

Arsenic in Tobacco Smoke

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IN some of the tobacco growing sections of the United States, it is necessary to dust the plants with arsenicals during the growing season in order adequately to control insect pests. Lead arsenate is the insecticide most commonly used, but in some cases, particularly with plantings of cigar wrapper tobaccos, Paris green is employed.

Remington¹ apparently was the first to call attention to the presence of arsenic in commercial tobacco products. He found that samples of American pipe-smoking and chewing tobaccos carried arsenical residues ranging from 0.05 to 0.27 gr. of As_2O_3 per lb. (7 to 38.5 p.p.m.). In addition, he reported the hitherto unknown facts that about 50 per cent of the arsenic in the smoking tobaccos was volatilized in the smoke and that about 50 per cent of the arsenic in chewing tobaccos was water-soluble. Inasmuch as Remington devoted his study largely to pipe-smoking and chewing tobaccos, it is believed that the results of similar investigations made by the Insecticide Division on cigars, cigarettes, and smoking tobaccos will be of interest. The description of the smoking apparatus used in making these tests will also be of value.

SMOKING APPARATUS DEvised TO CARRY OUT THE SMOKING TESTS

The apparatus devised to carry out the smoking tests is shown diagrammatically in Figure I. It was operated as follows: In order to imitate as nearly as possible normal smoking conditions, the apparatus was designed to

draw intermittently. This was accomplished by using a small water syphon (S) by which approximately 50 c.c. of air was drawn through the apparatus at each discharge. This air, with its unabsorbed smoke constituents, was prevented from returning into the absorption chambers by means of a check valve (CV), and was discharged into the atmosphere through the Bunsen valve (BV).

The smoke from the cigar, cigarette, or pipe was pulled by the syphon through an absorption train, consisting of two glass tubes about 20 cm. long and 2.0 cm. in diameter, each being constricted to about half the outside diameter at its mid-point. The absorbing material was absorbent cotton, moistened with 5 c.c. 1 per cent NaOH in (B) and 5 c.c. 3.5 per cent HCl in (A). Test runs showed that all the arsenic in the smoke was caught in the tube next to the smoking chamber (SC), but the second tube was retained as an additional safety measure.

The smoking chamber assembly (SC) consisted of a cigar holder, into which could be inserted a cigarette holder (CH) an ash tray (not shown in sketch) placed under the cigar or cigarette, and a glass jacket fitted with a ground glass joint and two side tubes. One side tube was left open for the entrance of air, while the other was connected by a rubber tube to a second absorption train, which in turn was connected to a continuous aspirator. The arsenic in any smoke given off between "draws" was thus absorbed in

this train. In testing smoking tobaccos, the tobacco could either be smoked in a pipe or be made into cigarettes and smoked in this way. In our tests the pipe was used, in which case the smoking chamber assembly was re-

and water was run into the syphon chamber at the rate of about 150 c.c. per minute. As soon as the syphon was functioning properly and discharging at the rate of about 3 times per minute, the cigar or cigarette or pipe was

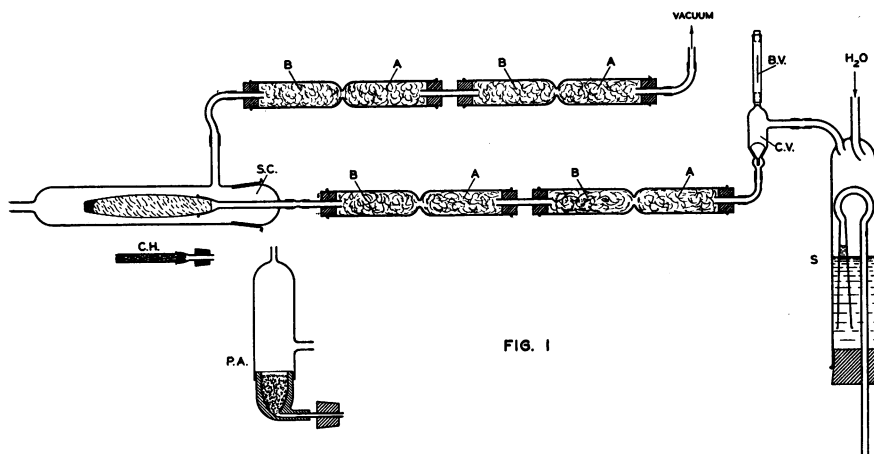


FIG. 1

placed by the pipe assembly (PA), and the tests were carried out thereafter in the same manner as for cigars and cigarettes.

