ORNL-5411

Carcinogenic Risk of Lead-210 and Polonium-210 in Tobacco Smoke — A Selected, Annotated Bibliography

C. C. Travis
E. L. Etnier
K. A. Kirkscey

HEALTH AND SAFETY RESEARCH DIVISION
OAK RIDGE NATIONAL LABORATORY

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Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
Price: Printed Copy $4.50; Microfiche $3.00

ORNL-5411
Dist. Category UC-41

Contract No. W-7405-eng-26

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CARCINOGENIC RISK OF LEAD-210 AND POLONIUM-210 IN TOBACCO SMOKE — A SELECTED, ANNOTATED BIBLIOGRAPHY

Date Published - May, 1978

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ACKNOWLEDGMENTS

Julia Watts of the Environmental Sciences Division is gratefully acknowledged for her many contributions to the production of this document.

ABSTRACT

This bibliography is concerned with the possible carcinogenic risk to man from the presence of lead-210 and polonium-210 in tobacco smoke. It includes a data base on such topics as background levels of lead-210 and polonium-210 in tobacco and tobacco smoke, tobacco plant uptake of lead-210 and polonium-210 from soil, metabolic models, and dose estimates. This data base should be of interest to those concerned with assessing the health effects resulting from the emanation of radon-222 from natural and technologically enhanced sources.

INTRODUCTION

It has long been known that the atmosphere contains appreciable quantities of radon as a result of its natural emanation from the earth's crust. Until recently, however, these background concentrations of radon and its long-lived daughters, lead-210 and polonium-210, have received little attention. This situation has changed with the realization that natural concentrations of lead-210 and polonium-210 in tobacco may be the primary initiators of respiratory carcinogenesis in smokers. Since polonium-210 is volatile at temperatures well below that found at the burning tip of a cigarette, it is present in mainstream smoke and, when inhaled, becomes a source of radiation to the tissues of the respiratory tract. Lead-210 is also present in inhaled smoke and, after possible association with insoluble smoke particles, is deposited in the lung where it decays to polonium-210. The role of the alpha emitter, polonium-210, as an initiator of bronchial cancer is, therefore, a subject of considerable current interest. This selected, annotated bibliography was originated to serve as a data base for a comprehensive review of the possible carcinogenic risk of lead-210 and polonium-210 in tobacco smoke. The authors' interest in this controversial subject was stimulated by current attention being given to the problem of estimating population radiation exposures which might result from uranium mining and milling activities in the western United States.

CITATION FORM

The bibliographic data were arranged according to the Environmental Information System standard format for computer entry of information.

As a result of computer limitation in indicating superscripts and subscripts in the standard manner, certain conventions have been established in the bibliography:

1) In chemical compounds and elements, "NaI03" means $NaIO_3$.

2) "1.0E8" (E denoting exponent) means 1.0×10^8.

<1>
AUTHOR: Albert, R. E.; Peterson, Jr., H.T.; Bohning, D.E.; Lippman, M.
TITLE: Short-Term Effects of Cigarette Smoking on Bronchial Clearance in Humans
PUB DESC: Arch. Environ. Health, 30:361-367
PUB DATE: 1975
ABSTRACT: The short-term effects of cigarette smoking on the bronchial clearance of inhaled monodisperse radioactive insoluble particles was studied in nine nonsmokers and six smokers. Each subject inhaled two aerosols of the same particle size, tagged with a different isotope, with an interval of several hours between aerosol exposures. Simultaneous measurements were made of the clearance of both aerosols. Smoking of from two to seven cigarettes was started shortly after the second tagged aerosol was inhaled. Comparison of the bronchial clearance times of the two tagged aerosols gave a minimum estimate of a twofold transient speedup in deep bronchial clearance caused by the cigarette smoking in both smokers and nonsmokers. However, it was found that there were no consistent changes in the rate of upper bronchial clearance as a result of smoking.

<2>
AUTHOR: Athalye, V.V.; Mistry, K.B.
TITLE: Uptake and Distribution of Polonium-210 and Lead-210 in Tobacco Plants
PUB DESC: Radiat. Bot., Vol. 12:421-425
PUB DATE: 1972
ABSTRACT: Two varieties of flue-cured tobacco were grown in solutions labeled with Po-210 and Pb-210, and the roots and shoots were assayed for radioactive content. In both varieties, massive accumulation of the radionuclides occurred in the roots. The distribution patterns of Pb-210 and Po-210 showed highest concentrations in older leaves and lower concentrations in younger leaves and in the stem.

<3>
AUTHOR: Athalye, V.V.; Shah, V.M.; Mistry, K.B.
TITLE: Polonium-210 in Cigarette Smoke
PUB DESC: Indian J. Environ. Health 19(1):54-62
PUB DATE: 1972
ABSTRACT: This paper reports the results of studies on the levels of Po-210 in the mainstream smoke of several Indian cigarettes. The authors give dose estimates for the pulmonary compartment from smoking these cigarettes. The mainstream smoke of 20 brands of cigarettes, 10 with filters and 10 without, was analyzed for Po-210 content. The levels of Po-210 were found to be in the range of 0 - 0.4 pCi per cigarette. The data indicate no apparent correlation with the presence of a filter-tip or the size of the cigarette. The authors present a model used to estimate the average integral dose to the pulmonary compartment due to inhalation of Po-210. This model considers deposition patterns of the inhaled radioactive material as well as residence time and clearance from various compartments of the respiratory system. Dose estimates from smoking 20 cigarettes per day were computed for the different brands of cigarettes studied. The doses range from 2.0 - 63.7 mrem per year for a particle size of 0.01 u and 3.6 - 115.1 mrem per year for a particle size of 0.20 u.

<4>
AUTHOR: Auerbach, O.; Stout, A.P.; Hammond, E. C.; Garfinkel, L.
TITLE: Changes in Bronchial Epithelium in Relaton to Cigarette Smoking and in Relation to Lung Cancer
PUB DESC: N. Engl. J. Med., 265(6):253-267
PUB DATE: 1961
ABSTRACT: The authors report a continuation of a study of the relative frequency of carcinoma-in- situ, squamous metaplasia, stratification and basal-cell hyperplasia in the lungs of nonsmokers and light and heavy cigarette smokers. Altogether, 402 white males were studied, and the following observations made: for every cause-of-death category except lung cancer the frequency of hyperplasia, lesions with cilia absent and carcinoma-in-situ increased consistently with the amount of cigarette smoking; for cases of lung cancer there was little difference between light and heavy smokers; it was found that the percentage of sections with carcinoma-in-situ was much less in the trachea than other parts of the bronchial tree; in all parts of the bronchial tree higher percentages of epithelial changes were found in areas of bifurcation.

<5>
AUTHOR: Bair, W.J.; Kellerer, A.; Stannard, J.N.; Thompson, R.C.
TITLE: Alpha-Emitting Particles in Lungs
PUB DESC: National Council on Radiation Protection and Measurements Report, NCRP-46; 28 pages.
PUB DATE: 1975
ABSTRACT: This is a report prepared by the Ad Hoc Committee on "Hot Particles." The committee concludes that present data indicate that particulate plutonium in the lung is no greater hazard than the same amount of plutonium more uniformly distributed throughout the lung.

<6>
AUTHOR: Berger, K.C.; Erhardt, W.H.; Francis, C.W.
TITLE: Polonium-210 Analyses of Vegetables, Cured and Uncured Tobacco, and Associated Soils
PUB DESC: Science 150:1738-1739
PUB DATE: 1966
ABSTRACT: Analysis of the edible portions of vegetables and samples of green leaf tobacco failed to show detectable amounts of polonium-210 even when the soil contained small quantities of the element. However, significant levels of polonium-210 were found in air-cured leaf tobacco. The authors conclude that since freshly harvested tobacco samples showed no detectable polonium-210, whereas cured tobacco contained significant quantities, it appears that polonium-210 accumulates in the tobacco leaf during curing.

<7>
AUTHOR: Black, S. C.; Bretthauer, E. W.
TITLE: Polonium-210 in Tobacco
PUB DESC: Radiat. Data Rep. 9:145-152
PUB DATE: 1968
ABSTRACT: Variations in Po-210 content in domestic tobaccos and foreign cigarettes were studied, as well as the effect of various types of commercial cigarette filters on the concentration of Po-210 in mainstream smoke (33-58% removal). It was found that there was no Po-210 enrichment in cigarette butts, the average Po-210 content of whole cigarettes being 0.483 pCi/g and of butts, 0.477 pCi/g. Experiments relating puff-size to Po-210 showed that the Po-210 content and concentration in mainstream smoke increased with puff size. An estimate of the maximum and minimum possible dosage to a heavy smoker is made with the range being 0.032 to 82.5 mrad/day.

<8>
AUTHOR: Black, S. C.; Bretthauer, E. W.
TITLE: Synergistic Effect of Polonium-210 and Cigarette Smoke in Rats
PUB DESC: National Environmental Research Center, Las Vegas, Nevada, 12 pp. EPA-680/1-75-001
PUB DATE: 1975
ABSTRACT: This study was initiated to investigate the effect of added Po-210 on the carcinogenic activity of cigarette smoke in rats. Rats were exposed to mainstream smoke containing 12.5 plus or minus 0.8 nanocuries of Po-210 per cigarette, and sacrificed immediately. Lung deposition of Po-210 was found to be 31 plus or minus 2%. Based on exposure to one cigarette/day for 5 days/week, an alpha-radiation exposure of 116 mrad/day to the lung was estimated. Of the Po-210 deposited, 92% was eliminated with a half-time of 4 hours, and the remainder with a half-time of 84 hours. Lung pathology which may have been produced by exposure to cigarette smoke included bronchitis, emphysema, one bronchogenic carcinoma and one adenoma. Adequate controls were not established. The added polonium exposure did not change the mortality rate.

