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

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

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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 NaI0_3.
2) "1.0E8" (E denoting exponent) means 1.0 x 10^8.
The short-term effects of cigarette smoking on bronchial clearance in humans were studied in nine non-smokers 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 cigarette smoking in both smokers and nonsmokers. However, it was found that there were no marked changes in the rate of upper bronchial clearance as a result of smoking.

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 stems.

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 mCi per cigarette. The data indicate no apparent correlation with the presence of a filter-tip or the size of the cigarette. The authors propose a model used to estimate the average integral dose to the pulmonary compartment due to inhalation of Po-210. This model considers deposition of the inhaled radioactive material as well as residence time and clearance from various compartments of the respiratory system. The model was tested on smoking 20 cigarettes per day, and the differences in patterns of the inhaled radioactive material were studied.

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AUTHOR: Black, S. C.; Bretthauer, E. W.
TITLE: Synergistic Effect of Po-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 deposits 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 for 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, ephyma, one bronchogenic carcinoma and one adenoma. Adequate controls were not established. The added polonium exposure did not change the mortality rate.

AUTHOR: Blanchard, E.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. Results 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.

AUTHOR: Bretthauer, E. W.; Black, S. C.
TITLE: Po-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.

AUTHOR: Carfi, N.; Dugnani Lonati, R.
TITLE: Po-210 in Italian Tobacco
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 the standard procedure and plated on nickel discs. The discs were mounted on 25S phosphores 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 range. It is necessary for determining accurately the minute quantities of Po-210 (of the order of 1.0E-2 pCi). The Po-210 content of a 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.

AUTHOR: Dreseswar, F.
TITLE: Polonium in Tobacco
PUB DESC: Naturwiss. Rundsch. 20:12
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 tobacco from South Africa and the United States are presented.

AUTHOR: Eisele, H.
TITLE: Polonium-210 and Bladder Cancer
PUB DATE: 1966
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.

AUTHOR: Ferri, E.S.; Baratta, E.J.
TITLE: Po210 in Tobacco Products and Human Tissues
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 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.
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 unfiltered brands. Analysis of polonium-210 concentrations in human organs in smokers and nonsmokers, in that order, contained 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.

AUTHOR: Ferri, E.S.; Baratta, E.J.
TITLE: Polonium-210 in Tobacco, Cigarette Smoke, and Selected Human Organs
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, muscle, and bone obtained from smokers and nonsmokers indicated higher levels of polonium-210 in the organs of smokers.

AUTHOR: Ferri, E.S.; Christiansen, H.
TITLE: Lead-210 in Tobacco and Cigarette Smoke
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. The 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.
are within the range of Po-210 alpha particles, and in one-fifth of the same epithelium the basal cells were within the range of both Po-210 and Po-214 alpha particles, assuming the radioactive substances are located on the surface of a 7 µ 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 may explain the increased incidence of lung cancer in miners who smoke.

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. Submicron 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 correlates the particles with radioactive particles. Relative sizes, 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.

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 the description lung cancer risks as high as 1.0 x 10^-3 to 1.0 x 10^-8 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 once 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 < 1.0 x 10^8 particles.
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 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/year for thinner slabs. High local dose rates in the human lung could occur only if there is a mechanism for selectively clearing the polonium-210 or its decay products 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.

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.

AUTHOR: Holtzman, R. B.; Ilczynski, P. N.
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 Pb-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 tissues at autopsy or surgically obtained from smokers, 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.

AUTHOR: Ide, G.; Santzeff, V.; Cowdry, E.V.
TITLE: A Comparison of the Histopathology of Tracheal and Bronchial Epithelium of Smokers and Nonsmokers
PUB DESC: Cancer, 12:473-486
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 bronchoeal cilia were found to decrease in height with increased smoking, as did the percentage of ciliated cells present (35% in nonsmokers and 22.3-28.5% in light and heavy smokers). Squamous metaplasia 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.
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 the various brands of cigarettes, with the content of Po-210 apparently depending on the amount of particulate matter in the 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 particulate matter because the polonium is apparently adsorbed on smoke particles during the combustion process.

