ISSUES RAISED BY GOULD, et al.

Jay Gould, et al.,recently published a paper entitled, *Strontium-90 in Deciduous Teeth as a Factor in Early Childhood Cancer*, 30 Int'l J. of Health Services no. 3 at 515-539 (2000). In this paper, the authors correlate strontium-90 (Sr-90) activity in baby teeth with the rate of cancer in children ages 0 to 4. The authors contend that the sources of the fission products of concern include Brookhaven National Laboratory (BNL) and airborne emissions from civilian nuclear power reactors located at Indian Point, NY; Salem, NJ; Oyster Creek, NJ; Millstone, CT; and Haddam Neck, CT.

The staff's review of the issues raised by Gould, et al., with relevant quotations from their article, is provided. Additional information related to the issues and alternative explanations are provided for each issue.

ISSUE: SOURCE OF ENVIRONMENTAL STRONTIUM (Sr-90) IN SUFFOLK AND NASSAU COUNTIES

> It is clear that the RPHP [Radiation and Public Health Project] levels [of Sr-90] are far higher–about three times higher–than the levels expected based on the assumption that no additional Sr-90 was introduced into the atmosphere after 1970, a significant difference (P value is infinitesimal). Gould, et al., supra at 525.
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> Sr-90 levels in deciduous teeth for children born during the 1980s and early 1990s are currently equal to those observed in the mid-1950s and are much greater than the levels expected after the cessation of all atmospheric weapons tests. Id. at 534.
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> Suffolk is also proximate to several other reactors operating in the 1980s and 1990s. Id. at 520.

Response:

Releases of radioactive Sr-90 into the environment and exposure of human populations are associated with several activities, practices, and events involving radiation sources. The main contribution to the global collective dose has come from the atmospheric testing of nuclear weapons. This practice occurred from 1945 through 1980. Each atmospheric nuclear test resulted in unrestrained release into the environment of substantial quantities of Sr-90. Approximately 622 peta becquerels (PBq) (16.8 million curies) of Sr-90 were produced and globally dispersed in atmospheric nuclear weapons testing.

Atmospheric nuclear testing did not cease when a bilateral moratorium was declared between the United States and the Soviet Union. Between 1970 and 1980, the French and Chinese governments conducted 41 additional atmospheric nuclear weapons tests with a combined yield of 16 megatons (MT) of TNT. Of this amount, 8.63 MT of fission yield material were injected into the stratosphere. These atmospheric tests replenished the atmospheric Sr-90 inventory so that no changes were observed between 1967 and 1974 (UNSCEAR 1977 and 2000).

Numerous measurements of the global disposition of Sr-90 (and cesium-137) and the occurrence of these and other fallout radionuclides in foodstuffs and the human body were made at the time the atmospheric tests were taking place. The worldwide average contribution to effective dose from ingesting Sr-90 (1945 to date) is 97 microsieverts (µSv) [9.7 millirem (mrem)]. The worldwide average contribution to effective dose from inhaling Sr-90 (1945 to 1985) is 9.2 µSv (0.92 mrem). No statistically significant excess of biological effects caused by Sr-90 exposures at levels characteristic of world-wide fallout has been demonstrated (NCRP Report No. 110).

Another source of global Sr-90 is the result of the April 1986 Chernobyl accident. Approximately 8 PBq (216,000 curies) of Sr-90 were released into the atmosphere. Apart from childhood thyroid cancer (attributable to radio iodine ingestion), no increase in overall cancer incidence or mortality has been observed that can be attributed to ionizing radiation from the Chernobyl accident (UNSCEAR 2000).

A third source of Sr-90 in the environment is from nuclear power reactors. The total annual release of Sr-90 into the atmosphere from all U.S. nuclear power plants is typically 37 MBq (1/1000th curie). The amount of Sr-90 released into the environment from a nuclear facility is generally so low [10's of kilobequerels (Kbq) per year (microcuries per year)] that the only chance of detecting “reactor” Sr-90 is in the nuclear power plant effluents themselves. Any Sr-90 detected in environmental samples (soil or water) is most likely residual fallout from atmospheric nuclear weapons testing, not nuclear power plant emissions. To differentiate reactor-generated fission products from those of nuclear weapons fallout, environmental samples suspected of containing strontium must be analyzed for both Sr-89 and Sr-90, as well as the presence of yttrium-90 (Y-90). However, this methodology only works if there is sufficient Sr-89 present in the environmental sample relative to Sr-90.

