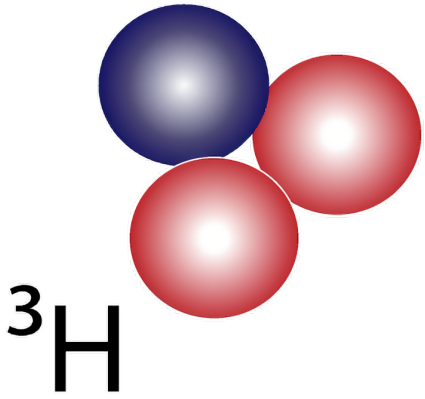
THE CARCINOGENIC, MUTAGENIC, TERATOGENIC, AND TRANSMUTATIONAL EFFECTS OF

TRITIUM



CITIZENS AWARENESS NETWORK

WWW.NUKEBUSTERS.ORG

APRIL 1994

Updated January 2001

Contact:
Deborah Katz
Executive Director

deb@nukebusters.org

Citizens Awareness Network
PO Box 83
Shelburne Falls, MA 01370

413-339-5781

INTRODUCTION

During the past two decades, residents of the Deerfield River Valley in Massachusetts suffered alarming health problems: an increased cancer rate, miscarriages, multi birth-defected children, and a ten-fold increase in Down's Syndrome (a congenital disease characterized by mental retardation and bodily malformation). Local health authorities were unable or unwilling to account for the region's growing pattern of health anomalies.

Attention turned to the safety of the nearby Yankee Rowe nuclear power station, the nation's first 'experimental' commercial reactor, and the effectiveness of the standard nuclear safety guidelines of the Nuclear Regulatory Commission [NRC]. During a series of public meetings, area residents learned that the Yankee Rowe reactor had used the nearby Deerfield River as a radioactive waste dump over the past thirty years. The Nuclear Regulatory Commission, the agency that oversees the operation of commercial nuclear reactors in America, permitted this dumping of radioactive waste.

Concerned citizens, realizing that the river had been widely used for well water, crop irrigation, and recreational purposes, began to question whether the increases in disease were due to the reactor's regular releases of radioactive materials into the river.

It was at this point that the Citizens Awareness Network [CAN] was formed as a grassroots organization primarily concerned with the health and safety of its community.

The Citizens Awareness Network began to investigate effluent releases from the Yankee Rowe reactor into the Deerfield River, and compiled a 30-year history of reported releases. CAN found that large quantities of tritium, a dangerous enviro-toxin, had been released into the river (given the river's size and the degree of contact the community routinely had with its water).

The Massachusetts Department of Public Health [MDPH] initially denied that there was cause for concern. After continuing pressure from CAN and the local community, MDPH agreed to a preliminary investigation of the diseases. After eight years the MDPH completed an initial investigation, which determined that there was statistical significance in cancers and children with Down's syndrome. Investigations are ongoing with the Department of Environmental Protection (DEP).

With the professional assistance of epidemiologist Dr. Sidney Cobb, and the work of concerned citizens, CAN coordinated research into state health statistics, effluent reports and meteorological data. Dr. Cobb analyzed the raw data and concluded that an epidemic indeed existed in the Deerfield River Valley, and that a full-scale epidemiological study was warranted. A Health Committee of local residents formed, coordinated by CAN to access the professional help needed to document both the diseases in the Deerfield River Valley and the mechanism of contamination. Over the years CAN enlisted the help of Harvard School of Public Health, US Geological Services, and the Center for Disease Control (CDC).

An analysis of statewide statistics provided by MDPH confirmed a statistically significant increase in various types of cancer in the Deerfield River Valley.

Moreover, deficiencies in MDPH's records for the incidence of Down's syndrome prompted CAN, community leaders, and local legislators to advocate for a new statewide birth defects registry. At this time a birth defects registry is forming with the help of the CDC.

The Citizens Awareness Network has continued its investigation of the nuclear reactor, leading to our research on *tritium*, one of the nuclear isotopes regularly released into the Deerfield River. We present this research with the experience of successfully influencing legislators and health officials through information and awareness. We believe that ordinary citizens can—and must—understand the scientific and social issues related to the production of nuclear power.

CAN believes that the standard operation of a nuclear power station causes untold harm, sickness and death. The focus on nuclear accidents results in misleading and diversionary arguments over the safety and effectiveness of existing technology. We believe that Yankee Rowe has been one of the 'safest' reactors in the country, according to NRC guidelines. **It is the NRC guidelines that need re-evaluation.**

The epidemic of disease in the Deerfield River Valley did not become apparent until 25 to 30 years after operation began. We are now beginning to see the health effects of long-term exposure to low level radiation in our community, and communities throughout the world.