While this apparatus was designed primarily for the determination of arsenic in tobacco smoke, other constituents of the smoke or tar could also be determined by its aid. For example, nicotine could be determined by the method of Waser and Stähle (*Z. Unters Lebensm.* 64:470-85, 1932); pyridine and ammonia by that of Schaarschmidt (*Chem. Ztg.* 56:911-13, 1932); and the compounds in the tarry matter could be ascertained by special methods used in organic analysis. The presence or absence of lead, copper, or fluorine in the smoke could also be easily determined.

METHOD OF MAKING SMOKING TESTS

After the apparatus had been assembled and the absorption tubes charged, a cigar or cigarette or loaded pipe was inserted into its proper holder,

lighted, and the jacket of the smoking chamber was put in place.

When the cigars and cigarettes were smoked down to about $\frac{1}{2}$ " to $\frac{3}{4}$ ", the apparatus was disconnected and the ash, butt and absorbents in both trains were reserved for individual analysis. (In the pipe-smoking tests, the entire pipe load was smoked.) Any tarry matter which had condensed in the holder, was removed with alcohol and added to the absorbents from the lower train, while the tarry substance deposited on the inside wall of the jacket was combined with the absorbents in the upper train.

ANALYTICAL PROCEDURE

All arsenic analyses were made by the method developed by Gross² which eliminates the low results occurring when analysis is made by the Gutzeit method in the presence of undigested residues of the tobacco alkaloid nicotine. In this method the material is digested in the usual manner with nitric

and sulphuric acids, and a suitable aliquot of the diluted solution is made ammoniacal and precipitated with ammonium phosphate and magnesia mixture. The co-precipitated magnesium ammonium phosphate and arsenate is then filtered and rinsed free of interfering nicotine residues, redissolved in hydrochloric acid solution, and analyzed for arsenic by the Gutzeit method, according to the A.O.A.C. procedure.³

QUANTITIES OF ARSENIC IN TOBACCO PRODUCTS STUDIED

Five widely sold domestic brands of cigars, 5 of cigarettes, and 4 of smoking

tobacco were selected for experimentation. Before the smoking tests were conducted, preliminary analyses were made on representative samples of each of the brands to determine the range of arsenical residues present. The analyses were made on analytical units composed of either 1 cigar, 4 cigarettes, or 5 gm. of smoking tobacco. Five such analytical groups were analyzed for each brand studied. The results of these analyses together with those made in the smoking tests reported later were calculated as p.p.m. of As_2O_3 . For general comparison purposes this form of expression was deemed preferable to

TABLE I
TOTAL ARSENIC PRESENT IN TOBACCO PRODUCTS

Brand No.	Av. Wt. Sample (grams)	As ₂ O ₃ in Parts per Million					
		Tests					
		1	2	3	4	5	Average
	1 Cigar			Cigars			
1	8.67	15.3	48.4	16.5	27.1	20.9	25.9
2	6.27	48.4	21.9	11.6	28.6	22.8	26.6
3	7.33	23.0	26.7	19.3	21.7	17.7	21.7
4	8.28	12.1	10.6	14.7	9.7	11.0	11.6
5	9.10	11.9	30.4	11.1	8.3	17.1	15.7
	4 Cigarettes			Cigarettes			
1	3.76	25.6	22.9	21.3	20.7	23.7	22.9
2	4.24	26.7	24.4	24.4	23.6	21.1	24.1
3	4.46	33.6	25.3	36.3	35.4	35.3	33.2
4	4.25	13.0	12.0	9.7	11.1	12.0	11.6
5	4.20	22.9	24.6	25.7	24.4	26.1	24.7
	Weighed Portions			Pipe Tobacco			
1	5.00	44.0	40.0	44.0	50.0	48.0	45.1
2	5.00	42.0	40.0	36.0	38.0	36.0	38.4
3	5.00	32.0	30.0	34.0	34.0	28.0	31.6
4	5.00	34.0	36.0	28.0	32.0	26.0	31.1