<9>
AUTHOR: Blanchard, R.L.
TITLE: Concentrations of 210-Pb and 210-Po in Human Soft Tissues
PUB DESC: Health Phys. 13:625-632
PUB DATE: 1967
ABSTRACT: Concentrations of Pb-210 and Po-210 in various tissues such as the kidney, liver, lung, pancreas, spleen, gonads, thyroid, and heart from twenty individuals are reported. All tissues reflect higher Po-210 levels in the smokers than in the nonsmokers. However, only the lungs of smokers contain significantly more Po-210 than the lung of nonsmokers. The average concentration of Po-210 in the lungs of smokers being three times greater than that found in the lungs of nonsmokers. Tests indicate that the liver of smokers may contain higher concentrations of Pb-210 than the liver of nonsmokers. Dose rates delivered by the Po-210 to the various tissues are discussed.

<10>
AUTHOR: Bretthauer, E. W.; Black, S. C.
TITLE: Polonium-210: Removal from Smoke by Resin Filters
PUB DESC: Science 156:1375-1376
PUB DATE: 1967
ABSTRACT: Experiments were conducted on the removal of polonium-210 from mainstream smoke by the use of resin filters. The procedure was to smoke cigarettes first with the normal filter intact and then with the filter removed. Finally cigarettes were smoked in which the granular charcoal of the normal filter had been replaced with an ion-exchange resin. The results indicate that normal filters on cigarettes remove about 50 percent of the polonium in mainstream smoke, and that resin substituted for the charcoal removes 92 percent or more. The authors conclude that exposure of smokers' lungs to polonium-210 could be markedly reduced by incorporation of an ion-exchange resin in cigarette filters.

<11>
AUTHOR: Carfi, N.; Dugnani Lonati, R.
TITLE: Polonium-210 in Italian Tobacco
PUB DESC: Radiation Protection, Part 2, Snyder, W.S. et al. (ed.), New York, Pergamon Press, Inc. p. 1097-1098
PUB DATE: 1968
ABSTRACT: It is known that Po-210 contained in tobacco is volatile at the temperature of a burning cigarette, and a radiation hazard from Po-210 may arise for a smoker's bronchial epithelium. Hence measurements of Po-210 were started in the most popular Italian cigarettes. Polonium was extracted from tobacco samples by a wet ashing procedure and plated on nickel discs. The discs were mounted on ZnS phosphors and the alpha activity was counted. The polonium alpha spectrum was measured by an ionization chamber. The method can be simply carried out, but difficulty arises from the low-background alpha counting necessary for determining accurately the minute quantities of Po-210 (of the order of 1.0E-2 pCi). The Po-210 content of 4 popular cigarettes, corrected for the yield of the chemical separation and counting efficiency, range from 0.37 plus or minus 0.03 pCi/g of tobacco to 0.53 plus or minus 0.03 pCi/g.

<12>
AUTHOR: Droessmar, F.
TITLE: Polonium in Tobacco
PUB DESC: Naturwiss. Rundsch.20:338
PUB DATE: 1967
ABSTRACT: The natural radioactivity in different types of tobacco was examined in an attempt to measure the bismuth-210 and polonium-210 content of the tobacco. The activities of bismuth-210 and polonium-210 found in tobaccos from South Africa and the United States are presented.

<13>
AUTHOR: Eisler, H.
TITLE: Polonium-210 and Bladder Cancer
PUB DESC: Science 144:952-953
PUB DATE: 1964
ABSTRACT: The author notes that the urine of heavy smokers contains nearly six times as much polonium as the urine of nonsmokers, and suggests a possible connection between increased polonium content in the urine and increased death rate from bladder cancer in heavy smokers. Since the tar carcinogens of cigarette smoke do not seem to find their way to the urine, the role played by polonium may be a major one for smokers' bladder cancer and perhaps also greater than supposed for lung cancer.

<14>
AUTHOR: Ferri, E.S.; Baratta, E.J.
TITLE: Polonium-210 in Tobacco Products and Human Tissues
PUB DESC: Radiat. Data Rep. 7:485-488
PUB DATE: 1966
ABSTRACT: The levels of polonium-210 and related nuclides in various nonfiltered cigarettes, filtered cigarettes, cigarettes treated for removal of tar and nicotine, cigars, and pipe tobacco were measured in this study. To determine whether the polonium-210 was present independently or in equilibrium with its precursors, radium-226 and lead-210 levels were also measured. In addition, selected samples of human organs from smokers and nonsmokers were measured for polonium-210 concentrations to determine whether a difference could be detected due to smoking. The parent, radium-226, was found not to be in equilibrium with its daughters, lead-210, bismuth-210, and polonium-210. All cigarettes showed lead-210 and polonium-210 to be in equilibrium, but pipe tobacco showed only 50 percent equilibrium. Using a smoking machine, unsmoked cigarettes were analyzed for polonium-210 and smoked cigarettes were analyzed for polonium-210 in inhaled smoke, sidestream smoke, unsmoked tobacco and ash,

<14> CONT.
and filter. All brands tested showed approximately the same activity per gram in the total cigarette. However, the filtered cigarettes contained 33 to 50 percent less activity in the inhaled smoke and showed a higher sidestream to mainstream smoke ratio than did the nonfiltered brands. Analysis of polonium-210 concentrations in human organs indicate that the lung, blood, and liver of smokers, in that order, contain more polonium-210 than the corresponding organs of nonsmokers, while levels in the kidney, heart, muscle, and bone are about the same in smokers and nonsmokers.

<15>
AUTHOR: Ferri, E.S.; Baratta, E.J.
TITLE: Polonium-210 in Tobacco, Cigarette Smoke, and Selected Human Organs
PUB DESC: Public Health Rep. 81:121-127
PUB DATE: 1966
ABSTRACT: The levels of polonium-210 were analyzed in several brands of cigarettes, and the concentrations of lead-210 and radium-226 were measured to determine whether the polonium-210 was in equilibrium with these precursors or was present independently. Samples of human organs were also analyzed for polonium-210 content to see whether a difference could be detected in the concentration of this radionuclide between smokers and nonsmokers. Polonium-210, lead-210, and bismuth-210 were found to be present in tobacco, along with smaller quantities of radium-226. Tests indicated that lead-210 was deposited in the tobacco independently of radium-226 and bismuth-210. For the various brands tested, the activities of Po-210 were of about the same level, and values in inhaled smoke ranged from 11.0 to 35.7 percent of that in the total cigarette. Average doses to the lungs of a person smoking two packages of cigarettes a day were calculated to be far below the maximum permissible concentration per person for Po-210 in air. The intake from a cellulose-filtered cigarette was 58.5 percent and from a filtered treated-tobacco cigarette was 45.1 percent of that from a nonfiltered cigarette. Random specimens of lung, liver, kidney, heart, and psoas muscle obtained from smokers and nonsmokers indicated higher levels of polonium-210 in the organs of smokers.

<16>
AUTHOR: Ferri, E.S.; Christiansen, H.
TITLE: Lead-210 in Tobacco and Cigarette Smoke
PUB DESC: Public Health Rep. 82:828-832
PUB DATE: 1967
ABSTRACT: A study was undertaken to determine the concentration of lead-210, as opposed to polonium-210, in tobacco and cigarette smoke. Comparisons indicate that in smoke from five brands, the lead-210 activity was about half that of polonium-210. From four of the six brands of cigarettes tested, intake of lead-210 from smoking 20 cigarettes a day was double that from breathing normal air, and in the two other brands the intake was about equal. This intake was less than one percent of the maximum permissible concentration for lead-210 in air for large populations. Although the relationship is not constant, smoke from cigarettes with larger amounts of tar and nicotine also had higher concentrations of lead-210. Using the International Committee for Radiological Protection lung model, dosages to the pulmonary compartment of the respiratory tract were calculated for a person smoking 20 cigarettes a day. 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.

<17>
AUTHOR: Fleischer, R.L.; Parungo, F.P.
TITLE: Aerosol Particles on Tobacco Trichomes
PUB DESC: Nature 250:158-159
PUB DATE: 1974
ABSTRACT: In support of the hypothesis that radon and its decay products attach to sub-micron atmospheric particles which are then trapped on the sticky tips of tobacco trichomes, the authors analyzed the leaves of air-cured tobacco to see if aerosols are on and inside tobacco trichome tips. They found that the tips contained both continental and marine aerosols. This finding gives support to the theory that radon daughters precipitate on aerosols which then diffuse to trichome tips.

<18>
AUTHOR: Francis, C.W.; Chesters, G.; Erhardt, W.H.
TITLE: Po-210 Entry into Plants
PUB DESC: Environ. Sci. Technol. 2(9):690-695
PUB DATE: 1968
ABSTRACT: An investigation was conducted to determine the mode of entry of Po-210 into plants. Little or no evidence was found for direct root uptake of Po-210 or Pb-210 from soils. Therefore, natural radioactive fallout was indicated as the most likely source of Pb-210 in plants. The principal component of radioactive fallout is precipitation and the measurement of appreciable quantities of Pb-210 in rainfall strengthened the hypothesis that natural radioactive fallout was a feasible mechanism of Po-210 entry into plants. Calculations showed that, in the tobacco crop studied, sufficient Pb-210 was present in the rainfall to account for all of the Po-210 in the plants.

