volumetric flask and made up to volume with water washings from the Kjeldahl flask. This solution was subjected to atomic absorption analysis. Initial trials had shown that this extraction and digestion procedure produced results which were similar to those achieved by direct digestion of the Cambridge filter pads in 1:4 concentrated perchloric/nitric acid mixture. The procedure used was simple and overcame the problems associated with the use of concentrated acid mixtures.

The vapour phase sample was prepared by passing smoke from five cigarettes through a Cambridge filter into a liquid absorption trap containing 10 ml of 5N nitric acid. Solutions from eight such traps were pooled and heated until the volume had been reduced to 2 ml. This solution was then made up to 25 ml with water and analysed.

Tobacco Sample Preparation

One cigarette, including paper but excluding filter materials, was digested in 30 ml of concentrated nitric acid and 2 ml concentrated perchloric acid and evaporated to 2 ml. The resulting solution was diluted to 25 ml with water and analysed. Solutions prepared in this way produced results which were equivalent to those obtained by digestion in a 1:4 mixture of concentrated perchloric and nitric acids.

Samples of Smoke Retained by Filters

Two batches of five filters were placed in glass tubes and 30 ml of 5N nitric acid passed through each batch. The eluates from both batches of filters were pooled and evaporated to 2 ml. The solution was made up to 25 ml and analysed.

Blanks

Blanks for each sample type were prepared exactly as described above except for the omission of tobacco or smoke.

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Reagents

All the water used in this work was deionised and all acids were of analytical reagent grade.

Atomic Absorption Analysis

All samples were analysed on a Techtron AA5 Atomic Absorption Instrument which incorporated a long path length air/acetylene burner.

The cadmium analysis was calibrated with solutions containing 0, 0.1 and 0.2 $\mu\text{g/ml}$ and an acid content equivalent to that of the samples being examined. The nickel and lead analyses were calibrated with solutions containing 0, 1 and 2 μg nickel and lead/ml and an acid content also equivalent to that of the samples being examined. The relationship between absorption and metal concentrations was linear for all three metals within the calibration ranges and is shown in Fig. 1.

Figure 1.

RESULTS

Our results obtained using tobaccos from various countries, two different plant positions, different curing processes and some European commercial cigarettes are shown in Tables 1, 2, 3, 4 respectively.

The results of our analyses carried out upon the smoke particulate phase from cigarettes manufactured using a single grade of tobacco are given in Table 5, whilst the cadmium levels from a number of commercial cigarettes are listed in Table 6.

The distribution of the metals between the particulate and vapour phases of smoke, and the retention of filters for cadmium are given in Tables 7 and 8.

All reported values are the mean of duplicate analyses.

DISCUSSION OF RESULTS

The results (Tables 1-4) show that the levels of cadmium, nickel and lead in the tobaccos examined lie within the range 0.5 to 3.5, 4 to 9.5 and 8 to 23 μg metal per gram of conditioned tobacco respectively.

The levels of each metal found in the tobacco types we examined were generally similar, although the

Table 1. The cadmium, nickel and lead content of flue-cured tobaccos from several countries.

Country of origin	Cadmium ($\mu\text{g/g}$)	Nickel ($\mu\text{g/g}$)	Lead ($\mu\text{g/g}$)
USA (Old Belt)	0.70	4.51	12.25
USA (New Belt)	1.01	4.81	8.93
Malawi	1.07	4.52	11.80
USA (Georgia)	0.77	4.28	12.31
Canada	3.50	6.81	18.72
Brazil	1.72	5.54	7.92
India	1.08	8.18	12.98
Japan	3.20	4.71	13.95

Table 2. The effect of plant position on metal content of Georgia tobacco.

Plant position	Cadmium ($\mu\text{g/g}$)	Nickel ($\mu\text{g/g}$)	Lead ($\mu\text{g/g}$)
Tip	0.77	4.28	12.31
Lug	1.27	4.68	22.20

Table 3. The metal content of three types of Malawi tobacco.

Type	Cadmium ($\mu\text{g/g}$)	Nickel ($\mu\text{g/g}$)	Lead ($\mu\text{g/g}$)
Flue-cured	1.07	4.52	11.80
Burley	0.55	7.83	16.20
Sun-cured	0.56	7.55	11.00

Table 4. The cadmium, nickel and lead content of commercial cigarette tobaccos.