calculations made in terms of gr. of As_2O_3 per lb. of sample. Table I shows the amounts of arsenic found in the brands of tobacco analyzed.

The data show a maximum of 48.4, 36.3, and 50.0 p.p.m. of As_2O_3 , respectively, for the cigars, cigarettes, and smoking tobaccos studied. These figures are not conspicuously higher than the maximum of 38.5 p.p.m. found by Remington for arsenic in smoking and chewing tobaccos.

Quite a variation is apparent in the arsenical load carried by individual cigars of the same brand. In cigarettes and pipe tobaccos the variations in arsenical content in any given brand lie within much narrower limits. This is probably due to the mixing such tobaccos receive during the commercial blending process.

DISCUSSION AND RESULTS OF SMOKING TESTS

Analytical units similar to those mentioned above were used in the smoking tests. After smoking either 1 cigar (usually weighing between 6 and 8 gm.), 4 cigarettes (total weight about 4 gm.) or 3 pipeloads of tobacco (adjusted to total 5 gm.), the arsenic was determined in (1) the absorbents of the lower train (containing the arsenic present in the puffed smoke), (2) the absorbents in the upper train (representing the arsenic in the smoke between puffs), (3) the ash, and (4) the butts (except on pipe tobaccos where all the tobacco was smoked).

The results obtained during the smoking tests calculated as p.p.m. of As_2O_3 are given in Table II. Since in all 70 smoking tests were made, and each test for cigars and cigarettes required 4 different analyses, and each on pipe tobaccos 3, the completed data would be too voluminous for expression here. Therefore only the average results from each brand investigated are included in this table.

An exception is made of cigar brand No. 1, which is given in detail, in order to show the method of averaging the data as well as the approximate range of arsenical residues encountered.

All calculations of p.p.m. of As_2O_3 in Table II are based on the original weight of the sample smoked. The totals in the last column agree quite closely with those obtained for the same brands and given in Table I, indicating that the samples tested were representative of the brand.

The data resulting from these smoking tests furnish the opportunity for drawing interesting comparisons between the quantities of arsenic a smoker may inhale and the quantity permitted by law in food products, which is 1.43 p.p.m. (0.01 gr. of As_2O_3 per lb.). The average figures for p.p.m. in the puffed smoke show that a smoker may draw into his mouth the quantity tolerated in 1 lb. of food by the smoking of 1.35 lb. of cigars, 0.56 lb. of cigarettes or 0.16 lb. (about 2.6 oz.) of pipe tobacco. Of course, some of the arsenic is still in the smoke when it is exhaled, and therefore it is different from arsenic in food, in which case the body is exposed to all the arsenic present.

Attention is called to the relatively small quantity of smoking tobacco required to furnish volatile arsenic in the quantity mentioned. Several factors contribute to bring this about. (1) The brands of smoking tobacco tested contained more arsenic than the cigar and cigarette brands. (2) When a pipe is smoked, apparently most of the volatile arsenic is contained in the puffed smoke, due to the dying down of the ember between puffs. In the case of cigars and cigarettes, the amounts of arsenic in the unpuffed and puffed smoke are about equal. (3) All the tobacco was smoked; while with cigars and cigarettes, about 22 per cent was discarded in the butts. (4) A con-