The annual average effective dose to individuals living within 50 km (31 miles) of a nuclear power plant, from all released radionuclides, is 5 µSv (0.5 mrem) for pressurized water reactors and 10 µSv (1 mrem) for boiling-water reactors (UNSCEAR 2000). Sr-90 contributes a very small fraction of this annual average effective dose.

Given the preceding information, it is unlikely that a difference can be detected between measured Sr-90 levels and those expected from atmospheric weapons testing and the Chernobyl accident. Nuclear power plant emissions of Sr-90 are inconsequential compared with other man-made sources and should be undetectable in deciduous teeth.

ISSUE: RADIOACTIVE RELEASES FROM NUCLEAR POWER PLANTS AND CHILDHOOD CANCER

The observation of rises and declines of Sr-90 levels in deciduous teeth following known large radioactive releases into the environment, measured independently by state and federal agencies, means that these levels reflect recent reactor releases, not past bomb test fallout. Gould, et al., supra at 534.

A three-year delay between Suffolk Sr-90 measures at birth and the incidence of cancer in 0-to 4-year-olds was found to give the best fit. Id. at 526.

Response:

There is little reason to believe that airborne emissions from any civilian nuclear power plant are contributing to childhood cancer in populations living near these plants. The National Institutes of Health (NIH) conducted a survey of cancer mortality in populations living near nuclear facilities in the United States. The results of this survey were published in 1990 as a report entitled *Cancer in Populations Living Near Nuclear Facilities*. This study encompassed all 62 nuclear facilities that went into service before 1982. The relative risk of mortality was compiled for 16 different types of cancer and for five different age groups, including children under 10 years of age. Based on the results of its survey, NIH concluded that there is no evidence to suggest that the occurrence of leukemia or any other form of cancer was generally higher in those counties containing a nuclear reactor. For example, NIH did not observe any statistically significant increased risk of cancer in children or adults under the age of 40 in the immediate or adjacent counties around Indian Point, Oyster Creek, Haddam Neck, Millstone, or Oyster Creek nuclear power plants. For childhood leukemia, the relative risk, comparing the leukemia rates for counties containing a nuclear power plant with neighboring (control) counties before plant startup, was 1.08, whereas after startup, it was 1.03, a small but statistically insignificant decrease in cancer mortality. For leukemia at all ages, the relative risks were 1.02 before startup and 0.98 after startup. These comparisons do not provide evidence of any cause-effect relationship between particular facilities and cancer occurrence in nearby populations. However, if any excess cancer risk were present in counties with nuclear facilities, it was too small to be detected by the methods employed in the 1990 NIH survey.

The following information summarizes data from the 1990 NIH report for the five NRC-licensed nuclear power plants “proximate” to Suffolk County, New York:

- *Salem* - There was no evidence of excess mortality from childhood leukemia or from any other form of cancer in any age group below 40. In fact, leukemia mortality in children below 10 was one half the pre-startup rate.

- *Haddam Neck* - With three possible exceptions, there was no evidence of excess mortality from cancer in any age group. The only relative risk comparing the study and control areas after startup that differed significantly from 1.00 were for colorectal cancer in those aged 20-59, for other lymphoma in those 40-59, and Hodgkin’s disease for those over 60.

- *Oyster Creek* - There was no evidence of excess mortality from childhood leukemia or from any other form of cancer in any age group below 40.

• *Millstone* - None of the relative risks comparing the study and control areas after startup was significantly different from 1.00 in the age groups below 40.

• *Indian Point* - In no age group below 60 was the relative risk significantly larger than 1.00.

In January 2001, the Connecticut Academy of Science and Engineering (CASE) issued a report stating that exposures to radionuclides emitted from the Haddam Neck nuclear power plant, operated by Connecticut Yankee Atomic Power, are so low as to be negligible. The CASE committee also found no meaningful associations among the cancers studied and proximity to the Haddam Neck nuclear power station. The committee concluded that atmospheric emissions from Haddam Neck have not had a detectable influence on cancer incidence and that additional study of this topic is unlikely to produce any positive correlation.