We have all participated in a terrible experiment. The data from the investigation of Yankee Rowe and other nuclear facilities will provide information to educate citizens about the effects of radiation on the health of their generation and future generations.

TRITIUM

Tritium is a radionuclide emitted as waste from pressurized water nuclear reactors, heavy water nuclear reactors and the new generation of nuclear reactors. It has been an integral part of the nuclear weapons industry: tritium was released into the atmosphere as part of weapons testing in the 1950's and 60's. It is a beta emitter and has a half-life of 12.5 years. It decays to an isotope of helium, releasing a neutrino and a beta particle (an electron). The electron is slow-moving and has a very short range.

Tritium was believed to be a relatively benign radionuclide because of the weakness of the beta radiation emitted when it decays. The beta electron is a small particle that passes readily through most barriers. The dangers of tritium come from inhalation, ingestion, and absorption.

Tritiated water (HTO) passes through the human body in 12 days. However, when the radionuclide unites with carbon in the human body, plants, or animals, it becomes organically bound (OBT) and can remain in the human body for 450 to 650 days. One study found traces of tritium in the body 10 years after exposure.(24)

As tritium makes its way up the food chain it may become more concentrated. **(16)** Pigs fed with tritiated food them became tritiated, as did their offspring. The blood, heart, and kidneys of the piglets were more tritiated than the mother. (**23)**

Tritium is carcinogenic, mutagenic, and teratogenic. **(21)** Human beings can receive chronic exposure to OBT through the ingestion of plants and animals exposed in the effluent pathway, in addition to direct uptake through inhalation, absorption and drinking contaminated water. Especially sensitive to the effects of tritium are rapidly growing cells such as fetal tissue, genetic materials and blood forming organs. **(2, 12, 19, 21, 20)**

Tritium is dense and has a short track length. It releases all its activity at one time. This makes it more potent and similar to soft x-rays, which are more effective than hard x-rays. (**15**) When and where it deposits its radioactivity, it creates at least one lesion in the cell. This lesion must be repaired within 24 hours or the cell will be carcinogenic when it eventually divides.(**26, 30)** There may be a threshold below which the repair mechanism is not activated in the body, **(13, 15, 2 7, 32)** therefore, low levels of chronic radiation exposure can accumulate in the body without the repair system being activated. **(11**, **25, 27, 30, 32, 36)**

Tritium has a transmutational effect which is mutagenic. After the particle releases its radioactivity into the cell, a helium ion is formed. The helium springs away from the 9-particle and severs the bond with the compound to which the tritium had attached itself. The compound acquires a positive charge and becomes chemically active. (**22**)

It then can attach itself to a ring of a protein precursor that will make up the chromosomal strands in the DNA. Depending on the ring it attaches to, it can affect the protein precursors and damage the DNA. This would create a mutational effect. (**22**)

Radiological research has found a correlation between tritium and cumulative genetic injury. (**21**) There was found in successive generations a reduction in relative brain weight, reduction in litter size, and increased reabsorption of embryos. Correlations have been found in epidemiological research between tritium and Down's' Syndrome. Associations have also been found between low-level radiation and Down's Syndrome.(**6, 7, 8, 10, 31**)

The Deerfield River Valley (DRV)

Nuclear power stations ***must*** dispose of waste to operate. For pressurized water reactors (such as Yankee Rowe), the main effluent release is into a body of water. Thus the Deerfield River Valley becomes a radiation waste dump for Yankee Rowe. When tritium is released into such an environment, plants, animals, and human beings in the vicinity can be contaminated. (**17, 24**)

The Deerfield River is a small winding river in western Massachusetts. It has white water and is fast running. The valley through which the river runs is 800 feet on either side, creating a tunnel where inversions are held 34% of the time. Fog hangs in the valley for days at a time. Yankee Atomic Electric Co developed this meteorological data.

The river has been used for recreational purposes during the 31 year history of the Yankee Rowe reactor. Citizens swim, fish and boat in the river. Wells and cropland are adjacent to the river, and in times of drought, river water is used to irrigate crops. Each year 500,000 people use the river.

For 31 years the Deerfield River has been a dumping ground for low-level radioactive waste. During the 1960's and early 70's, Yankee Rowe had problems with faulty fuel rods and dumped large amounts of tritium into the river. Up to 1,800 curies a year were released, nominally within NRC guidelines.

