

the observed deaths were only 15% of the expected number. No reason for these differences is known.

The studies mentioned above examined radium dial workers. In contrast, Rowland et al. (1989) examined breast cancer mortality in a cohort of female dial painters. (The term *dial workers* includes not only those who painted dials but also those who worked at other tasks in the dial painting workplace. The term *dial painters* refers only to those who actually painted the dials.) Rowland et al. identified a population of 1,261 female dial painters that did not include any cases with the well-known radium-induced malignancies, the bone sarcomas or the head carcinomas. This population started work before 1950 and had been measured for radium while living; the length of employment was also known for each case. This last requirement was introduced to test the effect of external gamma radiation on the induction of breast cancer, because the total external dose would be proportional to the length of exposure or the period of employment.

This defined population contained 924 painters still alive at last contact or at the end of 1985 and 377 known to be deceased. Of the 377 deaths, 26 were attributed to breast cancer (16 expected); this difference is significant at the $p < 0.05$ level by the chi-square test. However, when the external dose to the whole body was estimated from the employment history, the mortality from breast cancer did not increase with increasing whole-body dose. The authors suggested that the actual breast dose might be the significant parameter. Because of the placement of a supply of radium paint directly in front of each painter, the actual breast dose would be greater than the estimated whole-body dose from all the sources in the workplace. An estimate of 15 cGy/yr to the breast was made for the average painter, but this dose was recognized to depend strongly on the work habits of each dial painter. Some may have placed the paint supply near their bodies as they sat at their work benches, while others may have placed the paint supply farther away.

The studies reviewed above clearly show that breast cancer was elevated in some but not all of the workplaces. However, no clear evidence indicates that this elevation was due to the radium acquired internally or to the external gamma-ray dose.

At the end of 1990 the radium case files contained data for 1,903 women who had their radium body contents measured at least once. Of these, 815 were known to be deceased. A total of 37 deaths were coded to breast cancer, and 32 of these were dial painters. This measured group included 1,541 dial painters or 81% of the cases, and they experienced 86% of the breast cancer deaths.