<19>
AUTHOR: Francis, C.W.; Chesters, G.
TITLE: Radioactive Ingrowth of 210-Po in Tobacco Plants
PUB DESC: J. Agric. Food Chem. 15:704-706
PUB DATE: 1967
ABSTRACT: This study was initiated to evaluate the extent of Po-210 in tobacco and to determine the possible existence of an equilibrium between Pb-210 and Po-210. The Po-210 content of cured tobacco leaves was determined at intervals of approximately three months for a period of one year. Increasing concentrations of Po-210 were found after storage, thereby proving the existence of Po-210 ingrowth from some radioactive precursor. Calculations indicated that Po-210 in the tobacco leaves is derived from, and therefore in equilibrium with, Pb-210, and that Po-210 does not enter the plant per se but enters either by plant uptake or by deposition in natural radioactive fallout.

<20>
AUTHOR: Gastineau, R.M.; Walsh, P.J.; Underwood, N.
TITLE: Thickness of Bronchial Epithelium with Relation to Exposure to Radon
PUB DESC: Health Phys. 23:857-860
PUB DATE: 1972
ABSTRACT: The depths of the basal cells of normal bronchial epithelium were measured for use in the calculation of the ionizing radiation dose from inhaled radon and radon daughters. In over two-thirds of the epithelium of the lobar and segmental bronchi the basal cells

<20> CONT.
are within the range of Po-210 alpha particles, and in one-fifth of the same epithelium the basal cells are within the range of both Po-210 and Po-214 alpha particles, assuming the radioactive substances are located on the surface of a 7 u thick layer of mucus. Although the basal cells in the normal mainstem bronchial epithelium are outside the range of alpha radiation, areas of metaplasia were noted which were thin enough to permit exposure of the basal cells. It is postulated that the presence of thin areas of metaplasia in the bronchial epithelium could result in the occurrence of bronchogenic cancer in the main-stem bronchi, which may explain the increased incidence of lung cancer in miners who smoke.

<21>
AUTHOR: Geesaman, D. P.
TITLE: An Analysis of the Carcinogenic Risk from an Insoluble Alpha-Emitting Aerosol Deposited in Deep Respiratory Tissue
PUB DESC: UCRL-50387, 17 pages
PUB DATE: 1968
ABSTRACT: The author discusses the gross and microscopic function of the lung relative to the questions of pulmonary deposition and clearance. In the upper respiratory tract inertial deposition occurs, while in the lower tracts, gravitational settling accounts for most of the deposition. Submicronic particles are deposited by Brownian diffusion. Clearance rates are discussed relative to the location of deposition. Particles in the deep respiratory zone may show long residence times, up to 500 days, and this constitutes the problem for radioactive particles. Relative times, lengths and geometrics are noted in order to construct a simple model of deep respiratory tissue lattice. Pu-238 dioxide and Pu-239 dioxide are used as representative aerosols in making quantitative estimates of tissue exposure and response using the lattice models generated. In the absence of an accurate knowledge of clearance, local shielding responses, and the mechanisms of cancer induction, the suggested course is an experimental determination of the number of source particles per induced cancer.

<22>
AUTHOR: Geesaman, D. P.
TITLE: An Analysis of the Carcinogenic Risk from an Insoluble Alpha-Emitting Aerosol Deposited in Deep Respiratory Tissue: Addendum
PUB DESC: UCRL-50387, Addendum, 9 pages
PUB DATE: 1968
ABSTRACT: Several experiments are reviewed involving skin and lung carcinogenesis in mammals after intense localized doses of ionizing radiation. A high incidence of cancer occurs for the exposures described. The observations suggest that the carcinogenesis is primarily mediated by injury or disruption of local tissue. It is concluded that there is a substantial possibility of enhanced cancer risk associated with the deposition of intense alpha-emitting particulates in deep respiratory tissue. Within this description lung cancer risks as high as 1.0E-3 to 1.0E-4 per disruptive source particle are indicated. The possibility of this enhanced risk places the present standard for maximum permissible lung burdens in serious question when applied to particulates such as Pu-238 dioxide and Pu-239 dioxide. It is again suggested that in the absence of a detailed knowledge of pulmonary carcinogenesis, the best course of action is an experimental determination of the risk per disruptive particle for particle burdens << 1.0E-8 particles.

<23>
AUTHOR: Gregory, L.P.
TITLE: Polonium-210 in Leaf Tobacco from Four Countries
PUB DESC: Science 150:74-76
PUB DATE: 1965
ABSTRACT: Tobaccos grown in the United States, Rhodesia, South Africa, and New Zealand were measured for their polonium-210 content. Results show that the average Po-210 activity in the New Zealand grown leaf samples was 0.15 pCi/g, compared with 0.49 pCi/g in the United States samples. The level in South African tobacco was approximately the same as United States tobacco, with the level in Rhodesian tobacco significantly higher. The reason for the lower level of Po-210 in New Zealand tobacco is not fully understood, but may be due to the radon diffusing from the land's surface being dispersed over the sea. The resulting natural fallout of the lead-210 precursor of Po-210 may be significantly less over a country with a predominantly insular climate.

<24>
AUTHOR: Grossman, B.N.; Little, J.B.; O'Toole, W.F.
TITLE: Role of Carrier Particles in the Induction of Bronchial Cancer in Hamsters by Polonium-210 Alpha Radiation
PUB DESC: Radiat. Res. 47:253-254
PUB DATE: 1971
ABSTRACT: In order to investigate the role of carrier particles in the induction of bronchial cancer in hamsters, 4 groups of 50 hamsters were given separate intratrachial instillations consisting of various combinations of polonium-210 alone (in saline) and polonium-210 adsorbed onto Fe2O3 particles. Preliminary autoradiographic studies indicate that Polonium-210 administered adsorbed onto Fe2O3 remained firmly associated with the particles, and its deposition was nonuniform depending on that of the particles. Polonium-210 administered alone in saline was found to be distributed homogenously throughout the lung parenchyma. The results suggest that under these conditions of exposure alpha radiation may be more carcinogenic when it is more uniformly distributed in the lung.

<25>
AUTHOR: Guerin, M.R.
TITLE: Discussion - Identification of Carcinogens, Tumor Promotors and Cocarcinogens in Tobacco Smoke
PUB DESC: ORNL Conf. 750633-2, 13 p.
PUB DATE: 1975
ABSTRACT: The author notes the possible relationship between Po-210 and low level alpha radiation with tobacco carcinogenesis. He points out the role of metals in smoke-induced carcinogenesis and notes that the "form" of the metal may be more important than the metal itself. Nickel subsulfide, in particular, may be a potent respiratory carcinogen resulting from the reaction of sulfur and nickel in smoke. Chromatographic profiling methods and condensate fractions were used to expedite the identification of biologically significant constiuents. Peaks which correlate highly indicate constituents which can be identified and studied first. The author points out the importance of in vivo studies of carcinogens and co-carcinogens to identify biologically

<25> CONT.
active smoke constituents.

<26>
AUTHOR: Hill, C.R.
TITLE: Polonium-210 in Man
PUB DESC: Nature 208:423-428
PUB DATE: 1965
ABSTRACT: This article defines the part played by polonium-210 in contributing to the biologically effective radiation dose received by man in a variety of environments. Polonium-210 concentrations in a number of cigarette tobaccos of different origin are given, with the results indicating no striking differences between tobaccos from the different major producing areas. A popular brand of cigarette was found to contain 0.49 plus or minus 0.07 pCi polonium per cigarette, and an appreciable part of the polonium appeared in the mainstream smoke. The specific polonium-210 alpha-radioactivity in condensed smoke is of the order of 2 pCi/g, therefore the radiation dose rate at the surface of a thick slab of material would be 0.1 rad per year and less for thinner slabs. High local dose rates in the human lung could occur only if there is a mechanism for selective clearance from the lung. Measurements of the polonium-210 tissue level in smokers and nonsmokers are given, and the polonium-210 content of the average smoker's lung exceeds that of the average nonsmoker by 5.4 pCi. No appreciable excess polonium-210 activity was found in the bronchial bifurcations of cigarette smokers. The author concludes that cigarette smoking does not seem to lead to abnormal levels of polonium-210 in tissues other than the lung, and the levels here are not such as would lead to abnormally high radiation dose rates.

<27>
AUTHOR: Holtzman, R. B.
TITLE: Polonium-210 in Bronchial Epithelium of Cigarette Smokers
PUB DESC: Science 155:607
PUB DATE: 1967
ABSTRACT: The author discusses the fact that recent data showing the existence of areas of relatively high levels of polonium-210 in human lung tissue do not disagree with those of previous studies. He notes, however, that the discrepancies are still not fully resolved either in the light of existing data or regarding some theoretical considerations.

<28>
AUTHOR: Holtzman, R. B.; Ilcewicz, F. H.
TITLE: Lead-210 and Polonium-210 in Tissues of Cigarette Smokers
PUB DESC: Science 153:1259-1260
PUB DATE: 1966
ABSTRACT: This study demonstrated that, in skeletal tissues, not only are the concentrations of Po-210 greater in smokers than in nonsmokers, but in both skeletal and lung tissues of smokers concentrations of Pb-210 are also greater. It is also shown that the Po-210 is in radioactive equilibrium with the Pb-210 in bone, and that Pb-210 is present in cigarette smoke. Measurements were made on rib bones and alveolar lung tissue taken at autopsy or surgery from subjects of known smoking habits, revealing that the mean concentrations of both Pb-210 and Po-210 in bones of smokers were more than double those in nonsmokers. The more limited data from lung tissue indicate that the Pb-210 concentration in heavy smokers is about 4 times that in nonsmokers. The correlations between cigarette smoking and the concentrations of nuclides in the lungs and skeletons of these subjects indicate that smoke is a significant source of intake of Po-210 and Pb-210.