The estimated concentrations of tritium were 10,000 times greater in the DRV than outside the valley. There were batch releases each month. People in the community were generally unaware that the river was radioactive, although it had been noted that since the reactor opened, the river never froze.

An analysis of the Deerfield River (done by a graduate student at John Hopkins University from US Geological Services studies) raised serious questions concerning the migration of contamination from the Deerfield River, the potential for wells in Ashfield, Deerfield, and Greenfield to share water supplies with the Deerfield, and the potential for recharging. Recommendations were made to study evaporation of tritium, measure pollutant contaminations, and ascertain information on the holding basins in the valley.

This analysis and its recommendations were presented to MDPH, however, the department did not investigate these issues or refer the concerns to other agencies that could be of help. There is presently an ongoing investigation of wells and pathways of contamination by the Department of Environmental Protection (DEP) in Massachusetts.

Epidemic of Disease in DRV

Increases in miscarriages, mental retardation, cancer and other health problems began to be noted in the 1980's through 1990's. There have been over 10 children born with Down's syndrome since the 1980's, all to mothers under the age of forty. In fact, an additional three children with Down's syndrome have been born in the 1990's. Most affected families live within a five-mile radius of each other in the effluent pathway, or have had extensive contact with the river during their pregnancies.

Down's Syndrome occurs, on average, in one of 700 to 1,000 live births. Of the approximately 2,000 live births within the valley in the last 20 years, the incidence of Down's syndrome is closer to one in 100. There have been six chromosomally damaged children conceived during the same time period. Two of these children were born. One died at 6 months, the other child was five years old with Down's syndrome features. Another of the chromosomally damaged fetuses was trisomic. The Massachusetts Department of Public Health initiated a preliminary investigation of the environs around Yankee Rowe, in the pristine rural environment of the DRV.

There is a 50% increase in five different cancers; a 40% increase in heart disease; and a 110% increase in infectious disease leading to mortality according to an analysis by Dr. Sidney Cobb of MDPH statistics. Cobb pressured the MDPH to study the valley and called for a large-scale health study to be undertaken by the state. Cobb had been instrumental in pressuring the state to engage in a health study of leukemia around the Pilgrim reactor in southeastern MA. That study found a 4-fold increase in leukemia in residents living within a 5 -mile radius of that reactor.

After eight years the MDPH released a preliminary investigation riddled with misinformation. The state refused to study the Deerfield River Valley as a whole even though the population of the valley was smaller than a small city (under 10,000 residents; 35,000 including Greenfield and Deerfield)). MDPH included inaccurate meteorological data that had wind patterns blowing away from the valley even though it had participated with CAN and the Deerfield River Valley Health Committee in a meteorological study done by Harvard School of Public Health. It refused to include certain children born or conceived in the valley with Down's syndrome, lowering the statistical significance from a 10-fold increase in to a four-fold increase. MDPH refused to include multi birth-defected children, brain tumors, heart disease, immune deficiency disease, and to acknowledge the reality that a "cluster" of Down's syndrome and other diseases existed.

It, however, acknowledged statistical significance in breast cancer, non-Hodgkin's Lymphoma, and Down's syndrome. Eleven cases of Multiple Myeloma were found in the valley. The state refused to acknowledge statistical significance in Multiple Myeloma because the cases were scattered among the 8 towns studied. Greenfield, MA, located between the Yankee Rowe and the Vermont Yankee reactor in Vernon, Vermont (which the state did not include in the study), had an additional 8 cases. Multiple Myeloma is a rare blood cancer; there are only 12,700 cases *diagnosed each year* in the US. The only known cause is ionizing radiation.

After MDPH refused to revise its study or proceed with a full-scale health study in the area, CAN obtained statistics from the MA Cancer Registry which found 27 cases of Multiple Myeloma from 1982-1992 in the Valley and Greenfield. (14 in the 8 towns and 13 in Greenfield.) Additionally, we found 17 cases of brain tumors between 1982-92 in the valley and 18 brain tumors in Greenfield during the same period, bringing the combined total to 35 brain tumors. These are alarming statistics for a poor, rural community with limited medical services. It is a terrible reality for ordinary people faced with the burden of caring for sick and dying relatives and friends.

Citizens Awareness Network (CAN) and Nuclear Information Resource Service (NIRS) have demanded that NRC fund an independent epidemiological investigation of the DRV. This would entail an effluent pathway study of the river. We have also demanded that NRC reevaluate their inadequate and unfounded dosimetery standards for tritium.