TABLE II
ARSENIC IN UNPUFFED AND PUFFED SMOKE, ASH AND UNSMOKED PORTIONS OF CIGARS,
CIGARETTES, AND SMOKING TOBACCOS

Brand No.	Weight Sample* (grams)	As ₂ O ₃ Parts per Million				
		Unpuffed Smoke	Puffed Smoke	Ash	Butts	Total
Cigars, Individual Analyses, Brand 1						
1, Cigar 1	9.48	1.79	1.37	25.32	4.74	33.22
1, " 2	8.20	1.21	0.98	14.63	9.76	26.58
1, " 3	8.54	1.17	1.52	15.58	5.85	24.12
1, " 4	8.81	1.48	1.14	14.19	7.15	23.96
1, " 5	8.28	1.09	1.57	12.08	8.45	23.19
Av. Wt., (g)	8.66					
Av., (p.p.m.)		1.35	1.31	16.36	7.19	26.21
Av., (per cent)		5.15	5.00	62.42	27.43	100.00
Cigars, Averages, Each Brand						
1	8.66	1.3	1.3	16.4	7.2	26.2
2	5.97	1.2	1.5	15.2	6.7	24.6
3	7.54	1.2	1.1	13.1	5.4	20.8
4	8.00	0.8	0.7	6.6	2.6	10.7
5	9.06	1.0	0.7	8.8	6.2	16.7
Av. Wt., (g)	7.85					
Av., (p.p.m.)		1.1	1.1	12.0	5.6	19.8
Av., (per cent)		5.6	5.5	60.6	28.3	100.0
Cigarettes, Averages, Each Brand						
1	3.83	3.7	3.7	9.5	6.2	23.1
2	4.23	2.8	1.7	11.7	6.5	22.7
3	4.42	2.8	2.7	16.3	10.2	32.0
4	4.31	1.7	1.4	6.9	3.0	13.0
5	4.16	3.1	2.9	11.2	6.2	23.4
Av. Wt., (g)	4.19					
Av., (p.p.m.)		2.8	2.5	11.1	6.4	22.8
Av., (per cent)		12.3	11.0	48.6	28.1	100.0
Smoking Tobaccos, Averages, Each Brand						
1	5.00	1.5	12.4	28.8	....	42.7
2	5.00	1.2	8.8	28.2	....	38.2
3	5.00	1.4	8.0	19.3	....	28.7
4	5.00	2.5	6.7	20.4	....	29.6
Av. Wt., (g)	5.00					
Av., (p.p.m.)		1.6	9.0	24.2	....	34.8
Av., (per cent)		4.6	25.9	69.5	....	100.0

* Samples composed of 1 cigar, 4 cigarettes, or 5 grams of smoking tobacco.

siderable portion of the volatile arsenic is absorbed by or condensed in the butts of cigars or cigarettes. The way in which this fact was demonstrated will

be described later. The pipe smoker who smokes all the tobacco does not therefore have the protection afforded by the butts of cigars and cigarettes.

FORM IN WHICH VOLATILIZED

Whether or not the volatile arsenic in tobacco smoke is free or in combination has not been conclusively determined. From theoretical considerations it is believed that the arsenic is volatilized as As_2O_3 , to which form it has been converted by the conditions of incomplete combustion present during smoking. As_2O_3 would behave in the manner observed, subliming at the temperatures reached during smoking and tending to condense again on cool moist surfaces as represented by the butts. The ab-

sorbent cotton moistened with distilled water caught nearly all the arsenic present in the smoke. This fact is not reassuring when it is called to mind that the tissues of the mouth and lungs are normally moist.

PER CENT OF VOLATILE ARSENIC

Remington's pipe smoking tests indicated that about 50 per cent of the arsenic was volatile. The results of our own investigations, as shown in Table III, indicate maxima of 34.7, 41.3 and 32.8 per cent respectively, for

