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Natural Lead-210 Content of Man

Abstract. The natural Pb^{210} content of ash samples from 18 cadavers has been measured, and an average in vivo content of 0.015 picocurie per gram of wet bone is estimated. The contribution of Pb^{210} to the radioactive dose from natural sources is about one-fifth that from internally deposited Ra^{226} and its daughters.

The possible overexposure of man to radiation from artificial sources has heightened interest in his inevitable exposure to radiation from natural sources and in the question of whether this natural radiation produces detectable biological effects. The external radioactive environment (*1*) can be measured with comparatively little difficulty. Although the identification and measurement of the radioactive trace constituents within the body of man present a greater problem, notable advances have been made in the last 10 years.

The body content of Ra^{226} has been measured by various investigators (*2*) in the United States and abroad. Measurements of K^{40} as a function of age have recently been reported (*3*). The study reported here (*4*) supplements the available data by supplying measurements of Pb^{210} content of 18 cadavers obtained locally.

At least two 10-g aliquots from the whole body ash of each cadaver were analyzed for Po^{210}. This measurement, converted to disintegrations per unit time, is equivalent to the Pb^{210} activity, since the attainment of secular radioactive equilibrium for the Pb^{210} to Bi^{210} to Po^{210} decay sequence depends on the 139-day half-life of Po^{210}, and since the material was ashed 8 years prior to the polonium measurement. The method of polonium analysis was that described by Black (*5*) and involves a nitric-perchloric acid digestion of the ash, plating out of the polonium on a silver foil, and counting in a low-background, gas-flow, proportional counter.

The results are listed in Table 1. The figures in column 3 have been corrected by subtracting reagent blanks (= 0.061 count/min). Since the overall recovery and counting efficiency, as determined by spiking with standard polonium solutions, was found to be 46 percent, the counts per minute are equal to picocuries of activity. Since Po^{210} is in equilibrium with Pb^{210}, the data in column 3 may be interpreted as picocuries of Pb^{210} per 10 g of whole body ash.

In calculating the in vivo body content of Pb^{210} (Table 1, col. 4), it was assumed (i) that all of the lead resides in the skeleton during life and that the wet skeletal mass is three times the whole body ash, and (ii) that all of the radon formed from Ra^{226} during storage escaped from the container. The Pb^{210} at sampling time is therefore corrected for decay to the time of death. The values listed are therefore maximal estimates of the in vivo lead content if we assume that none of the lead is lost in the cremation process, as seems likely to be the case (*6*).

An alternative calculation of the in vivo Pb^{210} content can be made. In this case the lead measured is assumed to be derived from three sources; it includes (i) that taken in with natural lead from the environment (in food, water, or air); (ii) the portion formed in vivo as a daughter of radon (30 percent equilibrium with body Ra^{226}), it being assumed that no excretion of lead occurs; and (iii) the lead formed during storage in the container by the Ra^{226} content of the ash, it being assumed that no radon escapes.

The contribution to the measured value from sources (ii) and (iii) can be readily calculated, inasmuch as the Ra^{226} content of the ash and its history are known. The remainder of the measured value may be corrected for decay to the date of death and assigned to source (i). These manipulations permit estimation of the total in vivo body content of Pb^{210}. The average of these estimates is two-thirds the average of the data entered in column 4, Table 1.

In extending these measurements to an estimation of the natural radioactive dose component from Pb^{210} and its daughters, the maximum estimate of average lead content is used as a basis. It is assumed that the lead decays in bone and that no translocation or excretion of the bismuth daughter occurs. It turns out that these assumptions are of relatively little importance except as they affect the site of production of the alpha-particle-emitting Po^{210} daughter of bismuth, since this isotope is the principal contributor to the dose. Black (*5*), on the basis of polonium measurements on mice exposed to radon 90 to 100 days prior to death, estimates that approximately 50 percent of the polonium produced from Pb^{210} remains in the bone. On the basis of this estimate, the in vivo polonium content is calculated to be 0.0075 pc per gram of wet bone, a value which is in reasonable agreement with Black's measurements (*5*) on single bone samples of unexposed human beings and animals, which range from 0.0036 to 0.034 pc.

The dose calculation, based on the above assumptions and on a relative biological effectiveness factor of 10 for alpha particles, yields an estimated yearly dose of 7.4 mrem, less than 1.5

Table 1. Natural body burden of Pb^{210}.

Age at death (yr)	Total ash wt. (g)	Po^{210} net (count/min 10 g)	Total Pb^{210} in vivo (pc)	Pb^{210} in vivo pc/g of wet bone
48	4410	0.48	302	0.023
85	1500	.32	66	.015
60	2500	.24	82	.011
57	2100	.14	40	.006
77	1700	.42	102	.020
76	2000	.25	72	.012
83	2200	.47	143	.022
77	790	.35	38	.016
36	2480	.14	47	.0063
74	2260	.47	151	.022
81	1570	.15	35	.0073
66	1970	.27	75	.013
85	2570	.46	165	.021
75	2000	.17	48	.008
74	2310	.11	37	.0053
33	3190	.44	188	.020
57	2500	.71	238	.032
32	1105	.38	56	.017
Average				0.015

percent being attributable to the beta rays from lead and bismuth. As a basis for comparison, this dose is about one-fifth that which may be calculated for Ra^{226} and its daughters when the total body content of a standard man is 120 pc of Ra^{226}.

