Lead-210 in Tobacco and Cigarette Smoke

ESTHER S. FERRI and HOWARD CHRISTIANSEN

MANY recent investigations of cigarette smoke have been concerned with concentrations of polonium-210 and the radiation dose to the lungs of smokers who inhale it (*1*, *2*). To ascertain if further insult to the lungs occurs, a study of the levels of other radionuclides, specifically lead-210 in cigarette smoke, was undertaken at the Northeastern Radiological Health Laboratory, Public Health Service.

Limited data by Holtzman and Ilcewicz have indicated a transfer of lead-210 in the smoke (*3*), and stable lead in tobacco smoke has been reported also by Cogbill and Hobbs (*4*). Increased exposure of the lung to lead-210 may result because the nuclide has a longer effective half-life with subsequent daughter ingrowth. Calculations of the amount of lead-210 deposited in the lung, a critical organ, were based on the concentrations of lead-210 found in the smoke of various brands of cigarettes tested at this laboratory.

Methodology

Six brands of cigarettes, varying slightly in physical makeup were chosen for the study. These cigarettes included two which were nonfiltered, and one each with a cellulose filter, a cellulose and charcoal filter, a cellulose and charcoal filter with the tobacco treated for removal of tars and nicotine, and a cellulose filter with pipe tobacco.

Lead-210 and polonium-210 have been found in equilibrium in tobacco (*2*); therefore, the bismuth-210 was isolated and determined as a measure of the lead-210 activity. The tobacco was wet-ashed by using nitric and perchloric acids, converted to a 1.8 molar hydrochloric acid solution, and the bismuth-210 was isolated by anion exchange (*5*). To establish purity, decay of the 5-day bismuth-210 was observed. Concentrations of lead-210 in total tobacco content of the cigarettes are shown in table 1.

To determine the concentration of lead-210 in mainstream smoke, four to five packs of each brand of cigarettes were smoked by a smoking machine under the operating conditions described in an earlier study (*2*), and a constant butt length was maintained: 3.3 centimeters for filtered cigarettes (including filter) and 1.5 centimeters for nonfiltered cigarettes.

Because lead-210 and bismuth-210 in equilibrium in the tobacco may not exist in equilibrium in the smoke, the lead-210 was isolated by digesting the collection filters and the hydrochloric acid trap with nitric and perchloric acids. The lead-210 was isolated with added carrier by anion exchange, and time was allowed for ingrowth of bismuth-210. The bismuth-210 was collected with carrier by ion exchange, precipitated, and counted as oxychloride (*5*). Decay of this fraction was also measured to determine purity of the bismuth-210.

To establish whether possible environmental factors influence the analyses, a series of air

Mrs. Ferri is assistant director of Analytical Services, Northeastern Radiological Health Laboratory, Division of Radiological Health, Public Health Service, Winchester, Mass., and Mr. Christiansen is a graduate student in the department of epidemiology and public health, Yale University School of Medicine, New Haven, Conn. *This study was partly supported by Public Health Service Grant No. 3–T1–RH–70–01–A2 (for radiation specialist training).*

Table 1. Lead-210 in tobacco and smoke, by picocuries per cigarette (±2 standard deviations)

Brand and characteristics of cigarettes	Total cigarette		Mainstream smoke	
	Lead-210	Number of analyses	Lead-210	Number of analyses
A nonfiltered	0.403±0.066	6	0.055±0.036	4
B nonfiltered	.427± .074	4	.046± .005	5
C filtered with cellulose	.304± .106	5	.026± .007	4
D filtered with cellulose and charcoal	.487± .064	3	.049± .031	4
E filtered with cellulose and charcoal, filled with treated tobacco	.326± .050	3	.030± .022	4
F filtered with cellulose, filled with pipe tobacco	.393± .224	3	.052± .028	4

and reagent blanks were determined. Without igniting the tobacco and using the smoking machine, air was drawn through 20 cigarettes of each brand to substantiate the theory that lead from the tobacco, while it was not burning, was not contributing to the activity.

Since lead-210 normally is found in air, 12,500 cubic centimeters of laboratory air was also collected directly on a membrane filter. This volume of air is equivalent to the amount drawn through 20 cigarettes while being smoked on the machine.