TABLE III

PERCENTAGES OF ARSENIC VOLATILIZED DURING SMOKING OF CIGARS, CIGARETTES, AND SMOKING TOBACCOS

Brand No.	No. of Tests Made *	Av. Wt. (grams)		Percentage of Total Arsenic of Smoked Portion Found			
		Butts	Smoked Portion	In unpuffed smoke	In puffed smoke	Absorbed by butts	Total
Cigars							
1	3	1.92	6.62	6.8	7.6	9.8	24.2
2	3	1.57	4.57	5.8	7.9	1.4	15.1
3	3	1.62	5.88	7.3	7.1	5.8	20.2
4	4	1.70	6.50	9.4	7.9	3.9	21.2
5	3	1.94	7.15	8.3	5.6	20.8	34.7
Averages		1.75	6.14	7.5	7.2	8.3	23.0
Average wt., per cent		22.2	77.8				
Cigarettes							
1	3	0.94	2.90	16.4	14.0	10.9	41.3
2	2	1.02	3.38	14.9	8.9	10.9	34.7
3	5	1.08	3.34	11.4	11.2	9.6	32.2
4	5	0.90	3.41	16.4	13.3	2.7	32.4
5	5	0.84	3.32	16.8	15.4	7.7	39.9
Averages		0.96	3.27	15.2	12.6	8.3	36.1
Average per cent		22.7	77.3				
Smoking Tobaccos							
1	5	.....	5.00	3.5	29.0	.....	32.5
2	5	.....	5.00	3.1	23.0	.....	26.1
3	5	.....	5.00	4.9	27.9	.....	32.8
4	5	.....	5.00	8.4	22.7	.....	31.1
Averages				5.0	25.6	.....	30.6

* Each test composed of 1 cigar, 4 cigarettes, or 5 grams of smoking tobacco.

the brands of cigars, cigarettes, and pipe tobaccos tested.

These figures were obtained by adding the quantities of arsenic contained in the unpufted and pufted smoke and the quantity absorbed from the pufted smoke by the butt. This last quantity was ascertained by calculating the amount of arsenic that should be contained in the butts, knowing the weights of the entire cigar or cigarette, the weight of the butts, and the total weight of arsenic present, then subtracting this theoretical weight from that actually found by analysis.

The wide variations in the percentages absorbed by the butts, as shown in Table III, cannot be readily explained. They may be due to differences in moisture content or probably to the degree of packing of the tobaccos. However, the average results for percentages of arsenic absorbed should be reassuring to cigar and cigarette smokers and to pipe smokers who empty their pipes before reaching the "last drag."

SUMMARY

1. An apparatus is described for use in determining volatile arsenic and

other substances evolved during the smoking of cigars, cigarettes, and pipe tobacco.

2. Analyses of popular domestic brands of cigars, cigarettes, and smoking tobaccos show a range from 8.3 to 50.0 p.p.m. of As_2O_3 as compared with a range of 7 to 38.5 p.p.m. found by Remington in domestic smoking and chewing tobaccos.

3. On the basis of average figures, the arsenic inhaled in smoking 1.35 lb. of cigars, 0.57 lb. of cigarettes or 0.16 lb. (2.6 oz.) of pipe tobacco is calculated to be equivalent to that present in 1 lb. of food containing 1.43 p.p.m. of As_2O_3 which is the maximum permitted by law for food products.

4. The proportion of total arsenic volatilized during smoking ranges for cigars from 15.1 to 34.7 per cent, for cigarettes from 32.2 to 41.3 per cent, and for pipe tobaccos from 26.1 to 32.8 per cent. Remington reported about 50 per cent volatile in similar tests on pipe tobaccos.

REFERENCES

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2. *Indust. & Eng. Chem., Anal. Ed.*, 5:58 (Jan. 15), 1933.
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"Healthmobile" in Maryland

SEVEN counties in southern Maryland and on the eastern shore were visited by the "Healthmobile" of the Bureau of Child Hygiene of the Maryland State Department of Health on its tour this summer. During the eleven weeks of the tour, 85 communities were visited and 89 health conferences were

held for the examination of infants and children under school age. Of 1,589 children examined, 1,137 needed follow-up care of some sort, about 216 were underweight, and 142 had unhealthy tonsils. Of the total number, 1,341 children were given dental examinations and 767 were treated by the dentist.