H-bombs and Baby Teeth

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offices in January 1968, though the large collection of teeth and cards survived as they were kept in fire-proof metal file cabinets. When the federal and foundation grants ended in 1970, tooth collection and testing also ended.

Few studies of health hazards from bomb fallout

Six thermonuclear weapon tests conducted between March 1 and May 14, 1954 in the Marshall Islands — known as the "Castle" series — caused some of the most significant health and environmental impacts of U.S. atmospheric weapons testing. Totaling some 48 megatons of explosive force, they had negative impacts around the world. The first explosion, known as Bravo, produced an explosive yield of approximately 15 megatons, which was 1,000 times the destructive power of the Hiroshima atomic bomb. Because of its size and other factors, Bravo also spawned what the U.S. Radiochemical Society describes as "the worst radiological disaster in U.S. history" (U.S. Radiochemical Society, 2021). The people of Rongelap and Uterik atolls suffered severe impacts 200 miles away from the blast, including more than seven dozen people who received tissue-destructive radiation doses comparable to Japanese atomic bomb survivors (von Eschenbach, 2005).

Over the years, several U.S. government studies have documented that residents suffered from a high rate of thyroid disease from ingesting radioactive iodine. In 2010, researchers from the National Cancer Institute concluded that "our calculations project a substantial burden of radiation-related cancer in the more heavily-exposed Marshallese population groups..." (Land, 2010).

The AEC found that these enormous thermonuclear explosions created hazards 5,000 miles away in the United States. In November 1954, months after the six H-bomb tests known as Castle in the Marshall Islands, the director of the AEC's Biology and Medicine Division, John C. Bugher, reported to the General Advisory Committee that radioactive iodine from the Castle tests:

> "... can be detected in thyroids all over the U.S.... It is estimated that everyone in the U.S. [160 million people] received a dose of 1 rep in the thyroid as a result of Castle" (U.S. Atomic Energy Commission, November 1954).

This estimate represents nearly half of the per capita dose estimated decades later for members of the U.S. public by the National Cancer Institute from 100 open-air nuclear tests in Nevada (National Cancer Institute, 2019). Bugher also "cautioned against the use of milk in heavily contaminated areas" and "that Sr-90 in the New York milk supply has increased" (U.S. Atomic Energy Commission, November 1954).

Despite this, official studies on U.S. health casualties from aboveground bomb testing have been scant. In 1999, the National Cancer Institute released a study based on estimated radioactive iodine 131 in bomb fallout in each U.S. county from atmospheric tests in Nevada from 1951 to 1963. From these data, the institute estimated 11,300 to 212,000 thyroid cancers occurred in Americans who were under 20 years of age at time of exposure (Institute of Medicine, 1999).

In September 1998, a U.S. Senate investigation found that this congressionally mandated study was mismanaged and that the National Cancer Institute withheld key findings from the public for nearly five years (U.S. Senate Committee on Governmental Affairs, 1998).

Subsequently, the U.S. Centers for Disease Control and Prevention estimated 15,000 fatal cancers among Americans alive from 1951 to 2000 caused by worldwide atmospheric bomb test fallout. The report did not consider internal radiation exposure from breathing and ingesting radioactive particles such as Sr-90 (*The Guardian,* 2014).

In 2017, University of Arizona economics professor Keith Meyers looked at dose estimates of iodine 131 levels in milk from Nevada tests and estimated that 395,000 to 695,000 excess U.S. deaths occurred during the years 1951 to 1973. Meyers went further by making a rough calculation that the test ban treaty saved 11.7 to 24.0 million U.S. lives (Meyers, 2017). The wide spread in these results, which represented one of the few attempts to address fallout, suggests that impact on disease and death rates was still not well understood.

Found teeth launch health studies

Several European nations emulated St. Louis's tooth study efforts to track fallout. The Radiation and Public Health Project, a research and education group primarily interested in nuclear power reactors, also used the tooth study as a prototype for its own study of the same mix of radioactive chemicals (including Sr-90) in nuclear weapons tests. To date, the Radiation and Public Health Project study includes 5,000 baby teeth close to six U.S. nuclear power reactors. That study was the subject of five journal articles showing high and rising Sr-90 levels in teeth near reactors.