Reagent blanks on chemicals, glassware, and membrane filters used were determined. As shown in table 2, the only factor to be considered in calculating final concentrations of lead-210 is the reagent blank. Air passed through the cigarettes or collected separately showed no contribution to the blank. An ingrowth procedure was employed for all samples of collected smoke, and samples were allowed to reach greater than 90 percent equilibrium.

Chemical yields ranged from 86 to 99 percent. All samples, except a few recounted to observe decay, were counted for 900 minutes at a 37 percent efficiency obtainable with the geometry used (nylon ring and disk, mylar cover) on Geiger-Mueller end-window low-background beta counters.

Table 2. Lead-210 in air and reagents, in picocuries per cigarette (±2 standard deviations)

Sample	Lead-210	Number of analyses
Air through cigarettes and reagents	0.021 ±0.006	6
Laboratory air and reagents	[1] .028 ± .005	1
Reagents	.025 ± .002	4

[1] 2σ counting error.

Results

Comparison of the concentration of lead-210 with polonium-210 in the smoke (*2*) from the same brands of cigarettes indicated that with one exception, brand E, half as much lead-210 as polonium-210 is inhaled (table 3). However, the mainstream smoke from the treated tobacco cigarette, brand E, contained less radioactivity from lead-210 and polonium-210 than any of the other brands.

A comparison of the amount of lead-210 activity available in smoke from 20 cigarettes with that normally inhaled from breathing is shown in the chart. Concentrations of lead-210 in air collected in the vicinity of the laboratory have ranged from 0.010 to 0.041 picocuries per cubic meter (*6*). If 20 cubic meters per day is the average air intake from breathing (*7a*), then 0.20 to 0.82 picocuries of lead-210, or an average of approximately 0.5 picocuries of lead-210, are inhaled from air.

From four of the six brands of cigarettes tested, intake of lead-210 from smoking 20 cigarettes a day was double that from air, and in the two remaining brands the intake of lead-210 from 20 cigarettes was about equal to that from normal breathing. With the lung as the organ of reference, this intake was less than 1 percent of the maximum permissible concentration for lead-210 in air for large populations (*7b*).

Comparison of the "tar" and nicotine content

of smoke (*8*) from four brands of cigarettes in this study with the lead-210 in the mainstream smoke showed that although the relationship is not constant, smoke from cigarettes with larger amounts of tar and nicotine also had higher concentrations of lead-210 (table 4). However, at this time we have no evidence to demonstrate that lead-210 is attached to or mechanically carried on the tar and nicotine.

Lung Exposure

Based on the concentrations of lead-210 found in cigarette smoke at this laboratory, dosage calculations with the lung as the critical organ were made using the model set up by the Task Group on Lung Dynamics (*9*). (The task group is a constituent of the International Commission on Radiological Protection.) Particle sizes in tobacco smoke ranged from 0.01 to 0.25 microns (*10*). Using an average 0.13-micron particle size, the task group's model states that of 100 percent of the particles inhaled, 1 percent is retained in the nasopharyngeal compartment, 8 percent in the tracheal and bronchial compartment, 45 percent by the pulmonary compartment, and 46 percent is exhaled.

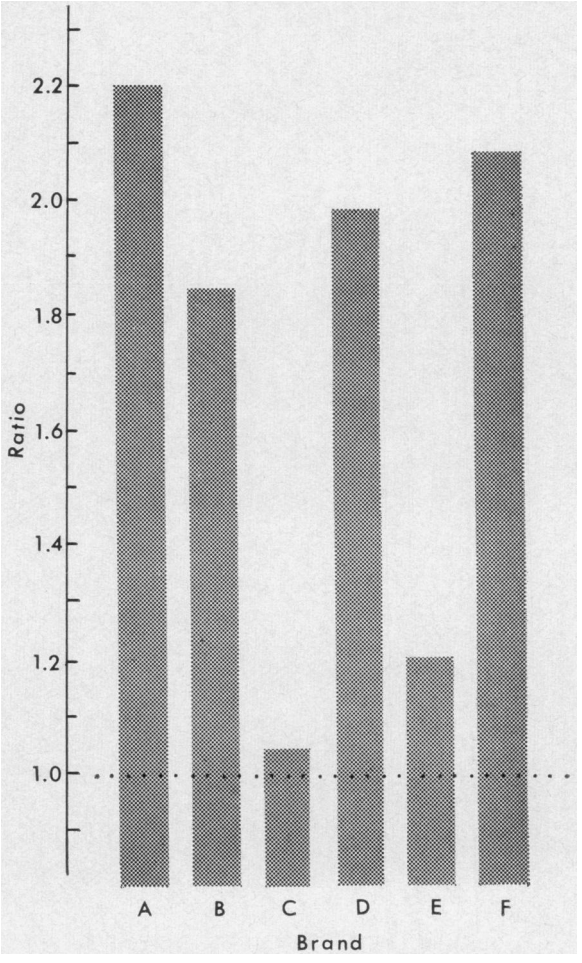
Lead was considered class W, falling within the 4a (IV–VI) group listed in table 3 of reference 9. Class W material has a clearance half-time from a few days to a few months. The model also states that for class W compounds 100 percent of the particles reaching the nasopharyngeal, tracheal, and bronchial compartments is cleared to either the gastrointestinal tract or the bloodstream with a biological half-life of 4 and 10 minutes, respectively. Because of this short residence time, the nasopharyngeal, tracheal, and bronchial compartments have been ignored in our calculations.