Cigarette type	Cadmium ($\mu\text{g/g}$)	Nickel ($\mu\text{g/g}$)	Lead ($\mu\text{g/g}$)
UK	1.66	5.62	14.72
France	1.59	8.91	15.21
Belgium	1.22	9.41	14.95
Italy	1.96	8.63	22.75
Germany	2.21	9.03	17.15

Table 5. The delivery of metals in particulate matter from single grade tobacco cigarettes (plain).

Tobacco type	Cadmium		Nickel		Lead	
	Delivery ($\mu\text{g}/\text{cigarette}$)	% Transfer	Delivery ($\mu\text{g}/\text{cigarette}$)	% Transfer	Delivery ($\mu\text{g}/\text{cigarette}$)	% Transfer
USA (New Belt) — Flue	0.19	24	0	0	0.64	9
Malawi — Flue	0.11	13	0	0	0.37	4
Malawi — Burley	0.09	21	0	0	0.61	5
Malawi — Sun-cured	0.12	25	0.19	3	0.64	7
USA (Georgia) — Tip flue	0.11	17	0	0	0.97	10
USA (Georgia) — Lug flue	0.14	15	0	0	0.25	2
Canada — Flue	0.31	12	0.12	2	0.72	5
Brazil — Flue	0.18	14	0.02	1	0.98	16
India — Flue	0.14	17	0.15	2	0.44	4
Japan — Flue	0.54	19	0.19	5	0.46	4

samples of Canadian and Japanese tobaccos contained more cadmium than the other samples. There is some slight evidence that tobacco from the lower leaves of the plant contain greater concentrations of metals than those from the upper part (Table 2) but this might be

Table 6. The cadmium content of particulate matter from some commercial cigarettes.

Cigarette type	Cadmium	
	Delivery ($\mu\text{g}/\text{cigarette}$)	% Transfer
UK Type 1 — Filter	0.09	5
UK Type 2 — Filter	0.07	6
UK Type 3 — Filter	0.07	6
UK Type 4 — Filter	0.10	6
UK Type 5 — Plain	0.19	15
France — Plain	0.18	15
Belgium — Filter	0.08	8
Italy — Filter	0.06	4
Germany — Filter	0.08	5

due to contamination of the lower leaves from soil and sand. The metal levels in different tobacco types from a single country, Malawi, show similar variations in values to the European commercial tobacco blends (Tables 3 and 4), which are known to contain tobaccos cured by different processes. The levels of cadmium in most flue-cured tobaccos examined by us were found to lie within the range of results shown in Table 4.

It is very likely, therefore, that the metal content of all tobaccos are similar irrespective of the tobacco source or the curing processes used after harvesting. The ranges of results are very probably reflecting the natural variability of samples rather than specific differences between the tobacco types. The levels reported in this work were generally similar to those of previous workers (5, 6).

The levels of cadmium in particulate phase smoke from single grade tobaccos (Table 5) and European commercial cigarettes (Table 6) were generally less than $0.2 \mu\text{g}$ per cigarette and these values support results reported by Szadowski (5) and Menden (6). The transfer of cadmium from the burnt tobacco portion, both puffed and smouldered, of a plain cigarette to particulate phase of smoke was found to be 12–25%, whereas that for filter cigarettes was lower, which naturally reflects the retention of particulate phase by the filter.

The level of nickel found in the particulate phase of smoke (Table 5) was found to be low and often not detectable and the percentage transferred to smoke was always less than 5%.

Generally less than 10% of lead was found to be transferred from the tobacco to the particulate phase of smoke, the deliveries being less than $1 \mu\text{g}$ per cigarette (Table 5).

The examination of two vapour phase samples revealed that some 15–20% of cadmium in smoke was present in the vapour phase, whereas about 36% of the lead was found in the vapour phase (Table 7). The level

Table 7. The distribution of metals in smoke between the particulate and vapour phases.

Cigarette type	Cadmium		Nickel		Lead	
	Particulate phase	Vapour phase	Particulate phase	Vapour phase	Particulate phase	Vapour phase
UK plain	0.19	0.05	0	0.04	0.32	0.18
UK filter	0.04	0.007	n. d.	0.08	n. d.	0.14

Deliveries are reported as $\mu\text{g}/\text{cigarette}$.
n. d. = not determined.

Table 8. The retention of cadmium by filters in UK commercial cigarettes.

Cigarette type	Filter type	Cadmium in smoke ($\mu\text{g}/\text{cigarette}$)	Cadmium in filter ($\mu\text{g}/\text{cigarette}$)	% Cadmium filter retention	% Nicotine filter retention
UK commercial Type 1	Myria/acetate	0.088	0.171	66.0	46.1
" Type 2	Myria/acetate	0.070	0.133	65.6	44.8
" Type 3	Ventilated Myria	0.065	0.184	73.9	66.2
" Type 4	Myria/acetate	0.096	0.125	56.6	52.5
" Type 5	Myria/carbon/acetate	0.043	0.282	86.9	49.7

of nickel in the vapour phase portion of smoke was found to be very low (Table 8).