Finally, the release of short- and long-lived fission products caused by the 1979 loss-of-coolant accident at the Three Mile Island electric utility in Pennsylvania has concerned local residents. The only significant increase in risk of cancer that was identified by the NIH investigators in the 1990 report was for breast cancer in women aged 60 and over. A small, but statistically insignificant, increase in childhood leukemia also was observed, but not for all age groups combined. In a June 2000 report, investigators from the University of Pittsburgh found no link between the radiation released during the Three Mile Island accident and cancer deaths among nearby residents. The University of Pittsburgh study followed more than 32,000 people who lived within 8 km (5 miles) of the plant. Although the study did find increases in certain types of cancer (i.e., female breast cancer) among this group of residents, the investigators did not find evidence that radioactivity released during the accident had a significant impact on cancer mortality. Continued follow-up of this group is planned. If a casual link between radionuclide emissions from Three Mile Island has not been established for nearby residents, it is unlikely that a casual link between the Three Mile Island accident and cancer mortality in Suffolk and Nassau Counties can be established.

Gould, et al., assert that radionuclide emissions from nuclear power plants are responsible for childhood cancer, based on several temporal correlations. Gould, et al., contend that childhood cancer incidence between 1987 and 1993 is temporally correlated with time-adjusted laboratory measurements of Sr-90 in baby teeth. If a 3-year latency period between relative radiation level and cancer diagnosis is assumed, the two curves coincidentally have similar shapes. However, there is no medical basis for assuming a 3-year latency period for all childhood cancers. Gould, et al., also contend that changes in gross alpha and beta activity in the Peconic River and changes in childhood cancer incidence appear to be temporally correlated. Again, a 3-year delay between changes in radiation measurements and cancer incidence provided the best correlation in the Gould, et al. study. There is no basis to assume a 3-year latency period for childhood cancer, and at no time did radionuclide levels in the Peconic River exceed the EPA safe drinking water standard.

ISSUE: CANCER IN SUFFOLK AND NASSAU COUNTIES

> A recent study by RPHP researchers linked the rise in breast cancer in both Suffolk and Nassau to fission products in the diet and water, produced by airborne releases from nearby nuclear plants. Gould, et al., supra at 519.

Response:

A 1994 study by the New York State Department of Health found elevated risks for postmenopausal breast cancer among women living close to "chemical facilities" in Nassau County. In response to the observed increase in the rate of such cancer in Nassau County, the Long Island Breast Cancer Study Project was initiated. The purpose of this on-going project is to investigate whether environmental factors other than radiation are responsible for breast cancer in Tolland County, Connecticut, and in the New York Counties of Nassau, Schoharie, and Suffolk. The study, which began in 1993, is funded and coordinated by the National Cancer Institute.

Although Brookhaven National Laboratory (BNL) is not located in Nassau County, community and activist groups are concerned about BNL's possible contribution to increased incidence of breast cancer. An epidemiology study was commissioned by the Suffolk County Legislature to assess the geographic patterns of cancer and congenital malformations around the BNL site. In a 1998 report, the Suffolk County Task Force concluded that cancer rates for all types of cancers, including childhood cancers, were not elevated in communities within a 24 km (15 mile) radius of the laboratory, and there was no evidence that cancer rates were correlated with underground plume or wind direction. However, the study reaffirmed an elevated rate of female breast cancer on the east end of Long Island, but this increase was not attributed to any liquid or atmospheric release from BNL.

In 1997, the Agency for Toxic Substances and Disease Registry conducted a health consultation on contaminated groundwater obtained from residential wells located near the BNL site. The Agency concluded that, "Sampling results of residential wells do not indicate that persons are currently being exposed to contaminant levels that would cause adverse health effects." Although low levels of tritium have been detected in off-site water samples, radiochemical analysis of these samples confirms that U.S. Environmental Protection Agency (EPA) drinking water standards have not been exceeded for any radionuclide, including tritium.

ISSUE: RADIOACTIVE MATERIALS RELEASED FROM BNL

A few gross alpha and beta readings in the Peconic River have been ten or more times greater than the typical levels, suggesting that BNL reactors may be a major source of the fluctuations in observed alpha and beta activity; Gould, et al., supra at 532.