Table 3. Lead-210 and polonium-210 in mainstream smoke, in picocuries per cigarette

Cigarette brand	Total lead-210 and polonium-210	Lead-210	Polonium-210 [1]	Ratio of lead-210 to polonium-210
B	0. 128	0. 046	0. 082	0. 56:1. 00
C	. 075	. 026	. 049	. 53:1. 00
D	. 136	. 049	. 087	. 56:1. 00
E	. 067	. 030	. 037	. 81:1. 00
F	. 157	. 052	. 105	. 50:1. 00

[1] Reference 2.

Ratios [1] of lead-210 in smoke of five brands of cigarettes to lead-210 normally inhaled in air



[1] Picocuries of lead-210 in 20 cigarettes to lead-210 in 20 cubic meters of air. Normal daily inhalation of air is 20 cubic meters. Air at Winchester, Mass., contains a daily average of 0.5 picocuries of lead-210.

Of the compound reaching the pulmonary compartment, 60 percent is cleared with a 90-day biological half-life.

Table 5 lists the dosage (dependent on particle size) of lead-210 plus daughters reaching the pulmonary compartment from the various brands of cigarettes by smoking 20 per day. In our calculations, the mass of this compartment has been taken as 1,000 grams. At 390 days, lead-210 is in 95 percent equilibrium in the body.

The effective energy (defined in *7c*) for the chain from lead-210 to polonium-210 is 25 Mev

(*7d*). Table 5 also includes polonium-210 dosages based on calculations using the newer task group model from intakes determined in an earlier study (*2*). The effective half-life of polonium-210 was assumed to be 54 days derived from the 138-day radioactive and 90-day biological half-lives. Although the intakes of lead-210 and polonium-210 differ in most cases by a factor of 2, we demonstrated that the radiation dose to the lung is doubled due to inhalation of lead-210 and the subsequent buildup of daughters.

Summary

Tests of six brands of cigarettes have shown that lead-210 is a component of mainstream smoke. These brands of cigarettes included two which were nonfiltered, and one each with a cellulose filter, a cellulose and charcoal filter, a cellulose and charcoal filter with the tobacco treated for the removal of "tars" and nicotine, and a cellulose filter with pipe tobacco.

In smoke from five brands, the lead-210 activity was about half the polonium-210 activity. Compared with average levels of lead-210 inhaled from air in normal breathing, the intake of lead-210 from four brands of cigarettes was double the lead-210 in air, and in two brands was about equal to the lead-210 in air.

A constant relationship between levels of radioactivity, tar, and nicotine content of the smoke could not be demonstrated. Using a recent model established by the International Commission on Radiological Protection, dosages to the pulmonary compartment of the respiratory tract were calculated, for each of the six brands, for a person smoking 20 ciga-

Table 4. Comparison of lead-210 activity in mainstream smoke to tar and nicotine content of total smoke

Cigarette brand	Picocuries of lead-210 per cigarette	Milligrams per cigarette		Picocuries per milligram	
		Tar	Nicotine	Lead-210 to tar	Lead-210 to nicotine
B	0. 046	27. 2	1. 42	1.69×10^{-3}	3.24×10^{-2}
C	. 026	19. 4	1. 05	1.34×10^{-3}	2.48×10^{-2}
D	. 049	20. 0	1. 45	2.45×10^{-3}	3.38×10^{-2}
F	. 052	30. 1	2. 11	1.73×10^{-3}	2.46×10^{-2}