It may be pertinent to note that the individuals whose cadavers provided the ashed material were in the upper age brackets. Since a major contributing factor to the level of body lead is the level of lead in the environment, and since this has risen during the past several decades, a group of younger subjects who are actively forming bone mineral might yield a higher result.

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8 June 1960

Previous Breeding Experience and Hormone-Induced Incubation Behavior in the Ring Dove

Abstract. Injected progesterone induces incubation behavior much faster, and in a higher percentage of cases, in doves with previous breeding experience than in those without such experience. The nature of the animal's previous experience is thus one of the variables influencing behavioral responses to exogenous hormones.

When a male and female ring dove *(Streptopelia risoria)*, each of which has had previous breeding experience but not with the other, are introduced into a breeding cage containing a nest and eggs, they do not sit on the eggs until after 3 to 6 days, during which time they engage in nest-building activity (*1*). If, however, the birds are injected daily with progesterone during the 7-day period before they are placed in the cage together, they sit on the eggs almost immediately (*2*). The purpose of the experiment reported here was to study the effect of progesterone upon incubation behavior in birds that had had no previous breeding experience, and to compare birds that had and had not had breeding experience with respect to their responses to eggs after progesterone injection.

Table 1. Latency of response to eggs by pairs of progesterone-treated ring doves with and without previous breeding experience. Time was measured from the introduction of the birds into the cage to the first occurrence of the response. Range is given in parentheses.

Response	Latency (median and range)	
	Experienced doves	Inexperienced doves
Standing near nest	<1 min (<1 min– 1 min)	34.5 min (3 min–>2 hr)
Standing on nest	1 min (<1 min– 3 min)	60.5 min (<1 min–>2 hr)
Settling on eggs	6.5 min (3 min–26 min)	>2 hr (56 min–>2 hr)
Established incubation	21.5 min (6 min– 3 hr)	24.5 hr (82 min–nil*)

* Represents three pairs which never established incubation.

Male and female ring doves were separated from their parents at the age of 21 days and placed in stock cages in groups of six to ten birds. At 4 months of age, the sex of each bird was determined by exploratory laparotomy (*3*), and the birds were placed individually in small cages in which they were visually isolated from other birds. When the birds were 5 to 6 months old (that is, sexually mature), ten breeding pairs were constituted by selecting males and females from the isolation cages and placing them in breeding cages. These birds were permitted to carry out a complete breeding cycle, which consisted of building the nest, laying and incubating the eggs, and rearing the young to the age of 21 days. The parents were then returned to the individual isolation cages. After spending 3 to 5 weeks in the isolation cages they were considered available for use in our experiment, constituting the "experienced" group.

The "inexperienced" group consisted of birds which remained in the small isolation cages throughout the period in which the birds of the "experienced" group were acquiring their breeding experience. These birds were matched with the birds of the experienced group with respect to date of hatching and age at time of testing (for details of housing and maintenance, see *1* and *3*).

All birds were given seven daily injections of 100 μg of progesterone (*4*) in sesame oil, injected into the pectoral muscles on alternate sides on alternate days. At approximately 10:00 A.M. on the day following the last injection, a pair of birds was introduced into a breeding cage containing a nest with two eggs. The arrangement of the cage was such that the nest and eggs were always in full view of any bird in the cage. The birds were watched continuously for 2 hours, during which time a verbal report of their behavior was recorded on a dictating machine, and subsequently they were visited briefly at hourly intervals, for up to 10 days when necessary (*5*).

Table 1 shows the results of the experiment. "Standing near nest" means that the bird was in the quadrant of the cage which contained the nest for longer than 15 seconds. "Settling on eggs" means that the bird sat on the eggs like an incubating bird, raising the ventral abdominal feathers so that the area of naked skin on the underside of the body (*6*) came into contact with the eggs. "Established incubation" means that the bird sat for 30 minutes or more. [Observations on these and other birds (*7*) indicate that, once doves have established incubation by this criterion, they continue to incubate for at least the normal incubation period of 14 days.]

Regardless of which response is considered, there is obviously a striking difference between the two groups; more of the experienced than of the inexperienced birds incubated, and the experienced birds did so sooner than the inexperienced ones. It may be noted that the latency scores for the two groups did not overlap at all with respect to two of the measures. The overlap in the ranges for the other two measures was based on only one pair in each group. In the case of the last measure (established incubation), the overlap is due entirely to the fact that one of the experienced birds, which first settled on the eggs 6 minutes after being introduced into the cage, spent the time between 6 minutes and 3 hours alternately settling on the eggs and repairing the nest. With respect to each of the four measures, a median test, by Fisher's exact probability method (*8*), shows that the differences between experienced and inexperienced birds are significant at the .005 level. Qualitative differences were immediately apparent to the observer: the experienced birds usually went directly to the nest, in contrast to the inexperienced ones.

Although the occurrence of incubation behavior in response to exogenous progesterone is here shown to be greatly facilitated by previous breeding experience, the present data do not indicate what this "experience" consists of, or how it affects subsequent behavior. It will be interesting to discover exactly