In the summer of 2001, Washington University biology professor Daniel Kohl, who had been on the faculty since the 1960s and was well acquainted with the original tooth study, led an inspection of a school-owned storage unit at Tyson Valley just outside of St. Louis. Kohl and his colleagues found long shoe boxes filled with teeth in envelopes attached to small index cards. He notified biology department administrators, who had no interest in retaining the teeth. He then called Commoner, who also did not want the teeth, but recommended they be given to the Radiation and Public Health Project. The teeth were donated soon after.

The project found that a large number of teeth — about 100,000 — had never been tested. Apparently, whoever stored the teeth had forgotten they were there. Because Sr-90 decays slowly, the chemical still could be measured in teeth. Tooth donors and their parents reacted in numerous media articles with a combination of nostalgia, pride, and interest in knowing more about the human health hazards of fallout.

Valley Children's Healthcare, Madera, California

As a health research organization, the Radiation and Public Health Project's interest in the teeth was not to track patterns of Sr-90 over time, as Washington University had done, but to use teeth to estimate correlations of health hazards from fallout. The long period of time since teeth were donated was actually an advantage, since tooth donors were now well into adulthood, and could be identified through death records and public databases such as voter registration files.

In 2011, the project's members published an article in the *International Journal of Health Services* using the St. Louis teeth. Twenty incisors from male bottle-fed St. Louis tooth donors born 1958-1960 who died of cancer by age 50 had more than double the Sr-90 concentration than in 40 incisors from controls who had no major health problems at age 50 (Mangano, 2011). The difference was statistically significant and received attention from media, including from the *New York Times*.

To date, no attempts have been made to replicate results of the Washington University study or the Radiation and Public Health Project study of Sr-90 in U.S. baby teeth. In future studies, the 100,000 teeth may be crucial. That is, the teeth represent evidence of exposure — intake of long-lived radioisotopes from bomb test fallout — which should help with risk estimation based on retrospective dose reconstruction and dispersion modeling (National Research Council, 1990). These uncertainties in risk estimation for bomb test fallout are similar to that of estimating risks to U.S. nuclear weapons workers who were individually measured for exposure. For instance, the Department of Health and Human Services has declared that dose reconstruction for thousands of workers at several nuclear sites, such as Hanford, the Nevada Test Site, and Los Alamos have proven infeasible, especially during the first decades of operation. This has restricted the department's abilities to offer compensation (Centers for Disease Control and Prevention, 2021).

A Harvard University grant opens up tooth research

Planning a study based on such a large collection of teeth has been extremely difficult. Information remained on the small index cards, and sifting through thousands of teeth was cumbersome and inefficient. In 2019, Harvard public health professor Marc Weisskopf, who had met Radiation and Public Health Project Executive Director Joseph Mangano a few years earlier, obtained a five-year grant from the National Institutes of Health to study health hazards of early-life exposure to heavy metals using a sample of 1,000 teeth.

The first year of the grant was mostly spent entering data on the teeth and donors into an automated spreadsheet. That work was done by the Radiation and Public Health Project and a contractor. The final tally of teeth was greater than previously thought; the collection consists of nearly 100,000 teeth, all from persons born between 1946 and 1965. While the majority of teeth are from the St. Louis area, at least 12 teeth from persons born in each of the 50 states, plus 45 foreign countries, exist.

Teeth can be studied for scientific research purposes beyond radiation and heavy metals, including for insight into pesticides, fluoride, genetics, dental research, and anthropology. The Radiation and Public Health Project makes teeth available for any of these efforts. Largely forgotten for several decades, the baby tooth collection's intrinsic scientific value to human health research is unique given its size and its portrait of the large generation of "baby boomers" born after World War II. These data address the still-unresolved legacy of radioactive fallout and provide rare human evidence of potentially harmful substances found outside of the nuclear industries.

The St. Louis baby tooth study relied on the simple acts of donating children's baby teeth for scientific research. This grassroots movement, driven by citizen participation, documented increasing levels of toxic radiation in human bodies from nuclear weapons tests. Evidence from the study helped speed the passage of the treaty banning these tests. University of North Carolina epidemiologist Steven Wing stated that:

> "By joining movements for human rights and social justice, health scientists can identify research questions that are relevant to public health, develop methods that are appropriate to answering those questions, and contribute to efforts to reduce health inequalities" (Wing, 2016).

The St. Louis tooth study was a groundbreaking example of Wing's call to join political movements to protect the environment. Decades after the study began, the discovery of a large number of untested teeth spanning an entire generation offers support for his belief that such movements can document health problems, answer questions about health, and reduce inequalities by providing important and enduring scientific evidence.

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