<29>
AUTHOR: Ide, G.; Suntzeff, V.; Cowdry, E.V.
TITLE: A Comparison of the Histopathology of Tracheal and Bronchial Epithelium of Smokers and Nonsmokers
PUB DESC: Cancer, 12:473-484
PUB DATE: 1959
ABSTRACT: The authors studied tracheal and bronchial materials taken at autopsy and correlated the results with smoking history and occurrence of pneumonia. The mean thickness of tracheal epithelium was found to be greater than that of bronchial epithelium for nonsmokers, light smokers and heavy smokers. However the thickness was found to increase in both areas in relation to the amount of smoking. Tracheal and bronchial cilia were found to decrease in height with increased smoking, as did the percentage of ciliated cells present (33% in nonsmokers and 22.3-28.5% in light and heavy smokers). Squamous metaplasias and basal cell hyperplasias were more numerous in light and heavy smokers without pneumonia than they were in nonsmokers. In areas of basal cell hyperplasia the cilia remain well developed, but in squamous cell metaplasia the cilia were found to be almost completely absent. The percentages of goblet cells present were found to increase in nonsmokers and decrease in heavy smokers. The deep glands were increased in light and heavy smokers. The authors discuss reasons why the incidence of tracheal cancer has not exhibited a similar increase in cancer development to that of bronchial epithelium in response to the great increase in cigarette smoking.

<30>
AUTHOR: Kaminski, E.J.; Fancher, O.E.; Calandra, J.C.
TITLE: In Vivo Studies of the Ciliastatic Effects of Tobacco Smoke
PUB DESC: Arch. Environ. Health 16:188-193
PUB DATE: 1968
ABSTRACT: In vivo experiments were undertaken to determine the degree of absorption of ciliatoxic components of tobacco smoke by a wet surface and the extent of the resulting reduction in ciliary inhibition. It was found that cigarette smoke which has been passed through a chamber containing wet surfaces produces significantly lower inhibition of mucociliary activity. No significant reduction of inhibition due to the presence of a wet chamber resulted in the case of cigarettes containing charcoal filters. The authors believe these results indicate that some ciliatoxic components of tobacco smoke may be absorbed in the saliva and the mucous membranes of the oral cavity of smokers before they reach the lung.

<31>
AUTHOR: Kelley, T. F.
TITLE: Polonium-210 Content of Mainstream Cigarette Smoke
PUB DESC: Science 149:537-538
PUB DATE: 1965
ABSTRACT: The quantities of Po-210 in mainstream smoke of cigarettes and the characteristic of cigarette filters which makes them effective against Po-210 were investigated. Eleven popular brands of cigarettes were smoked in a standardized manner, the particulate phase removed and measured, and the Po-210 content analyzed, so that a comparison could be made

<31> CONT.
between the amounts of Po-210 and particulate matter in mainstream smoke. The Po-210 content of tobacco from whole unburned cigarettes was also determined. The quantities of Po-210 in mainstream smoke measured in this study were considerably lower than in a previous study, and the author concludes that the Po-210 content of mainstream smoke depends upon the manner of smoking. There were no significant differences in the Po-210 content of whole tobacco between the brands tested. There were considerable differences in the Po-210 content in mainstream smoke from the various brands of cigarettes, with the content of Po-210 apparently depending on the amount of particulate matter in the mainstream smoke, and not on the presence or absence of a filter or on the nature of construction of the filter. The relationship exists between the Po-210 content and the amount of particulate matter because the polonium is apparently adsorbed on smoke particles during the combustion process.

<32>
AUTHOR: Kennedy, A.R.; Little, J.B.
TITLE: The Transport and Localization of Benzo(alpha)pyrene-Hematite and Hematite-210Po in the Hamster Lung Following Intratracheal Instillation
PUB DESC: Cancer Res. 34: 1344-1352
PUB DATE: 1974
ABSTRACT: When administered intratracheally, adsorbed onto hematite carrier particles, Po-210 and benzo(alpha)pyrene (BP) induce lung tumors of different histologies and apparent sites of origin. Hematite-210Po produces combined epidermoid and adenocarcinomas in the peripheral lung, while BP-hematite produces mainly epidermoid carcinomas of the major bronchi and trachea. To determine whether cells in the lung are differentially sensitive to the two types of carcinogen or whether the carcinogens are reaching and acting at different sites, the authors studied their transport and localization following intratracheal administration on carrier particles: Po-210 localization by freeze-dry autoradiography and BP localization by ultraviolet light fluorescence microscopy of frozen sections. The results show that Po-210 represents a firmly bound insoluble carcinogen which delivers its primary dose in the peripheral lung from the particles that are retained in the alveolar duct region. BP, on the other hand, is a loosely bound soluble carcinogen which leaves the carrier particles and enters upper airway epithelial cells during clearance of the particles on the mucous ciliary escalator. The authors conclude that BP induces central tumors because a significant amount of the carcinogen reaches the upper airway epithelial cells, while Po-210 induces peripheral tumors because the major radiation dose is delivered to the alveolar region.

<33>
AUTHOR: Kilibarda, M.; Petrovic, D.; Panov, D.; Djuric, D.
TITLE: Contamination with Polonium-210, Uranium and Radium-226 Due to Smoking.
PUB DESC: Radiation Protection, Part 2, Snyder, W.S. et al. (ed.), New York, Pergamon Press, Inc. P. 1099-1103
PUB DATE: 1968
ABSTRACT: The content of Po-210, uranium and radium-226 was studied in Yugoslavian tobacco and cigarettes. The results obtained for uranium and radium were very low, and statistical evaluation was impossible. The mean value of Po-210 in 4 different cigarettes was 0.38 pCi/g. The distribution of Po-210 in smoke, ash and cigarette stubs as a function of combustion temperature was studied. The authors concluded that 3% of Po-210 present in a cigarette is inhaled. The urine of smokers and nonsmokers was analyzed for Po-210, and statistical evaluation established that a significantly higher concentration exists in the urine of smokers. The authors conclude that of the inhaled Po-210, about 10-15% is absorbed and excreted. The polonium content in various tobaccos and cigarettes did not vary much for different regions of the country.

<34>
AUTHOR: Langer, G.; Fisher, M.A.
TITLE: Concentration and Particle Size of Cigarette-Smoke Particles
PUB DESC: Arch. Ind. Health 13:372-378
PUB DATE: 1956
ABSTRACT: A study of the particle size, particle concentration, and filtration characteristics of cigarette smoke was conducted to aid in studying the appearance of the smoke, the relation of tobacco type to smoke properties, and the retention of smoke by the body. The median diameter of the cigarette smoke particles from the unfiltered cigarette was 0.6 u for puffs 2, 6, and 10, and for the filter cigarette was 0.5 u, 0.5 u, and 0.6 u for puffs 2, 6, and 10, respectively. The concentration increased from 2.2E8 particles per cubic centimeter for puff 2, to 5.3E8 particles per cubic centimeter for puff 10 of the unfiltered cigarette and from 2.0E8 to 2.9E8 particles per cubic centimeter for the filter cigarette. The weight of smoke per puff increased from 1.8 to 5.2mg and from 0.8 to 2.4mg for the second to the tenth puff, respectively, for the unfiltered and filtered cigarette.

<35>
AUTHOR: Lawrenco, R.V.; Klimek, M.F.; Borowski, C.J.
TITLE: Deposition and Clearance of 2 u Particles in the Tracheobronchial Tree of Normal Subjects - Smokers and Nonsmokers
PUB DESC: J. Clin. Invest., 50:1411-1420
PUB DATE: 1971
ABSTRACT: Deposition and clearance of inhaled particles of iron oxide labeled with Au-198 were studied in 19 normal subjects (10 nonsmokers and 9 smokers). In all subjects, smokers and nonsmokers, the deposition of the particles was uniform throughout both lung fields, with approximately half of the particles deposited in the ciliated airways (tracheobronchial deposition) and half in the nonciliated airways (alveolar deposition). Tracheobronchial clearance in nonsmokers occurred immediately after inhalation. Photoscintigrams showed that the particles cleared steadily with no retention in any area. In smokers, tracheobronchial clearance was delayed for periods of 1-4 hours after inhalation. Furthermore, in contrast with the findings in nonsmokers,significant clearance was still occurring in many of the smokers in the 5th and 6th hour after inhalation. Also, photoscintigrams showed an abnormal accumulation of particles in the large airways several hours after inhalation of the aerosol.

<36>
AUTHOR: Little, J.B.; Kennedy, A.R.; McGandy, R.B.
TITLE: Lung Cancer Induced in Hamsters by Low Doses of Alpha Radiation from Polonium-210

<36> CONT.
PUB DESC: Science, 188:737-738
PUB DATE: 1975
ABSTRACT: Lung cancers have been induced in 9 to 53 percent of hamsters given multiple intratracheal instillations of polonium-210 in amounts yielding lifetime exposures of 15 to 300 rads to the lungs. Cigarette smokers have previously been estimated to receive 20 rads to areas of the bronchial epithelium from deposited polonium-210 over a 25-year period. Po-210 administered on carrier particles was deposited in a nonhomogeneous fashion, associated with hematite aggregates in macrophages surrounding alveolar ducts. The carcinogenic effect might be due to the localization of these "hot spots." Po-210 administered in a saline solution was distributed homogeneously throughout the bronchiolar-alveolar region. This Po-210 yielded a lower radiation dose than the Po-210 deposited on particles, probably because the soluble Po-210 (in saline) was more efficiently cleared from the lung, particularly via the bloodstream. The amount of Po-210 given to the lowest exposure group (9% malignancies) is 1/5 the amount inhaled in 25 years by a heavy smoker. These findings support the hypothesis that alpha radiation resulting from the polonium-210 or lead-210 present in cigarette smoke may be a significant causative factor in human lung cancer.