Response:

Past practices at BNL, Upton, N.Y., have resulted in on-site and off-site groundwater contamination with heavy metals, chemicals, and radionuclides. In 1995, chemical contamination, predominantly volatile organic compounds found in solvents that were used in many industrial processes at the Laboratory, above Federal and State standards, was detected in groundwater beyond the laboratory site boundary.

Past practices at BNL have resulted in on-site and off-site contamination with radionuclides such as tritium and Sr-90. The discovery of a tritium leak from the spent fuel pool of one of the two operating research reactors at Brookhaven also attracted heightened awareness and interest in BNL activities from special interest groups. The total amount of tritium that leaked into the groundwater is estimated at 200 to 400 gigaBecquerels (GBq) (5 to 10 curies). Independent agencies regularly monitor the public drinking water supplies on-site and off-site to determine exactly what is present in the water. As a result of this monitoring, tritium has been detected in several private wells southeast of the BNL. Although the tritium is above background levels, these levels are well below EPA drinking water standards.

Figure 6 of the Gould article reports 3-year moving averages of gross alpha and beta activity in the Peconic River measured between 1984 and 1993. However, none of the data in the article exceeds the EPA Safe Drinking Water Standards. The highest total gross alpha activity [0.13 becquerels/liter (Bq/L)(3.6 picocuries(pCi)/L)] was well below the 0.55 Bq/L (15 pCi/L) maximum contaminant level. Similarly, the highest gross beta activity [0.52 Bq/L (14 pCi/L) is well below the 1.85 Bq/L (50 pCi/L) gross beta-particle activity screening level promulgated by EPA. Furthermore, the authors do not mention naturally occurring radionuclides. The presence of naturally occurring beta-particle emitting radionuclides must be taken into account when evaluating the source of high beta-particle activity in ground water. For example, the presence of potassium-40 occurring naturally in fertilizer is a significant source of beta-particle activity in the majority of water samples analyzed by EPA and the US Geological Survey. A sample with short-term gross beta-particle activity of 1.19 Bq/L (32.1 pCi/L) (collected at a public water system in Massachusetts) had a large contribution from potassium-40 [1.05 Bq/L (28.4 pCi/L)]. For a selected number of ground-water samples, naturally occurring radium-228 also may be a significant source of beta-particle activity.

Many public water supplies also contain naturally occurring alpha emitters such as polonium [concentrations ranging from 0.04 Bq/L to .4 Bq/L (1 to 10 pCi/L)]; thorium [concentrations generally are near 0.04 Bq/L (1 pCi/L)]; plutonium [concentrations were generally less than 0.004 Bq/L (0.1 pCi/L)]; and lead-210. The greatest frequency of detection of lead-210, a decay product of uranium-238, is in the Appalachian Physiographic Province of the northeastern United States, especially in Connecticut and Pennsylvania. One possible explanation for the frequent detection of lead-210 in the Appalachian region may be the high concentrations of naturally-occurring radon-222 in groundwater in this region.

ISSUE: USING BABY TEETH TO MEASURE ENVIRONMENTAL EXPOSURE TO Sr-90

> The deciduous tooth may be considered a stable structure and can be taken to reflect the mineral composition acquired at the time of its formation. It therefore provides information about Sr-90 uptake during the year of the child's birth. Gould, et al., supra at 522.
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> Strontium-90 readings for each tooth at the time it was lost by the child are converted to levels at birth, creating a standardized measure that can be compared regardless of how old the tooth is. This conversion is made using the decay rate of a 28.7-year half-life for the radionuclide, using the month of birth and the month of tooth analysis. Id. at 523.

