The Boice Report #56

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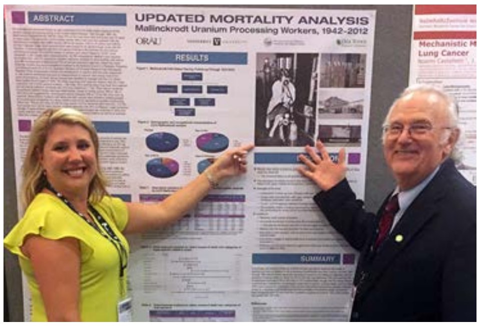
Mallinckrodt Changed the World in 1942



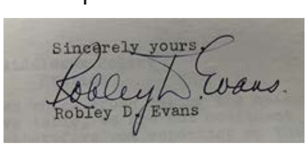
Ashley Golden (left) discusses with John Boice "Updated Mortality Analysis of the Mallinckrodt Uranium Processing Workers, 1942–2012" at the meeting of the Radiation Research Society, October 2016, Kona, Hawaii. Naomi Harley is the woman in the photograph demonstrating radon breath capture in the 1950s.
Photo courtesy of John Boice

"The story of the supply of uranium is by itself a thrilling one, and the production of enough pure metallic uranium to do our task in time was a technological and industrial miracle."
—Arthur Holly Compton

In addition to discovering the Compton effect, Arthur Compton was an influential scientist during World War II, overseeing both Enrico Fermi and Robert Oppenheimer during the Manhattan Project. In 1942, he met with his friend Edward Mallinckrodt, Jr., the president of the Mallinckrodt Chemical Works (MCW), and persuaded him to use ether, a dangerous and explosive solvent, to refine uranium ore and produce uranium metal and uranium oxide. Mallinckrodt agreed with a handshake, and the uranium processing began in July 1942. On 2 December 1942, the entire 40,000 kg of uranium oxide produced at the Mallinckrodt facility in St. Louis were used at the University of Chicago by Enrico Fermi to produce the first man-made sustained and controlled nuclear reaction. The atomic age was born. The world was irrevocably changed.

Radiation epidemiology is 5% inspiration and 95% perspiration.

External exposure of over 2,500 white male workers employed at MCW between 1942 and 1966 was evaluated previously through 1993 by E. Dupree-Ellis and colleagues. The current study updated the follow-up through 2012 and vital status was obtained for 99.2% of the workers; a remarkable accomplishment for a population working 50 to 70 years ago! Organ dose reconstruction was the most comprehensive of any radiation epidemiologic study yet conducted with the inclusion of external gamma rays from the decay products in the pitchblende and uranium ore being processed, internal intakes of uranium and radium based on 39,451 urine bioassays and 2,341 radon breath results, 16,790 occupational medical x rays required during employment, and 210 records of radiation exposure received at facilities both before and after employment at Mallinckrodt.


Sincerely yours,
Robley D. Evans

Robley D. Evans's signature on a radon breath analysis letter to Merril Eisenbud in 1949. Both were giants in health physics.
Photo courtesy of John Boice

In the 1940s, radon breath and other analyses were reported by Robley Evans (professor at Massachusetts Institute of Technology and a future president of the Health Physics Society [HPS]) to Merril Eisenbud (chief of the Radiation Health and Safety Branch, Atomic Energy Commission, and a future president of HPS). Further, the contributions of uranium dust and silica exposures to risk could be addressed because measurements of uranium dust were made during most of the years of processing. The mean external dose was approximately 50 mSv (maximum 1 Sv; 13% of workers >100 mSv). The mean dose to kidney from occupational chest x rays was approximately 14 mGy (maximum 46 mGy). The mean dose to kidney, including both external and internal dose (relative biological effectiveness set at 1), was 59 mGy (maximum 1.1 Gy).

Is it radioactivity or is it dust?

There were no significant radiation dose-response relationships, except for kidney cancer and nonmalignant kidney diseases such as nephritis. Associations were found, however, with cumulative silica and uranium dust inhalation. Silica is a possible kidney carcinogen and has been linked to increased nonmalignant kidney disease. Uranium is a heavy metal toxin, but the evidence as a human carcinogen is limited. Thus, silica and/or the nonradiogenic properties of uranium may have been more important than the radiation dose received. Further analyses are ongoing.

Does choice of analysis and software package matter?

Yes! Oak Ridge Associated Universities (ORAU) and Vanderbilt University are evaluating the different statistical approaches and software packages used in the analysis of radiation epidemiology data: Cox proportional hazard models, Poisson regression, and Poisson piece-wise regression available in software packages such as SAS, R, and Epicure. The influence of adjusting for specific covariates such as duration of employment and socioeconomic status also is being evaluated. Preliminary results suggest that the choice of analytic approach and/or the adjustment variables can determine whether the results are statistically significant or not. Choose wisely and properly and, when in doubt, present all results.

Exposures 75 years ago are relevant today—Mission Mars.

The National Aeronautics and Space Administration (NASA) is interested in potential behavioral and cognitive impairments due to space irradiation effects on the central nervous system, especially from galactic cosmic radiation (GCR), the high-velocity heavy ions (e.g., ^{56}Fe) whizzing through space after a supernova explodes (NCRP Commentary No. 25). Early and late neurological disorders from brief exposures to these heavy ions are seen in mice studies. There are no human exposures/analogues similar to GCR in space. However, workers at MCW and Middlesex Sampling Plant, the facility that stored the pitchblende processed at MCW, had intakes of radium that resulted in a high linear-energy-transfer dose to brain tissue from alpha particles. Workers with intakes of radium, polonium, and plutonium are being combined to look at dementia, Alzheimer's disease, Parkinson's disease, and motor neuron disease. The human brain exposed for years to alpha particles may be more relevant to a NASA Mars mission than a mouse brain exposed to heavy ions for half a day.

Don't discount the past; it's the prologue to the future. The past is now addressing questions for the future that hadn't been asked until now! And don't forget to register for the NCRP Annual Meeting 6–7 March 2017 in beautiful downtown Bethesda on emergency preparedness for nuclear terrorism. *It's free!*

ORAU, Oak Ridge National Laboratory (ORNL), Vanderbilt, and NCRP Working Group at Oak Ridge

From left to right: Derek Hagemeyer (ORAU), Donna Cragle (ORAU), Ashley Golden (ORAU), Betsy Ellis (ORAU), Phil Wallace (ORAU, retired), Dick Toohey (MH Chew & Associates), Rich Leggett (ORNL), and Keith Eckerman (ORNL). Missing: Sarah Cohen (EpidStat), Mike Mumma (International Epidemiology Institute), David Girardi (ORAU), Heidi Chen (Vanderbilt), and John Boice (NCRP, Vanderbilt).
Photo courtesy of John Boice