<37>
AUTHOR: Little, J.B.; McGandy, R.B.
TITLE: Measurement of Polonium-210 in Human Blood
PUB DESC: Nature 211:842-843
PUB DATE: 1966
ABSTRACT: Body burdens of polonium-210 are usually determined by measuring its activity in tissue samples or urine. Tissue and urine samples, however, may be inconvenient to obtain and process. The authors have found that polonium-210 can be easily detected in 10ml human blood samples by a simple radiochemical and counting technique. This may be a practical method of estimating body burdens of this isotope, as well as of its parent lead-210. The authors related blood concentrations to smoking habits in a group of middle-aged men. They found that the average polonium-210 concentration in smokers was 1.72 pCi/kg blood, compared with 0.76 pCi/kg in nonsmokers. Although a significant difference existed between blood concentrations in smokers and nonsmokers, a two- to three-fold variation among individuals was present in each group.

<38>
AUTHOR: Little, J.B.; McGandy, R.B.
TITLE: Systemic Absorption of Polonium-210 Inhaled in Cigarette Smoke
PUB DESC: Arch. Environ. Health 17:693-696
PUB DATE: 1968
ABSTRACT: The kinetics of the change in concentration of polonium-210 in the blood of six cigarette smokers has been studied up to 89 days after sudden cessation of smoking to estimate the degree of clearance of polonium-210 from the lungs into the blood. Circulating polonium-210 levels declined an average of 14% after three to four days and 20.5% after 11 to 14 days. Results indicate that direct absorption into the blood stream represents a major mechanism by which polonium-210 is cleared from the lungs. On the basis of several assumptions, the authors conclude that a minimum systemic absorption of 38% of Po-210 retained each day from cigarette smoke must have occurred in the subjects, with actual systemic absorption probably considerably higher. The authors also conclude that systemic absorption of inhaled Po-210 occurs directly across the respiratory epithelium. The finding that a considerable fraction of the isotope is absorbed directly into the blood stream indicates that systemic absorption of at least one potentially carcinogenic component of cigarette smoke occurs in men. The chemical form in which polonium exists in tobacco smoke is not known, but this element might serve as a model for pulmonary clearance mechanisms of other heavy metals such as lead.

<39>
AUTHOR: Little, J.B.; O'Toole, W.F.
TITLE: Respiratory Tract Tumors in Hamsters Induced by Benzo(alpha)pyrene and Po-210 Alpha-Radiation
PUB DESC: Cancer Res. 34:3026-3039
PUB DATE: 1974
ABSTRACT: A high incidence of respiratory cancer has been induced in Syrian golden hamsters by repeated intratracheal instillations of either benzo(alpha)pyrene or Po-210 adsorbed onto hematite carrier particles. Both the tumor incidence and the mean induction time were related to the dose of carcinogen. Benzo(alpha)pyrene induced a spectrum of tumors. The type occurring most frequently was epidermoid carcinoma of the trachea or major bronchi. Po-210-induced tumors were almost exclusively combined epidermoid and adenocarcinomas that arose peripherally; these tumors occurred in 94% of animals in the highest exposure group. Hamsters appear particularly susceptible to the induction of lung cancer by alpha-radiation at doses that do not produce concomitant lung damage, and they may provide a good model for the study of interactions between radiation and chemical agents in respiratory carcinogenesis.

<40>
AUTHOR: Little, J.B.; Radford, Jr., E.P.; McCombs, H.L.; Hunt, V.R.
TITLE: Distribution of Polonium in Pulmonary Tissues of Cigarette Smokers
PUB DESC: N. Engl. J. Med. 273:1343-1351
PUB DATE: 1965
ABSTRACT: Studies were undertaken to measure polonium-210 concentrations in pulmonary tissues of smokers and nonsmokers. Concentrations were found to be higher in lung parenchyma, peribronchial lymph nodes and bronchial epithelium of smokers than in nonsmokers. From its distribution within the lung, the authors conclude that clearance of the majority of smoke particles is rapid and occurs primarily by way of the bronchi. By far the highest local concentrations of polonium-210 were found at segmental bifurcations of the bronchial epithelium. On the basis of these results, the authors believe that polonium-210 may be an important factor in the initiation of bronchial carcinoma in man.

<41>
AUTHOR: Little, J.B.; Radford, Jr., E.P.
TITLE: Polonium-210 in Bronchial Epithelium of Cigarette Smokers
PUB DESC: Science 155:606-607
PUB DATE: 1967
ABSTRACT: The analysis of tissues from 25 cigarette smokers revealed average concentrations of Po-210 in wet tissue of the bronchial epithelium as 0.12 pCi/g in the trachea, 0.19 pCi/g in the lobar bronchi, and 4.5 pCi/g in the segmental bifurcations. The Po-210 concentrations in the bronchial wall

<41> CONT.
and submucosa and in superficial mucus were very low. Most of the measured activity lay in the epithelium, yet the epithelium accounts for only 2 to 3 percent of a bronchial specimen by weight. It is therefore evident that the Po-210 concentration measured in a whole specimen of bronchus may appear low, while the epithelial concentration may be higher by nearly two orders of magnitude. The authors maintain that their estimates of radiation dose for small areas of the bronchial epithelium are compatible with those obtained by others, with the differences in dose estimates resulting from different techniques.

<42>
AUTHOR: Little, J.B.; Radford, Jr., E.P.; McCombs, H.L.; Hunt, V.R.; Nelson, C.
TITLE: Polonium-210 in Lungs and Soft Tissue of Cigarette Smokers
PUB DESC: Radiat. Res. 22:209
PUB DATE: 1964
ABSTRACT: Fresh autopsy specimens of lungs and other tissues from five non-smokers and twelve chronic smokers who smoked until 1-10 days prior to death were analyzed for Po-210 concentrations. Po-210 levels in lung parenchyma showed considerable variation within the same lung, and the average level in smokers was four times that of non-smokers. In the bronchial epithelium of proven non-smokers little or no Po-210 was found, but in smoker's epithelium, the average levels per gram of tissue were 4-40 times that found in smoker's parenchyma. Except for the pulmonary tissues, no difference in Po-210 levels in smokers and non-smokers was observed, although urinary excretion of Po-210 was higher in smokers.

<43>
AUTHOR: Marsden, Sir Ernest
TITLE: Incidence and Possible Significance of Inhaled or Ingested Polonium
PUB DESC: Nature 203:230-233
PUB DATE: 1964
ABSTRACT: The author has investigated the amount and sources of the alpha activity of tobacco, as well as the possible influence of polonium on the incidence of lung cancer in cigarette smokers. The tobaccos showing the highest alpha activity are those grown on soils of low pH. These soils are derived from radioactive older granites occurring in parts of Southern Rhodesia, North Queensland, and elsewhere. There is apparently some small effect of polonium fallout on tobacco plant activity, but in the case of higher activity tobacco it is only a minor factor compared with activity derived from soil through the roots. The author notes that a man inhaling the smoke of 25 average British cigarettes a day probably deposits on his lungs and trachea some 8 pCi/day of polonium. He substantiates the influence of polonium on lung cancer in cigarette smokers by pointing out the correspondence of increased incidence of lung cancer to increased importation of Southern Rhodesian tobacco. He also points out that the ratio of death rates from lung cancer for four countries studied showed a general relationship to the amount of polonium activity inhaled from cigarettes.

<44>
AUTHOR: Marsden, Sir Ernest
TITLE: Some Aspects of the Relationship of Radioactivity to Lung Cancer
PUB DESC: N. Z. Med. J. 64:367-376
PUB DATE: 1965
ABSTRACT: The author reviews some of the evidence that radioactivity present in tobacco is responsible for most of the lung cancer observed in man. He notes that lung cancer death rates over the years have increased several times more rapidly than the per capita consumption of tobacco. However, there is a direct correspondence between death rates from lung cancer in the United Kingdom and increasing importation of Rhodesian tobacco. Rhodesian tobacco is particularly high in alpha activity. The author also discusses the reported small lung cancer death rate in Russia. Russian grown tobacco is usually open air dried, which produces a tobacco smoke which is less acid and therefore less likely to adsorb the more volatile salts of polonium. The article goes on to consider the connection between cancer in man and polonium in the atmosphere and foodstuffs.

<45>
AUTHOR: Marsden, Sir Ernest; Collins, M. A.
TITLE: Alpha-Particle Activity and Free Radicals from Tobacco
PUB DESC: Nature 198:962-964
PUB DATE: 1963
ABSTRACT: The authors comment on their re-examination of factors dealt with in a paper by Turner and Radley [Lancet, 1197 (1960)] on the radiation hazards of cigarette smoking. Their results indicate that samples of cigarette tobacco leaf have several times the alpha-activity of the maximum quoted by Turner and Radley, and that several brands of cigarettes are much more radioactive than those cited previously. They do not claim to advance proof of carcinogenic action of radiation from cigarette tobacco, but merely present a case for further examination of the question by those with the necessary facilities. Free radicals in tobacco and their effect on lung cancer hazard and the inherent alpha-activity of tobacco are also discussed.

