Transfer of Metallic Constituents of Cigarettes to the Main Stream Smoke

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When tobacco is burned most of the metallic content remains in the ash although small quantities pass into the main stream smoke and become included in the particulate phase. The presence of metals in the smoke may be due to (1) vaporization of metallic compounds - chiefly their chlorides, or (2) due to mechanical entrainment of microfragments of ash or tobacco, or due to both. In order to determine which mechanism is the major factor, quantitative data on the transfer of various elements were obtained. If the metal passes into the smoke by mechanical entrainment, then the relative proportion of that metal to the other metals in the smoke should be nearly equal to its relative proportion in the tobacco. If, on the other hand, the transfer of the metal occurs as a result of vaporization, of its chloride for instance, then the relative proportion of the metal in smoke will vary from that in tobacco depending on the degree of its volatility - i.e. differences in the transfer efficiencies of the individual elements will depend on the differences of the volatility of their metallic compounds.

Methods:

Cigarettes tested were those of five popular domestic brands, 70 mm in length and without filters and were purchased in the summer of 1956.

Before smoking, the cigarettes were conditioned and weighed. Conditioning was accomplished by placing them in 58% relative humidity in a hygrostat over deliquescent sodium bromide with a resulting moisture content of 18.1% (measured as loss in weight at 110° C for 20 hours).

es from one carton of each brand were weighed and placed in groups matched in weight by .05 gram. The highest and lowest weight categories were rejected.

The automatic smoking apparatus, loaned by Liggett and Myers Tobacco Co., was designed for 15 cigarettes, and in succession 0.2 second puffs were taken every 60 seconds. Only 13 cigarettes were used leaving 2 spaces free to check puff volume which was about 35 ml. Ten puffs were taken on each cigarette leaving a butt length of 2.0 to 2.5 cm.

Three samples of smoke were collected.

#1 from 117 cigarettes Brand A
#2 " 130 " " B
#3 " 156 " of each of five
standard brands, or a total of 780 cigarettes.

Tobacco samples were taken from:

#1 - equivalent of cigarettes including paper of Brand A
#2 - " " " " " " " B
#3 - " " " " " " each of
five brands noted.

The smoke was condensed in a series of cold traps. The first series were three cylindrical flasks, 9 x 28 cm., with a volume of 1.7 liters each, followed by three spiral traps all connected with ground glass joints and immersed in cooling baths. The first flask was in ice at about 0°C, the other five were in dry-ice---alcohol baths with a temperature at - 72°C. The flasks were weighed before and after smoke collection at room temperature.

The cold traps were followed by two flasks packed with glass wool having approximate volumes of 500 ml and 125 ml respectively. These were weighed before and after smoke collection to determine the amount of filterable smoke escaping the cold traps.

About 4% of the total weight of smoke collected was in this first flask and about 0.1% in the second. it was assumed, then, that about 96% of the total smoke was collected in the cold traps, and this is the smoke that was analyzed. About 87% of the total weight was in the three cylindrical flasks,

The smoke to be analyzed was washed from the traps by alternate rinsing with redistilled acetone, 0.06NN hydrochloric acid in 90% acetone, and water. No mention is made in the article concerning the number of times the traps are washed or by what means it is determined that the smoke has been completely removed. After removal of the smoke, the traps were rinsed with 100cc of concentrated nitric acid which was saved and used later for digestion of the tobacco. The smoke solution was concentrated by evaporation until the acetone was removed. The average weight of smoke obtained was 7.4 mg per puff or 74 mg per cigarette.

The control tobacco sample was taken as follows: for each 13 cigarettes smoked in sample No. 1 and No. 2 one cigarette of the same weight group was reserved for the tobacco sample. Thus, for sample #1 there were nine groups of 13 cigarettes smoked and therefore nine cigarettes mixed together for the tobacco sample. In sample #2 these were ten groups and therefore ten cigarettes in the tobacco sample. In each sample the cigarettes were all mixed together and the equivalent of four cigarettes used for each sample. The sample for No. 3 was composed of one average cigarette of each of the five brands used.

Digestion of the organic matter in the smoke and tobacco was begun with dilute nitric acid.

Successive evaporations after additions of concentrated nitric acid were then done until the samples were liquified. This obviously applies to the tobacco sample, since the smoke was already in solution. No mention is made of the end point for the digestion of organic matter from the smoke sample. The solutions were then treated with equal volumes of water, concentrated nitric acid, and 72% perchloric acid, and then evaporated. This was repeated until colorless or light yellow solutions resulted, at which time the solutions were evaporated to near dryness.

Hot dilute hydrochloric acid was then added to the residue, the precipitated silica was filtered off and the resulting solutions made up to a definite volume (which was not stated).

The resulting solutions were analyzed by established photometric procedures. Na^+ and K^+ were determined by flame photometry using the Perkin - Elmer Model 32-C. Lead was isolated and measured colorimetrically by extraction with dithizone. Arsenic was separated as arsine and determined by the molybdenum blue colorimetric technique.

Element	Sample No.	Micrograms per Cigarette Tobacco	Smoke	Relative % Transfer
K	1	26800	134	0.50
	2	27100	138	0.51
Na	1	870	9.2	1.06
	2	890	7.1	0.80
Pb	1	21	1.0	4.8
	2	84	3.3	3.9
	3	41	1.9	4.6
As	1	7.1	0.31	4.4
	2	26.4	1.4	5.3
	3	13.2	0.046	3.5

Other metals analyzed were calcium, magnesium, aluminum, iron, manganese, copper, zinc, nickel, chromium.

From the wide range of transfer efficiencies found it was stated that

vaporization was almost completely responsible for the metallic material found in smoke. Mechanical entrainment alone was thought to account only for calcium, magnesium and aluminum in the smoke.

To explain this process of vaporization, it was pointed out in the discussion that the temperature in the burning cone of a cigarette is from 830° to 920°C. Some metals with low boiling points such as arsenic, lead, and zinc may undergo vaporization in the metallic state. It was felt that other metals were transported as chlorides. It is known that the alkali metal chlorides are volatile at temperature below their boiling points which is 1413°C for sodium chloride, 1550°C for potassium chloride and 950°C for lead chloride. Lead chloride vaporizes rapidly above 550°C and the chloride and oxide of trivalent arsenic vaporize below 700°C. The authors state that they felt that the major part of the arsenic and lead found in the smoke was from the insecticide applied to the tobacco plant. The arsenic-lead ratio in the cigarette is comparable to that in the lead arsenate insecticide.

Sample No.	Pb/cig. (ug)	As cig. (ug)	Ratio As/Pb
1	21	7.1	0.34
2	84	26.4	0.31
3	41	13.2	0.32
			0.32
Theoretical ratio Pb H As O_4 (insecticide)			0.36

It was concluded that the total quantity of metallic elements in the smoke of one cigarette was 150 micrograms, of which about 90% was potassium and 5% was sodium and about 1.5% lead.

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