To understand the effects of tritium exposure, the effects of organically bound tritium (OBT), and tritiated water (HTO) must be calculated. Since the effects of tritium are on a cellular level rather than an organ level, microdosimetry is required.

The issues raised in this report about the operation of the Yankee Rowe reactor were forwarded to the Inspector General of the Nuclear Regulatory Commission for investigation. The NRC subsequently acknowledged that over 10,000 curies of tritium were released into the Deerfield; it also stated that it was not within its regulations to authorize or organize a health study of the residents of the Deerfield River Valley.

Annotated bibliography of Down's Syndrome, low-level radiation studies and tritium research

Down's Syndrome

1 E. Alberman, J.A. Polani, Fraser Roberts, C.C. Spicer, M. Elliot, E. Armstrong, 'Parental Exposure to X-irradiation and Down's Syndrome." London: Ann. Him. Genet. 36 (1972): 195.

Effect of radiation on increase in Down's syndrome was greatest in subgroup where X-rays were received more than ten years before conception. There was significant increase of 'ever" X-rayed mothers in Down's syndrome group. The size or dose of X-ray was less important than the cumulative effect, as if damage was not followed by repair.

2 V. BEIR, 'Health Effects of Exposure to Low Levels of Ionizing Radiation." *Nat'l Acad Press*. 1990.

Report stated that there was no threshold for the effects of radiation when the brain is in its most sensitive stage of development. This was especially true from 8-1 5 weeks through 22 weeks of gestation.

3 Susan Harlap, 'Down's Syndrome in W. Jerusalem,' *Amer Journal Epidem,* 97, # 4. pp.225-232.

Research found that there were environmental factors involved in the etiology of Down's Syndrome. Harlap compared rates of Down's Syndrome in different groups in Israel. For mothers aged under 35, the age-adjusted risk of Down's Syndrome is increased eightfold in one group who used the ritual baths while for older mothers difference in risk is less than threefold.

4 N. Kochupillai,I.C. Verma, M.S. Grewal, V. Remalinggaswami, 'Down's Syndrome and related abnormalities in an area of high background radiation in coastal Kerala.' *Nature,* 262 (1976) 60-61.

Research compared high background population to control with low background radiation. The observed frequency was higher than in controls and significant. Higher frequency of cases of Down's Syndrome born to mothers aged 30-39. There was an association suggested between low dose radiation exposure of older maternal age, suggesting that the damaging event accelerates oocyte aging and causes primary trisomy rather than translocation trisomy.

5 CN Rasmey, Ellis, and Zeally, 'Down's Syndrome in the Lothian Region of Scotland 1978 to 1979.' *Biomed & Pharmacother45 (1991)* : 267-272.

Observable increases in Down's Syndrome were noted in Lothian Region of Scotland after the accident at Chernobyl. The highest rate of *27.1 2* in 1987 was significantly higher than average for the whole period. Increase in incidence peaked in late 1987 and subsequently returned to pre-1986 levels.

6 Sheehan, M. Patricia and B. Hillary Irene, 'An Unusual Cluster of Babies with Down's Syndrome Born to Former Pupils of an Irish Boarding School.' *British Jour. Med. 1* 1 Dec. 1983 : 287.

Sheehan found a cluster of children born with Down's Syndrome (8) to mothers who attended a girls school as adolescents, during the Windscale fire at that reprocessing reactor. The school was in the effluent pathway and the radionuclide released was tritium. There were 30 birth abnormalities in all in this small population.

7 **A.T.** Sigler, *et* al 'Radiation exposure in parents with children with mongolism (Down's Syndrome).' *Bulletin of John Hopkins Hospital,* 2 (1968): 1045-1049.

Radiation exposure increased the risk of mongolism in parents. There was validation of the view concerning cumulative radiation damage to genetic material. Exposure was result of fluoroscopic and therapeutic radiation.

8 **K.** Sperlind, J. Pelz,RD. Wegner, 1. Schulzke and E. Srruck, 'Frequency of Trisomy 21 in Germany before and after the Chernobyl accident.' *giomed&Pharmacother45,(1991):255-262.*

Increases in Down's Syndrome were observed in Germany after the Chernobyl accident. There was a peak in incidence in January 1987. This peak is highly significant.

9 Uchida, Irene and Elizabeth and J. Curtis, 'A Possible Association Between Maternal Radiation and Mongolism.' Lancet (10/14/61):848-850.

There is a strong association between the incidence of mongolism and a history of maternal abdominal radiation. Radiation effect may be age-dependent.