<46>
AUTHOR: Martell, E. A.
TITLE: Radioactivity of Tobacco Trichomes and Insoluble Cigarette Smoke Particles
PUB DESC: Nature 249:215-217
PUB DATE: 1974
ABSTRACT: A possible sequence of events that may account for bronchial cancer among smokers is presented. There is experimental evidence that radon daughters in air are concentrated on sub-micron particles. These particles then diffuse to the sticky, exudate coated tips of tobacco trichomes (hairs) on the leaf surfaces. Later, during curing, the sticky exudate polymerises to encapsulate the aerosols in highly insoluble particles. During smoking, these highly insoluble particles accumulate in the bronchial epithelium bifurcations of smokers and give rise to a high dose in a small volume of tissue.

<47>
AUTHOR: Martell, E. A.
TITLE: Tobacco Radioactivity and Cancer in Smokers
PUB DESC: Am. Sci. 63:404-412
PUB DATE: 1975
ABSTRACT: The author believes that lung cancer in smokers is caused as a result of the deposition of highly insoluble cigarette-smoke particles of very high specific lead-210 activity in localized areas of the lung. While the various suspected chemical carcinogenic agents in tobacco smoke, as well as certain chemicals and

<47> CONT.

fibrous dusts, are not the primary cause of lung cancer in cigarette smokers, they may play a significant role in enhancing tumor risks by inhibiting clearance and modifying the distribution of inhaled insoluble radioactive particles. Since studies have shown that radioactive particles deposited in pulmonary spaces are slowly translocated to other sites in the body via blood and lymph circulations, the author postulates that atherosclerosis, cancer and other diseases in the aging process may be the result of radiation-induced chromosome changes.

<48>

AUTHOR: McLaughlin, M.; Stopps, G. J.
TITLE: Smoking and Lead
PUB DESC: Arch. Environ. Health 26:131-136
PUB DATE: 1973
ABSTRACT: Over 4,000 Dupont employees were subjects for a longitudinal study on urine and blood lead levels in relation to smoking habits. A mean urine lead level of 27.1 u g/liter was found for nonsmokers, 28.6 u g/liter for cigarette smokers, and 29.0 u g/liter for pipe and/or cigar smokers. The mean blood lead level of the nonsmokers was found to be 19.1 u g/100 ml, while that of cigarette smokers was 19.9 u g/100 ml and that of pipe and cigar smokers was 17.3 u g/100 ml. The data was submitted to a multiple regression analysis to determine if the differences in groups were associated with smoking habits or a reflection of other variables. No evidence was found that nonsmokers had significantly different blood lead levels from smokers, and, while the influence of smoking on urine lead levels was statistically significant, it was very small compared with the total variability of the data and probably of no biological significance. The author notes that all factors considered in the multiple regression analysis account for only 2.5% of the total variation in the urine data and 10.7% of the variation in the blood data, thus indicating that all the factors studied play a very small role as a source of lead compared to other sources, such as ingested lead from food and water.

<49>

AUTHOR: Michelson, I.
TITLE: Cigarettes: Polonium-210
PUB DESC: Science 143:917
PUB DATE: 1964
ABSTRACT: The author questions an earlier report by Radford and Hunt [Science 143,247 (1964)] which stated that there were no significant differences in the Po-210 content of inhaled smoke from filter and nonfilter cigarettes. Recalling that their data showed that filter cigarettes yield 28 percent less polonium in the mainstream smoke than nonfilter cigarettes, the author states that it may be more than a coincidence that the yield of smoke particles from such cigarettes was found to be in a similar ratio by the Consumers Union. Although the 28 percent reduction found by Radford and Hunt might seem too small to show the value of cigarette filters, their data compare only two filter cigarettes with two nonfilter cigarettes. The Consumers Union 1961 tests revealed that some king-size filter cigarettes yield as much as 70 percent less tars than other brands, and one cigarette seems to afford a reduction of 85 percent. If the polonium-210 yields are similarly reduced, one might conclude that cigarette filters can effect a significant reduction in hazard.

<50>

AUTHOR: Mogro-Campero, A.; Fleischer, R.L.
TITLE: Upper Limits of Alpha-Radioactivity Per Particle of Cigarette Smoke
PUB DESC: Health Phys., 32 (1):39-40
PUB DATE: 1977
ABSTRACT: Measurements of the alpha-activity per particle of tobacco smoke, which are necessary in evaluating the likelihood of radiation induced cancer from cigarette smoking, are reported. The results shown on autoradiographs imply that each radioactive smoke particle must contain less than 2.0E-6 pCi of Po-210 or 1.0E-5 pCi of Pb-210. From this it would appear that at most a few tobacco trichomes can be incorporated into one radioactive smoke particle.

<51>

AUTHOR: Purkayostha, B.C.; Bhattacharyya, D.K.
TITLE: Estimation of Rare and Radioactive Constituents in Samples of Indian Tobacco with the Aid of Low-Level Beta Counter
PUB DESC: J. Radioanal. Chem. 27:345-351
PUB DATE: 1975
ABSTRACT: This study of the Nicotiana rustica variety of tobacco from North Bengal revealed that the respective amounts of radioactive nuclei K-40, Y-90 and rare earth activity as well as Pb-210 were found to be 4.04, 2.42, 4.52, and 0.052 pCi/g of cured leaves. In another investigation with Nicotiana tabaccum variety from Rajahmundri, Andhra Pradesh, contents of K-40, Sr-90, Y-90 and rare earth activity, and Pb-210 were observed to be 4.06, 1.02, 3.44 and 0.20 pCi/g of cured leaves, respectively. Results indicate that the amount of polonium which is presumably in equilibrium with RaD in these two varieties of Indian tobacco leaves is very small. Detailed studies on different varieties of Indian tobacco are in progress.

<52>

AUTHOR: Radford, Jr., E.P.
TITLE: Polonium-210 Alpha Radiation as a Cancer Initiator in Tobacco Smoke
PUB DESC: Presented at the 5th International Congress of Radiation Research, July 14-20, 1974, Seattle, Wash.
PUB DATE: 1974
ABSTRACT: Exposure to alpha-emitting radon daughters has been firmly established as increasing the risk of bronchial cancer among underground miners. Polonium-210 and lead-210 are found in tobacco smoke, and increased polonium activity is found in bronchial tissues of smokers. Therefore polonium alpha radiation may be a significant initiator in cigarette-induced bronchial cancer. Quantitative assessment of its importance as an initiator depends on comparing the cumulative rad dose to the bronchial epithelium of smokers to dose-response data in miners. This comparison depends largely on whether local "hot-spot" doses are comparable to the diffuse bronchial dose received by miners. The author states that polonium decay as an initiator accounts for a substantial fraction, if not all, of cigarette-induced lung cancers in males. He also discusses the role of other smoke constituents or viruses in lung cancer production, and the observed cell types of bronchial cancer in smokers and miners.

<53>

AUTHOR: Radford, Jr., E.P.; Hunt, V.R.; Little, J.B.
TITLE: Polonium-210 in Cigarette Smokers
PUB DESC: Science 146:87

<53> CONT.
PUB DATE: 1964
ABSTRACT: In reply to an article by Skrable, Haughey, and Alexander [Science 146,87(1964)], the authors state that the bronchial epithelium is the critical organ for inhaled insoluble aerosols containing alpha-emitters, a fact which they feel the International Committee on Radiation Protection (ICRP) has not adequately considered in setting the maximum permissible concentration of the relatively long-lived alpha-emitting elements. They do not feel that the ICRP model for calculating minimum critical dose for inhaled Po-210 applies to cigarette smoke because cigarette smoke particles are nearly all smaller than 0.4 micron. Furthermore, the authors defend their assumption that all of the smoke deposited is initially on the alveolar surface on the basis that the surface area of the alveoli of a normal adult is 100 times greater than the surface area of the ciliated bronchi. The authors maintain that their estimated dose of 36 rem arising from all Po-210 deposited in the lungs and cleared via the bronchial tree may be too high or too low for many reasons other than the question of initial deposition raised by Skrable et al. They still believe that their "minimum dose" estimates are conservative for polonium carried out in the mucus sheet and that the "in-transit dose" is of minor significance compared to the dose from polonium absorbed in the epithelium. While the ICRP model for insoluble particles is based on the assumption that 12 1/2 percent of inhaled particles are cleared from the lungs directly into the blood, the authors conclude that less than 5 percent of deposited polonium is cleared directly into the blood. Their measurements in lung parenchyma of smokers support the conclusion that most Po-210 is cleared by way of the bronchi in a relatively short half-life of a few days.

<54>
AUTHOR: Radford, Jr., E.P.; Hunt, V.R.
TITLE: Polonium-210: A Volatile Radioelement in Cigarettes
PUB DESC: Science 143:247-249
PUB DATE: 1964
ABSTRACT: Studies were undertaken to evaluate the concentration of polonium-210 in cigarettes and cigarette smoke. Cigarettes were puffed artificially in a manner simulating cigarette smoking by human subjects, and polonium concentrations were determined for whole cigarettes, ash, butt, total smoke, mainstream smoke, and sidestream smoke. The authors estimated that the minimum radiation dose for an individual smoking two packs of cigarettes a day for 25 years would be about 36 rem. Doses to the bronchial epithelial wall from localized concentrations of polonium were estimated to be 125 rem in 25 years. Using dose response relationships to calculate the lung cancer death rate in miners exposed to radon daughters, the radiation dose necessary to account for the lung cancer death rate in males smoking 40 cigarettes a day or more was estimated to be 1300 rem over a 25 year period. The authors conclude that while polonium-210 inhaled in cigarette smoke may act as an important initiator in the production of bronchogenic carcinoma, other chemical and physiological factors probably play an important part in the genesis of bronchial cancer in smokers.