Response:

Incorporation and metabolism of Sr-90 into the fetal and neonatal skeleton and baby teeth are dynamic processes. The rapid growth of the fetal and neonatal skeleton, which starts about the fifth month of gestation, causes the skeleton to be more sensitive to radiation from Sr-90 than at any other stage of life. However, Sr-90, inhaled or ingested by the mother immediately after conception, is generally not transferred across the placenta to the developing fetus. Although calcium and strontium are metabolized similarly in the mother's body, the placenta can initially discriminate against strontium in favor of calcium. However, the ability of placental membranes to discriminate against strontium decreases during the course of the pregnancy. By the end of the pregnancy, the placenta's ability to discriminate against strontium has almost disappeared and strontium is passed on to the fetus in the same concentration as that present in the maternal circulation. Consequently, the fetal skeleton accumulates the same amount of strontium during the last month of gestation as during all the previous months of pregnancy. For example, the estimated lifetime radiation dose to the infant skeleton from a single ingestion of 3.7 KBq (1 microcurie) Sr-90 at 6 months and 9 months of gestation is 6 milliGray (mGy)[(600 millirad (mrad)] and 18 mGy (1800 mrad), respectively (NCRP Report No. 128).

Incorporation of Sr-90 into deciduous teeth does not cease at birth. Calcium (and Sr-90) uptake into deciduous teeth continues through the 70^{th} week postconception. The dentine of the deciduous tooth continues to take up calcium, phosphorus, and strontium through the life of the tooth, typically 7 to 12 years, depending on the type of tooth. Sr-90 will be deposited uniformly throughout the tooth if a constant dietary source is provided. Conversely, Sr-90 will be deposited in bands, in the dentine beneath the tooth enamel, if dietary Sr-90 is ingested as single acute doses. Dental mapping of the tooth can indicate when and how much dietary Sr-90 was ingested. American Dental Association staff is mapping Sr-90 deposition in exfoliated teeth obtained from Russian adults exposed to Sr-90 during the cold war.

Consequently, the deciduous tooth is a dynamic rather than a stable structure. If Sr-90 readings for each tooth at the time of analysis is converted to levels at birth by correcting for radionuclide decay between the month of birth and month of tooth analysis, a gross over-estimate (approximately 30 to 40 percent) of Sr-90 in the deciduous tooth at the time of birth could be predicted.

An alternative method for evaluating Sr-90 content in baby teeth is comparing teeth obtained from suspected “high-exposure” areas with “low-exposure” areas. Unfortunately, RPHP investigators obtained very few teeth from low-exposure areas in New York and New Jersey; thus all the low-exposure area data were excluded from the technical analysis.

ISSUE: OTHER FACTORS RELATED TO NON-CANCER CHILDHOOD ILLNESSES

> Our results ...strongly support the hypothesis that the recent epidemic rise in the incidence of immune- and hormone-related diseases among children--such as cancer, asthma, low birth weight, hypothyroidism, ear infections, and bronchiolitis, as documented in recent publications--is most likely due to the unexpectedly severe effect of nuclear releases, often synergistically increased by chemicals and air pollutants. Gould, et al., supra at 535.

Response:

Many environmental factors affect the health of young children. The most significant environmental factors include exposure to secondhand tobacco smoke, maternal consumption of alcoholic beverages during pregnancy, and exposure to bacteria. According to a study by the Agency for Health Care Policy and Research, about half of the cases of early childhood asthma, chronic bronchitis, and wheezing are due to exposure to secondhand cigarette smoke. This study demonstrates that 38 percent of children aged 2 months to 5 years in a representative sample of the U. S. population (7,680) are exposed to environmental tobacco smoke (ETS) in the home, and 24 percent of these children were exposed by maternal smoking during pregnancy. ETS appears to increase the prevalence of asthma rather than the severity of the illness, which the researchers measured by medication use. Children exposed to tobacco smoke had similar use of prescription asthma medications to unexposed children. These findings are based on data from the Third National Health and Nutrition Examination Survey, 1988 to 1994, which included reports on household smoking and maternal smoking during pregnancy.

In 1991, the Journal of the American Medical Association reported that at least 5,000 infants are born each year with Fetal Alcohol Syndrome (FAS) -- approximately one out of every 750 live births. FAS is a series of mental and physical birth defects that can include mental retardation, growth deficiencies, central nervous system dysfunction, craniofacial abnormalities, and behavioral maladjustments.

According to a report by the Children's Medical Center of Dallas, almost half of all children will have at least one middle-ear infection before their first birthday. Furthermore, two-thirds of all children will have had a middle-ear infection by age three. Bacteria entering the middle ear from the nose or throat appear to be the major culprits for these middle-ear infections, not exposure to ionizing radiation.