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Review:

Study of the Lifetime Health and Mortality Experience of Employees of ERDA Contractors (COO-3428-3)

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This report is in three parts, a short account of the administrative background, a substantial report analysing data on mortality of workers at Hanford from 1944 to 1972 and a description of the source data assembled during the study. This short review is concerned primarily with the analytical report which was prepared by Dr. Alice Stewart and Mr. George Kneale in consultation with Dr. Mancuso.

The study draws on data from 24,939 males and an unspecified number of females from which there are 3520 certified deaths of males (213 uncertified) and 412 certified deaths of females. The analysis is concerned only with these certified deaths, the assumption being that uncertified deaths will be distributed in the same pattern with respect to dose as the certified deaths. The total accumulated radiation dose to the 3520 males was 3756 rads and to the 2184 males classified as 'exposed' this corresponds to a mean lifetime dose of 1.72 rads. There were a total of 670 deaths of males due to cancer, 442 of them being in the exposed group. The 123 'exposed' women from among the 412 received a total dose of 108 rads or a mean lifetime dose of 0.89 rads. These included 127 deaths due to cancer of which 38 were among the exposed females. There is very little analysis of the female data so discussion here concentrates on males.

The definition of an exposed worker in this report is anybody who had a recorded lifetime dose of 0.01 rad or more. Since typical levels of natural background radiation account for about 0.1 rad per year, there can be little radiological significance attached to the difference between an 'unexposed' member of the study population and the bulk of those classified as 'exposed'. Thus any alteration in the pattern of causes and ages at death due to radiation which this study may seek to detect, should be sought by comparing the unexposed with those who have experienced doses at most comparable or greater than natural background variations in

levels. The inclusion of many trivial doses will serve only to confuse any possible resolution. A summary of the distribution of doses among the exposed workers would have been a welcome set of data from which several obscurities may have been clarified. In more general terms, many of the 26 tables included in the report could have been replaced with the very much more useful basic information from which they were derived. A tabulation of age at death, calendar year of death, lifetime exposure, cause of death for those with more significant exposures (say greater than 5 rads) together with a statistical summary for those with less than (say) 1 rad, would have provided both the specialist and the non-specialist reader with a far clearer picture than that obtained from the 26 tables.

The underlying technique employed by the authors is to separate cancer and non-cancer deaths in the exposed and unexposed groups and to look at the mean accumulated lifetime dose of each category. Evidence of casual relationship is claimed if higher doses are associated with the cancer deaths in the exposed group. Unfortunately this technique does not need an excess of a specific malignancy to ascribe a radiation association, hence it is susceptible to spurious or systematic interference. Important among these factors are the ages and calendar years of the deaths in the compared groups. Table 11 is an example of data presentation which is of limited value for the above reasons. This table attempts to correlate the proportion of cancer deaths in a defined age group with the mean accumulated radiation dose of that group. There are five dose groups for men in five age ranges. A Spearman correlation test is applied to each age range and although the coefficients demonstrate low correlation for each range separately, taken together the coefficient is .46 ± .22 which for 5 groups of 5 points is just significant at the 5% level. Since the Spearman coefficient involves only the rank order of the sequence under test and not the numbers themselves, the result depends to a large extent on a few small numbers. There are more appropriate rank ordering tests available but since the Spearman test was employed it should have considered a Monte Carlo variation on the data to identify any undue influence of individual numbers in the table.

However, a more important correction should precede such a test. It is almost certain that the lifetime dose of men dying towards the end of the study period will be substantially higher than those dying earlier since they have more working years in which to accumulate their dose. During the 25 year study period there has been a significant increase in the proportions of many specific cancers, including lung cancer which contributes significantly to male deaths due to all cancers. Hence a correlation between dose and cancer deaths is inevitable even if none are induced by radiation. Thus it is essential to eliminate the calendar year of death effect before looking for a correlation between dose and cancer. There are insufficient data in the report for the reader to perform such a correction, so the correlation claimed by the authors has no radiological significance. This point could have been partially tested if table 2 had included some information on the mean cumulative dose for the 21,206 living as well as the 3520 dead workers.

Earlier in the report, Table 4, the observed neoplasms are tabulated into 18 specific types in order of descending mean cumulative dose. A line corresponding to the overall mean dose is drawn and falls between the eighth and the ninth in the list. They show in the same table generally higher ratios of observed to expected deaths due to neoplasms above the line than for those below the line. The claim that this demonstrates association with radiation suffers from the same uncertainty as in using table 11, since there is a far stronger correlation than that to which attention is drawn by table 4. 7 out of the 8 cancers above the line are increasing with time, 9 out of the 10 below the line are decreasing with time. The two at the top (myeloma and pancreatic) have increased very dramatically during the study period. Thus if more are occuring at later times, the doses will inevitably be higher. Only when this has been taken in account can any conclusions be drawn about the influence of the radiation.

Another difficulty with the separation of all cancers into so many groups, some with less than 5 deaths included, is that the probability becomes high that one or more groups will display a significant excess but purely as a statistical fluctuation. The adjusted significance of a single observation which is significant at the P level and which is one of n observations is $P_n = 1 - (1 - P)^n$. So for example if P = .05 and n = 18, $P_n = .6$ which means that there is a 60% chance that one out of eighteen results will be significant at the 5% level. This is an illustration of the dangers of separation into too many groups.

In table 16 and 22, estimated doubling doses are tabulated and their variation with age indicated. All of the figures quoted in table 16 which range from 0.8 rads for bone marrow to 12.2 rads for all cancers are very much smaller than any values compatible with other studies. Because of this one would have expected the authors to have given very careful consideration to these results. There is no evidence that they have done this. The very least necessary is to estimate the accuracy or uncertainty of these numbers. It is probable with the number of cases available for the study, that the uncertainties are very large. The results have little scientific value without such an assessment.

In summary both the text and the tables are of such obscurity that any association of the findings with radiation has been buried rather than extracted. The claims of the authors are of such consequence that the further analysis referred to in their discussion should have been carried out before publication of these results which are in such disagreement with all previous work. The major findings appear to be more related to the statistical methods employed than to information contained in the data. The survey does no more than suggest that it is necessary to continue studies of radiation workers and perhaps indicates that myelomas have a greater radiation association than was hitherto supposed (based on three deaths among the most highly exposed group). It is unfortunate that a reviewer feels motivated to such sweeping criticism; it is indeed unfortunate that many years of painstaking collection of data should be reflected publicly by an analysis which is at best incomplete and at worst misleads.