<55>
AUTHOR: Radford, Jr., E.P.; Martell, E. A.
TITLE: Polonium-210: Lead-210 Ratios as an Index of Residence Times of Insoluble Particles from Cigarette Smoke in Bronchial Epithelium
PUB DESC: Inhaled Particles and Vapors IV, Walton, W.H. (ed.) p. 567-582
PUB DATE: 1975
ABSTRACT: This paper describes a method to calculate the mean residence time of insoluble particles in the lung. The method depends on measurement of the ratio of polonium-210 activity to lead-210 activity in the lungs of cigarette smokers, the buildup of polonium daughters being the measure of time since the particle was inhaled. Assumptions made by the authors are that (1) insoluble particles in cigarette smoke containing lead-210 are stripped of polonium-210 at the time of smoking; (2) as lead-210 decays in the body after inhalation, the daughters remain localized; (3) the polonium-210 inhaled by smokers in a volatile form does not remain in the pulmonary or bronchial tissues; (4) soluble lead-210 will not contribute significantly to activity in bronchial tissues. A mean residence time of insoluble particles in the bronchial epithelium of smokers of 3-5 months was found.

<56>
AUTHOR: Rajewsky, B.; Stahlhofen, W.
TITLE: Polonium-210 Activity in the Lungs of Cigarette Smokers
PUB DESC: Nature 209:1312-1313
PUB DATE: 1966
ABSTRACT: The average activity of Po-210 was assessed in several brands of cigarettes, and the Po-210 content was measured in different parts of the lung of cigarette smokers and nonsmokers. On the average, 10 percent of Po-210 present in one cigarette was detected in the main stream smoke, 15 percent in the cigarette-ash, and 35 percent in the butt. For filter cigarettes, the maximum Po-210 activity detected in the filter was 5 percent, indicating that a filter has no noticeable protective effect against polonium inhalation. A daily Po-210 inhalation rate of 2 pCi was calculated for an individual smoking 20 cigarettes a day, as compared to the estimated rate of 0.02 pCi per day due to inhalation of Po-210 in the open air calculated in a previous study. The lung tissue dissected from heavy smokers was shown to contain three to four times the Po-210 activity found in the lungs of nonsmokers, and the specific activity of the epithelium was about ten times the value assessed in the remaining lung tissue. The alpha dose-rate in the bronchial epithelium was determined to be 41 mrem per year for the basal cell layer of the subsegmental bronchi and 79 mrem per year for the terminal bronchi, small values as compared to the 1-2 rem per year originating from the decay of naturally occurring radon and thoron. This would seem to show that carcinogenesis caused by the inhalation of Po-210 with tobacco smoke is unlikely.

<57>
AUTHOR: Schlesinger, R. B.; Cohen, V.R.; Lippman, M.
TITLE: Studies of Intrabronchial Particle Deposition Using Hollow Bronchial Casts, Experimental Lung Cancer, Carcinogenesis and Bioassays
PUB DESC: International Symposium held at Battelle Seattle Research Center, Seattle, WA, USA, June 23-26, 1974. Karbe, E. and J.F. Park. (ed.) p. 116-127
PUB DATE: 1974
ABSTRACT: Hollow casts of lungs were used in this study to determine the intrabronchial distribution pattern of deposited aerosols and the fractional deposition efficiencies at

<57> CONT.
various branching levels within the tracheobronchial tree. Also studied was the deposition of powder aerosols used for inhalation bronchography. This test series strengthens the association between localized regions of selective deposition and primary cancer sites.

<58>
AUTHOR: Skrable, K. W.; Haughey, F. J.; Alexander, E. L.
TITLE: Polonium-210 in Cigarette Smokers
PUB DESC: Science 146:86-87
PUB DATE: 1964
ABSTRACT: The authors have compared Radford and Hunt's [Science 143,247(1964)] assumptions and mathematical model and those of the International Council for Radiation Protection (ICRP) for calculating minimum critical dose from inhaled Po-210 contained on particles of cigarette smoke. They point out that Radford and Hunt's minimum dose estimate of 36 rem to the bronchial epithelium far exceeds the dose of 1.1 rem to the entire lung as calculated from their data and the recommendations of the ICRP. In Radford and Hunt's calculation the bronchial epithelium is considered a single uniform sheet over which all the Po-210 deposited in the alveoli passes with a mean residence time of 36 hours; but some portions of the bronchial epithelium would in fact receive only that Po-210 originating from alveoli connected to them. The I.C.R.P. assumes that only 12 1/2 percent of the total number of particles inhaled are removed in a short period of time, indicating that Radford and Hunt's dose estimate to the bronchial epithelium might be too high by a factor of 8. Radford and Hunt's assumptions tend to overestimate the total quantity of Po-210 passing over the bronchial epithelium, and hence to overestimate the dose. The authors conclude that, in reality, probably neither Radford and Hunt's model and assumptions nor those of the ICRP actually describe the situation in the lung.

<59>
AUTHOR: Smith, D.M.; Anderson, E.C.; Prine, J.R.; Holland, L.M.; Richmond, C.R.
TITLE: Biological Effect of Focal Alpha Radiation on the Hamster Lung
PUB DESC: Proc. of the Symposium on Biological Effects of Low Level Radiation Pertinent to Protection of Man and His Environment, Chicago, IL. Nov 3-7
PUB DATE: 1975
ABSTRACT: Monodispersed 10-um-diameter ZrO2 ceramic microspheres, containing varying amounts of Pu-210 dioxide or Pu-238 dioxide were injected into the jugular vein of hamsters. These biologically inert microspheres lodged subsequently in pulmonary capillaries. No consistent alteration of lifespans post-exposure was seen in the experimental hamsters compared with controls. Pulmonary tissue responses were minimal, with only 0.5% of the injected animals ultimately developing primary tumors of the lung.

<60>
AUTHOR: Soremark, R.; Hunt, V.R.
TITLE: Distribution of Polonium-210 in Mice Following Inhalation of Polonium-210-Tagged Tobacco Smoke
PUB DESC: Arch. Environ. Health, 14:585-588
PUB DATE: 1967
ABSTRACT: Adult mice were exposed to tobacco smoke tagged with Po-210, and sacrificed at various time intervals following exposure. Autoradiographs were made from sections of the animals, and it was found that the highest deposition of Po-210 was in the nasal cavities, trachea and bronchi, the lungs, and in the stomach. This latter was probably due to the licking of smoke from the fur. Uptake of Po-210 into the intestinal tract, liver and kidneys was noticed. A slight uptake in the vertebrae was evident. The distribution throughout the lung was not homogeneous, with tissue destruction occurring in the areas of high concentrations of Po-210. An earlier experiment where mice were given intravenous injections of Po-210 resulted in a uniform distribution of Po-210 in the lungs.

<61>
AUTHOR: Tola, S.; Nordman, C.H.
TITLE: Smoking and Blood Lead Concentrations in Lead Exposed and Unexposed Populations
PUB DESC: Environ. Res. 13:250-255
PUB DATE: 1977
ABSTRACT: Blood lead (Pb-B) concentrations were measured and the smoking history was taken from 355 men representing the general population and 2209 men occupationally exposed to lead in a study of the association between smoking and Pb-B concentrations of men with different degrees of occupational lead exposure. No association between smoking and Pb-B could be demonstrated in men from the general population, but a dose response relationahip was found between the amount of smoking and the Pb-B of men occupationally exposed to lead. The smokers in this group had significantly higher Pb-B levels than nonsmokers. The results of this study can probably be attributed to the contamination of fingers and cigarettes in the lead exposed workplaces rather than to the small amount of lead contained in the cigarettes. Moreover, the effect of smoking on lead absorption in workers exposed to lead may be partially explained by an impairment of the lung defense mechanisms due to depressed ciliary activity.

<62>
AUTHOR: Tso, T.C.; Ferri, E.S.; Baratta, E.J.
TITLE: Agronomic Factors Affecting Polonium-210 and Lead-210 Levels in Tobacco. II. Varieties and Curing Methods
PUB DESC: Agron. J. 60:650-652
PUB DATE: 1968
ABSTRACT: Tobacco plants accumulate Pb-210 and Po-210 at higher levels than that found in the soil. Vigorous young seedlings accumulate more Pb-210 and Po-210 than slower growing seedlings. At later stages of development, faster-growing and higher-yielding varieties were shown to have a higher dilution factor for the radioelements. Tobacco seed was shown to take up less Pb-210 and Po-210 than the leaf, with a preferential accumulation of lead over polonium suggested. Different curing methods were studied to find out if they would contribute significant levels of Po-210 or Pb-210 to the tobacco leaves, and it was found they would not.

<63>
AUTHOR: Tso, T.C.; Fisenne, I.
TITLE: Translocation and Distribution of Lead-210 and Polonium-210 Supplied to Tobacco Leaves
PUB DESC: Radiat. Bot. 8:457-462
PUB DATE: 1968
ABSTRACT: Lead-210 and polonium-210 were supplied to tobacco plants (Nicotiana tabacum L. cv. maryland catterton) from soil, stem, and leaf surface to study the patterns of translocation and distribution of these elements. Test plants took up Po-210 and

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Pb-210 from roots or stems and the elements were distributed to various tissues. Direct absorption of Po-210 is therefore considered a major source of Po-210 supply, in addition to that from ingrowth of Pb-210 in leaf tobacco. Only 2% of the Pb-210 and 6% of the Po-210 was taken up from the soil into the leaves and stems. When the radionuclides were applied through the stems, it was found that Po-210 and Pb-210 accumulated in the leaves in different manners. A higher concentration of Pb-210 accumulated in younger upper leaves than in older lower leaves, while a higher concentration of Po-210 accumulated in older lower leaves than in younger upper leaves. When the two elements were applied to the leaf surface, little translocation or redistribution of Pb-210 was found from one leaf area to the other leaf areas, but a very small portion of Po-210 applied on younger upper leaves transferred to older lower leaves. Po-210 applied on older lower leaves, however, remained where placed.