Table 5. Dosages of lead-210 and polonium-210 to the pulmonary compartment from smoking 20 cigarettes a day

Cigarette brand	Intake (picocuries per day)		Dosage to pulmonary compartment (millirems per year) for various particle sizes					
	Lead-210	Polonium-210	0.01 μ size		0.13 μ size (average)		0.25 μ size	
			Lead-210 [1]	Polonium-210	Lead-210 [1]	Polonium-210	Lead-210 [1]	Polonium-210
A	1. 10	----------	73	----------	43	----------	40	----------
B	. 92	1. 64	61	59	36	34	33	33
C	. 52	. 98	34	35	20	21	19	20
D	. 98	1. 74	65	63	38	36	35	35
E	. 60	. 74	40	27	23	15	22	15
F	1. 04	2. 10	67	76	41	44	37	42
Normalized [2]	*1. 00*	*1. 00*	*66*	*36*	*39*	*21*	*36*	*20*

[1] Lead-210 and daughters.

[2] Dosage calculations were based first on an assumed intake of 1.0 picocuries per day. This dose then was adjusted upward or downward based on actual intakes.

rettes per day. These results showed that the radiation dose to the lung from inhalation of lead-210 in smoke plus the subsequent daughter ingrowth was equal to the dose from polonium-210 in smoke.

REFERENCES

(1) Radford, E. P., Jr., and Hunt, V. R.: Polonium 210, a volatile radio-element in cigarettes. Science 143: 247–249, Jan. 17, 1964.

(2) Ferri, E. S., and Baratta, E. J.: Polonium 210 in tobacco, cigarette smoke, and selected human organs. Public Health Rep 81: 121–127, February 1966.

(3) Holtzman, R. B., and Ilcewicz, F. H.: Lead 210 and polonium 210 in tissues of cigarette smokers. Science 153: 1259–1260, Sept. 9, 1966.

(4) Cogbill, E. C., and Hobbs, M. E.: Transfer of metallic constituents of cigarettes to the mainstream smoke. Tobacco 144: 24–29, May 10, 1957.

(5) Baratta, E. J., Ferri, E. S., and Reavey, T. C.: Analysis of environmental samples: Supplementary chemical and radiochemical procedures. NERHL Report 65–4. Northeastern Radiological Health Laboratory, Public Health Service, Winchester, Mass., 1965.

(6) Shleien, B., Cochran, J. A., Bernard, L. L., and Friend, A. G.: Atmospheric radioactivity analysis and instrumentation status report II. NERHL Report 66–2. Northeastern Radiological Health Laboratory, Public Health Service, Winchester, Mass., 1966.

(7) International Commission on Radiological Protection, Committee II: Report on permissible dose for internal radiation. Health Phys 3: 2–234, June 1960, (*a*) p. 152; (*b*) p. 75; (*c*) pp. 27–30; (*d*) p. 133.

(8) Miller, L. M., and Monahan, J.: To the cigarette makers: Just the facts, please. Reader's Digest 89: 66–67, November 1966.

(9) International Commission on Radiological Protection: Deposition and retention models for internal dosimetry of the human respiratory tract. Report of Task Group on Lung Dynamics to Committee II. Health Phys 12: 173–207, February 1966.

(10) Hatch, T. F., and Gross, P.: Pulmonary deposition and retention of inhaled aerosals. Academic Press, Inc., New York, 1964, p. 6, figure 1.1.

New Records System for Psychiatric Hospitals

To simplify psychiatric recordkeeping, computers and telecommunications will be combined in a five-State system to be developed under a grant from the Public Health Service. The National Institute of Mental Health has awarded $250,245 for the first year of the 5-year project. The grant will be made to the research center at Rockland State Hospital and to the office of statistics and data processing, department of mental hygiene in New York State, one of the five States which will participate in the project. Support for the 5-year period is expected to total $6,109,479. The other States are Maine, Vermont, New Hampshire, and Illinois.

The new system will be based on printed forms on which the details of medical history, diagnosis, and treatment may be quickly checked off by the psychiatrist. These tapes and disks can be fed into a computer which will print a narrative description of an individual patient. Or, on demand, the computer will select out information for patient care, research purposes, program planning, and hospital administration. Once codified, the data will be available to participating hospitals and community mental health centers through telecommunications.