The values obtained for nickel content of particulate and vapour phases of smoke indicate that nickel is not easily transferred to smoke from tobacco. This is reflected in the non-detection of this metal in a number of smoke samples.

The examination of cadmium in particulate phase of smoke and the smoke retained by filter tips for UK commercial cigarettes shows that over 50% of the cadmium in smoke is retained by filters examined by us. We observed that the retention of cadmium by these filters is generally greater than that of nicotine.

CONCLUSIONS

The levels of cadmium, nickel and lead in tobaccos appear to be independent of country of origin or curing process. The levels of these metals in smoke are very low, especially nickel, and are similar for a variety of tobacco types and commercial brands.

Commercial filters, as expected, effect a reduction in the levels of cadmium in cigarette smoke.

SUMMARY

The cadmium, nickel and lead contents of a variety of tobacco types and their respective cigarette smokes have been measured by atomic absorption analysis. Their levels in tobacco were found to be in the ranges 0.5 to 3.5, 4 to 9.5 and 8 to 23 $\mu\text{g}/\text{g}$ respectively. The transfer of cadmium from tobacco to mainstream particulate phase was less than 25%, whereas for nickel it was less than 5% and for lead less than 10%.

Commercial filters were found to retain more than 50% of cadmium presented to them.

The levels of the metals in the vapour phase portion of smoke were found to be lower than those in the particulate phase, values for lead being higher than those of cadmium or nickel.

A small number of samples have been examined with respect to country of origin, curing processes and plant position which show some differences in metal content. These differences, in our opinion, are indicative of the likely spread of values rather than reflecting real differences due to the source of the tobacco or its treatment after harvesting.

ZUSAMMENFASSUNG

Die Gehalte an Cadmium, Nickel und Blei einer Reihe von Tabakarten und von deren jeweils entsprechendem Rauch wurden mit Hilfe der Atomabsorptions-Analyse bestimmt. In den Tabaken fanden sich folgende Werte: Cadmium 0,5–3,5 $\mu\text{g}/\text{g}$; Nickel 4–9,5 $\mu\text{g}/\text{g}$; Blei 8 bis 23 $\mu\text{g}/\text{g}$. Der Übergang des Cadmiums vom Tabak in die Partikelphase des Hauptstromrauches machte weniger als 25% aus, während Nickel zu weniger als 5% und Blei zu weniger als 10% übergingen.

Es zeigte sich, daß handelsübliche Filter mehr als 50% des Cadmiums retinieren, das ihnen zugeführt wird.

In der Dampfphase des Rauches war der Gehalt an den genannten Metallen kleiner als in der Partikelphase, wobei der Bleigehalt wiederum größer war als der an Cadmium oder Nickel.

Eine kleine Anzahl von Proben wurde hinsichtlich Ursprungsland, Trocknungsverfahren und Blattposition untersucht, die Unterschiede im Metallgehalt zeigten. Die Autoren sind der Ansicht, daß die beobachteten Unterschiede ein Zeichen eher der wahrscheinlichen Streuung der Werte als tatsächlicher Unterschiede sind, die auf die Herkunft des Tabaks oder die Behandlung nach der Ernte zurückzuführen sind.

RESUME

On a mesuré par analyse d'absorption atomique la teneur en cadmium, nickel et plomb de différentes variétés de tabac et de la fumée de cigarettes fabriquées avec celles-ci. On a trouvé des teneurs de l'ordre de 0,5 à 3,5; 4 à 9,5 et 8 à 23 $\mu\text{g}/\text{g}$ respectivement. Le transfert du cadmium dans la phase particulaire du flux principal est inférieur à 25%, celui du nickel inférieur à 5%, celui du plomb inférieur à 10%.

Les filtres commerciaux retiennent plus de 50% du cadmium présent.

La teneur en métal dans la phase vapeur de la fumée est inférieure à celle de la phase particulaire, les valeurs pour le plomb étant plus élevées que pour le cadmium ou le nickel.

Un petit nombre d'échantillons a été observé en fonction de son origine, des procédés de séchage, et de la position dans la plante, et donne de faibles différences en teneur de métal. Nous pensons que ces différences représentent d'avantage une dispersion des valeurs expérimentales, et ne sont pas dues à des différences d'origine ou de traitement après la moisson.

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