<64>
AUTHOR: Tso, T.C.; Hallden, N.A.; Alexander, L.T.
TITLE: Radium-226 and Polonium-210 in Leaf Tobacco and Tobacco Soil
PUB DESC: Science 146:1043-1045
PUB DATE: 1964
ABSTRACT: The natural radioactivity in different types of leaf tobacco and tobacco soil was examined in an attempt to measure the Po-210 content of tobacco and establish its origin. The radium-226 and polonium-210 contents in tobacco and soil vary with the source, with the differences seeming to result from production locality, culture, and method of curing. Fertilizer added to the soil may contribute to the high Ra-226 content of some soils. Polonium-210 in tobacco plants is derived from either the soil or the air. It may be taken up directly from the soil or result from the radioactive decay of lead-210 or radium-226 taken up from the soil. It may also result from radioactive decay of the daughters of radon-222 deposited on the leaves.

<65>
AUTHOR: Tso, T.C.; Harley, N.; Alexander, L.T.
TITLE: Sources of Lead-210 and Polonium-210 in Tobacco
PUB DESC: Science 153:880-882
PUB DATE: 1966
ABSTRACT: In experiments conducted to determine the source of Pb-210 and Po-210 in tobacco, tobacco plants were grown in an atmosphere enriched with Rn-222 gas, in a field with different sources of phosphate-containing fertilizer, and in a nutrient solution containing Pb-210 as lead nitrate in equilibrium with Po-210. Results indicate that atmospheric Rn-222 is not a major source of Po-210 in tobacco. The addition of phosphate fertilizer, however, resulted in an apparent increase in the activity of Po-210 in soil and in the tobacco. Plants grown in a nutrient solution with lead-210 nitrate in equilibrium with Po-210 adsorbed and translocated Pb-210 and Po-210 from solution cultures. The authors conclude that the principle source of Pb-210, and thus of Po-210, in tobacco is its adsorpton from the soil by the plant roots. However, other factors, such as the method of curing and the stage of leaf development, may also contribute to the final concentration of Po-210 in tobacco.

<66>
AUTHOR: Tso, T.C.; Steffens, G.L.; Ferri, E.S.; Baratta, E.J.
TITLE: Agronomic Factors Affecting Polonium-210 and Lead-210 Levels in Tobacco. I. Soil and Fertilizer
PUB DESC: Agron. J. 60:647-649
PUB DATE: 1968
ABSTRACT: Examination of soil samples from an area showed different levels of Po-210 and Pb-210 before and after fertilization and after harvesting of the tobacco crop, indicating a removal of these elements by the plants. Crop rotating practices, amounts of fertilizer used, as well as the parent material of the soil were shown to influence the levels of radioelements in the soil. Plants grown in pots with fertilizers of varying amounts of radioactivity did not show any consistent differences in leaf uptake. Plants grown in a minimum available nutrient supply did take up more Po-210 and Pb-210, however (possibly due to "hunger state" of plants). Phosphate is the main source of Ra-226, Pb-210 and Po-210 in commercial fertilizer. It was found that single applications of a fertilizer may not have a significant effect on the immediate crop, but there is a buildup of the elements (Po-210, Ra-226, Pb-210) in the soil from the phosphate applied which will become available to later crops.

<67>
AUTHOR: Turner, R.C.; Radley, J.M.
TITLE: Naturally Occurring Alpha Activity of Cigarette Tobacco
PUB DESC: Lancet 1:1197-1198
PUB DATE: 1960
ABSTRACT: The alpha activity due to the naturally occurring radium and thorium series was measured in the ash of 51 brands of cigarette and cigar tobaccos and in the raw tobacco of two brands. Without exception the alpha activities increased during the first 28 days after ashing and then remained constant, indicating that most of the equilibrium radon-222 is released during the smoking process and recovers to equilibrium activity during the subsequent 28 days. The authors state that, in view of the volatile nature of polonium-210, the absence of any further growth of alpha activity in the ash after 28 days points to the fact that lead-210 and polonium-210 are not present in raw tobacco at levels of activity of the same order as radium 226. Furthermore, no appreciable fraction of the longlived alpha activity of the tobacco is lost during the smoking process. The authors calculate a daily intake of 16 pCi of radon in the case of a person smoking 50 per day of the most active brand of English cigarette. They conclude that, even in the case of the heavy smoker, the additional alpha activity taken into the lungs per day due to the radium content of the cigarettes themselves is less than one percent of the atmospheric radon inhaled per day by both smoker and nonsmoker.

<68>
AUTHOR: Walsh, P.J.
TITLE: Radiation Dose to the Respiratory Tract Due to Inhalation of Cigarette Tobacco Smoke
PUB DESC: Presented at the Radiation in Consumer Products Symposium, 2-4-77, Atlanta, Ga.
PUB DATE: 1977
ABSTRACT: The author points out that the maximum intake of lead-210 and polonium-210 received by a two pack per day smoker would be about 2-4 pCi/day, while the intake due to continuous exposure to background levels of radon daughters would be about 200-2000

<68> CONT.
pCi/day. The author thus concludes that the higher levels of radioactivity in the lungs of smokers could be due to reduced lung clearance due to smoking and not from the radionuclide concentrations in tobacco. With regard to the "hot spots" at bronchial bifurcations, the author points out that the highest doses to bifurcations in smokers' lungs are comparable to the average doses to the entire tracheobronchial epithelium due to background levels of radon daughters, and that doses to bifurcations over a 50-year period are about an order of magnitude lower than doses associated with an approximate doubling in lung cancer incidence for uranium miners.

<69>
AUTHOR: Wynder, E.L.; Hoffman, D.
TITLE: Experimental Tobacco Carcinogenesis
PUB DESC: Science 162:862-871
PUB DATE: 1968
ABSTRACT: A review of the relationship between smoking and cancer in man is given. However, the possible carcinogenic role of radioactivity in tobacco smoke is not discussed. Tobacco smoke is thought to have an irreversible effect on the genetic apparatus of the cell, leading to a "dormant" turmor cell. A significant part of this initiating activity of tobacco smoke is due to the presence of polynuclear aromatic hydrocarbons. Tobacco smoke is also thought to contain tumor promoters, which are inactive by themselves. They can, however, evoke the initiated cell, thus causing tumor induction and proliferation. The role of several suspected carcinogens in tobacco is discussed. Experimetal studies have shown that both the gas and particulate phase of tobacco smoke contain ciliatoxic agents. The possibility is presented that the impairment of the natural defense mechanism of the respiratory system against inhaled tumorigenic compounds is a first step in respiratory carcinogenesis.

<70>
AUTHOR: Yavin, A. I.; Pasquali, G. de; Baron, P.
TITLE: Polonium in Cigarettes - Spectroscopic Analysis
PUB DESC: Nature 205:899-900
PUB DATE: 1965
ABSTRACT: This study was undertaken to identify spectroscopically and measure the amount of Po-210 and other polonium isotopes in cigarettes. A Po-210 activity of 0.45 plus or minus 0.10 pCi per cigarette was measured in unburned cigarettes, with no alpha-activity due to any other polonium isotopes observed. A measure of polonium in smoked cigarettes indicates that most of the polonium was carried in the smoke. Assuming that 10 percent of the polonium content of the cigarette eventually decays in the lung, the amount of Po-210 activity at equilibrium for a person smoking 50 cigarettes a day can reach a level of 400 pCi.

<71>
AUTHOR: Yuile, C.L.; Berke, H.L.; Hull, T.
TITLE: Lung Cancer Following Polonium-210 Inhalation in Rats
PUB DESC: Radiat. Res. 31, 760-774
PUB DATE: 1967
ABSTRACT: In this study rats were exposed to an aerosol of Po-210 for different periods of time, and the development of lung tumors was recorded, as well as other parameters such as shortening of life span, susceptibility to infection and the occurrence of radiation pneumonitis. Life span of the highest dose group was shortened, with 87% of the animals dying within one year after exposure, compared to 35% for controls. Increased incidence and severity of acute pneumonia was the chief cause of the high mortality. No primary lung tumors developed in control rats, but 44 were found in 288 exposed rats (15%.) Squamous cell carcinoma was the most common tumor type, accounting for 55% of the total number found.

<72>
AUTHOR: Zsoldos, T.; Faust, F.
TITLE: Determination of 210-Po (RaF), a Natural Radioactive Element from Cigarette, and Detection of the Isotope Inhaled by Smoking in the Blood
PUB DESC: Acta Biochim. Biophys., Acad. Sci. Hung., 6:460
PUB DATE: 1972
ABSTRACT: The Po-210 content of tobacco of the most frequently smoked Hungarian cigarettes (Kossuth, Fecske, Munkos) was measured. The results were compared with similar measurements from other countries in order to obtain relative information concerning the dose loading of the bronchial system. It was demonstrated that about 25 percent of Po-210 can get to the respiratory tract. Blood samples of smoking and nonsmoking persons were analyzed for Po-210 and it was found that a significant increase of Po-210 appears in the blood samples of smoking persons.

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