AUTHOR: Kennedy, A.R.; Little, J.B.
TITLE: The Transport and Localization of Po-210, Uranium and Radon-226 in the Hamster Lung Following Intratracheal Instillation
PUB DESC: Cancer Res. 34: 1968
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 site of origin. Hematite-210 Po 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 and benzo(alpha)pyrene. The median diameter of the cigarette smoke was 0.5 μm for puffs 2, 6, and 10, and for the filter cigarette was 0.5 μm, 0.5 μm, and 0.6 μm for puffs 2, 6, and 10, respectively. The concentration increased from 2.28E5 particles per cubic centimeter for puff 2, to 6.39E5 particles per cubic centimeter for puff 10 of the unfiltered cigarette and from 2.0E5 to 2.92E5 particles per cubic centimeter for the filter cigarette. The weight of smoke per puff increased from 1.8 to 5.28 mg and from 0.8 to 2.4 mg for the second to the tenth puff, respectively, for the unfiltered and filtered cigarette.

AUTHOR: Langer, G.; Fisher, N.A.
TITLE: Concentration and Particle Size of Cigarette-Smoke Particles
PUB DESC: Arch. Ind. Health 13: 1974
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 smoke 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 μm for puffs 2, 6, and 10, and for the filter cigarette was 0.5 μm, 0.5 μm, and 0.6 μm for puffs 2, 6, and 10, respectively. The concentration increased from 2.28E5 particles per cubic centimeter for puff 2, to 6.39E5 particles per cubic centimeter for puff 10 of the unfiltered cigarette and from 2.0E5 to 2.92E5 particles per cubic centimeter for the filter cigarette. The weight of smoke per puff increased from 1.8 to 5.28 mg and from 0.8 to 2.4 mg for the second to the tenth puff, respectively, for the unfiltered and filtered cigarette.

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ABSTRACT: Body burdens of polonium-210 are presumably increased in 9 to 53 percent of hamsters given multiple intratracheal instillations of polonium-210 in amounts yielding lifetime exposures of 5 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 broncholar-alveolar region. This Po-210 yielded a lower radiation dose than the Po-210 adsorbed 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.

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 carcinomas of the trachea or major bronchi. Po-210-induced tumors were almost exclusively combined epidermoid and adenoscarcinomas 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.

AUTHOR: Little, J.B.: Radford, Jr., E.P.; McCaubs, H.L.; Hunt, V.P.
TITLE: Distribution of Polonium in Pulmonary Tissues of Smokers
PUB DATE: 1965
ABSTRACT: Studies were undertaken to measure polonium-210 concentrations in pulmonary tissues of smokers and non-smokers. Concentrations were found to be higher in lungs of both male and female smokers than in non-smokers. 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.
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 air dried, which produces a tobacco smoke which is less acid and thereby less 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.

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 polymers 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.

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...
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.

<47> COST.

ABSTRACT: Over 4,000 DuPont employees were subjects in a longitudinal study on urine and blood lead levels in relation to smoking habits. A mean urine lead level of 27.1 u g/100 ml was found for smokers, and 29.0 u g/100 ml for pipe and/or cigar smokers. The mean blood lead level of the nonsmokers was found to be 19.9 u g/100 ml, while that of cigarette smokers was 19.3 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.

<48> AUTHOR: McLaughlin, H.; Stopps, G. J.
TITL: Smoking and Lead
PUB DESC: Arch. Environ. Health 26:131-136
PUB DATE: 1973
ABSTRACT: Over 4,000 DuPont employees were subjects in a longitudinal study on urine and blood lead levels in relation to smoking habits. A mean urine lead level of 27.1 u g/100 ml was found for smokers, and 29.0 u g/100 ml for pipe and/or cigar smokers. The mean blood lead level of the nonsmokers was found to be 19.9 u g/100 ml, while that of cigarette smokers was 19.3 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> TITLE: Cigarettes: Polonium-210
PUB DATE: 1964
ABSTRACT: The author questions an earlier report by Badford 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 20 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 Badford and Hunt might have been too small to show the value of cigarette filters, their data compare only two filter cigarettes with two nonfilter cigarettes. By Consumers Union test, these filters have revealed that some king-size filter cigarettes yield as much as 70 percent less tar 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-Caspe, A.; Fleischer, R.L.
TITL: Upper Limits of Alpha-Radioactivity Per Particle of Cigarette Smoke
PUB DESC: Science 174:351-351
PUB DATE: 1972
ABSTRACT: This study of the Nicotiana rustica variety of tobacco from North Bengal revealed that the respective amounts of radioactive nuclei K-40, Sr-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 Rehmanudil, Andhra Pradesh, contents of K-40, Sr-90, Y-90 and rare earth activity, and Pb-210 were observed to be 4.36, 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.

<51> AUTHOR: Parksyotha, B.C.; Bhatthacharyya, D.K.
TITL: 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, Sr-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 Rehmanudil, Andhra Pradesh, contents of K-40, Sr-90, Y-90 and rare earth activity, and Pb-210 were observed to be 4.36, 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: Badford, Jr., E.P.
TITL: Polonium-210 for the 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 with doses for 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 miners. 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: Badford, Jr., E.P.; Hunt, W.R.; Little, J.B.
TITL: Polonium-210 in Cigarette Smokers
PUB DESC: Science 146:87
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. Data 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.

<56> AUTHOR: Radford, J. R.; Hunt, V. S.
TITLE: Polonium-210 Activity in the Lungs of Cigarette Smokers
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. Data 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.

<57> AUTHOR: Schlesinger, R. B.; Cohen, V. R.; Lipps, E. A.
TITLE: Studies of Intrabronchial Particle Deposition Using Hollow Bronchial Casts, Experimental Lung Cancer, Carcinogenesis and Bioassay
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
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.

AUTHOR: Skrable, K. W.; Haughey, P. J.; Alexander, E. L.
TITLE: Polonium-210 in Cigarette Smokers
PUB DESC: Science 146:66-67
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 own 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.

AUTHOR: Smith, D. M.; Anderson, M.C.; Prime, J.B.; Holland, L.M.; Richcomb, 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, II. Nov 3-7
PUB DATE: 1975
ABSTRACT: Monodispersed 10-um-diameter Zr02 ceramic microspheres, containing varying amounts of Po-210 dioxide or Pu-230 dioxide were injected into the jugular vein of hamsters. These biologically inert microspheres lodged subsequently in pulmonary capillaries. No consistent alteration of lifespan 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.

AUTHOR: Soremark, R.; Hunt, V.H.
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 negligible. 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.

AUTHOR: Tola, S.; Nordman, C.H.
TITLE: Smoking and Blood Lead Concentrations in Lead Exposed and Unexposed Populations
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 relationship 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.

AUTHOR: Tso, T.C.; Ferris, E.S.; Baratta, E.J.
TITLE: Agenicotic Factors-Arronous-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.

AUTHOR: Tso, T.C.; Fineman, I.
TITLE: Translocation and Distribution of Lead-210 and Polonium-210 Supplied to Tobacco Leaves
PUB DATE: 1968
ABSTRACT: Lead-210 and polonium-210 were supplied to tobacco plants (Nicotiana tabacum L. cv. Maryland catterson) from soil, stem, and leaf surface to study the patterns of translocation and distribution of these elements. Test plants took up Po-210 and
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 older upper leaves was detected in lower leaves. Pb-210 applied on older lower leaves, however, remained where placed.

ABSTRACT: In experiments conducted to determine 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 the radioactive decay of lead-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 the accumulation of radium-226 in 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 Pb-210 in tobacco.
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.

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" tumor 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. Experimental studies have shown that both the gas and particulate phase of tobacco smoke contain ciliotoxic 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.

This study was undertaken to identify spectroscopically and measure the amount of Po-210 activity of 0.85 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.
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