10 T. Zuftan and W. Luxin, 'An Epidemiological investigation of Mutational Diseases in the High Background Radiation Area of Yangiang, China.' *1. Radiat. Res.* 27 (1986): 141-150.

There were increases in Down's Syndrome found in high background radiation area. Increases in cancer were not found. Average background dose was 330 mR/yr and 114 mR/yr in control group. There was a higher rate of cancer in control group, which had received a greater number of medical X-rays.

Tritium

11 D.F. Cahill and C.L. Yuile, 'Tritium Irradiation of Mammalian Fetus." *Radiation Research* 44 (1970) : *727.*

Offspring conceived by parents subjected to low level lifetime exposure manifest effects at HTO activity levels 10-100 times lower than those required during exposure in utero only.

12 L.A. Carsten and S.L. Cummerfored, 'Dominant Lethal Mutations in Mice Resulting from Chronic Tritiated Water lngestion.' *Radiation Research 66(1973):609.*

Two successive generations of mice were exposed to continued ingestion of tritiated water. In second-generation females, there was a significant reduction in the number of viable embryos.

13 A.L. Carsten, *et al,* ' 1989 Summary Update of the Brookhaven Tritium Toxicity Program with Emphasis on Recent Cytogenic and Lifetime-Shortening Studies in Proceedings of the Third Japan-US workshop on **Tritum Radiobiology and Health Physics.'** (Edited by S. Okada), Institute of Plasma Physics. Nagoya University, Nayoga, Japan. IPPJ-REV-3.

There may be an effect at very low doses where the radiation inhibits the repair mechanism. This may occur during tritium irradiation. Theory consistent with the track structure calculations of Goodhead using very weak X-rays. There was significant reduction in the number of viable embryos resulting from matings between animals maintained on tritium diet. There was no effect on breeding effectiveness.

14 R.L. Dobson and M.E. Cooper, 'Tritium Toxicity - Effects of low-level 3HOH Exposure in Developing Female Germ Cells in the Mouse,' *Radiation Research* 58. p. 91.

Adult female mice were maintained on tritium levels 8.5, 0.85 and 0.085 Ci/ml of body water from day of fertilization. In female offspring exposed to tritium from conception and sacrificed at 14 days, primary oococytes were decreased below control number by 90% at 8.5, and significantly at 0.085 level.

15 D.T. Goodhead and H. Nikjoo, "Current Status of Ultrasoft X-ray and Track Structure Analysis as Tools for Testing and Developing Biophysical Models of Radiation Action.' *Radiat. Prot. Dos.* 31, No. 1/4 (1990) 343-352.

Authors conclude that ultrasoft X-rays are more effective than equal doses of hard X-rays. Their RBEs increase with decreasing X-ray energy down to very small track lengths of 7 nm. Low energy electron track ends are a predominate cause of cell inactivation in **all** low LET radiations. (Ultrasoft X-rays are very similar in energies and track lengths to tritium 8-radiation).

16 Kirchman, *et al,* 'l 973 Studies on the Food Chain Contamination by Tritium.' *In Tritium,* editors Moghissi and Cater, Messenger Graphics, Phoenix, AZ, US.

Tritiated grass eaten by cows has been shown to be effectively transferred to their milk. OBT levels in their milk were 10 times higher in cows fed on tritiated grass than cows fed on HTO.

17 D. Macintosh, S. Lung, F. Tsai and J. Spengler, 'A Preliminary Assessment of the Potential Human Exposure to Tritium Emissions from the Yankee Atomic Electric Company Nuclear Power Facility Located *Near Rowe, MA*.' Harvard University School of Public Health, Dept .of Environmental Health 7(1993)

Graduate students, under the supervision of J. Spengler, conducted a preliminary assessment of potential exposures and doses to the Deerfield River Valley residents to tritium released from the Rowe nuclear power reactor. Concentrations of tritium were found to be 10,000 times greater in the valley than the surrounding area. Researchers suggested that an investigation be undertaken to study the effects of organically bound tritium, the effect of the river rapids and falls on HTO evaporation, and OBT aerosolization.

18].W. Laky, *et al,* 'Some Effects of Lifetime Parental Exposure to Low-Levels of Tritium on the F2 Generation." *Radiation Research* 56, (1973) :1 71.

Research done on effects of low-level exposure to tritiated water. Continued exposure calculated as whole body dose rates 3 to 3,000 mrads/day produced a 30% reduction in adult Fl male testes, but no impairment in growth or reproductive ability. Statistically significant effects on F2 neonates were: reduction in relative brain weight, decreased body weight, decreased litter size and increased reabsorption. Brain and testes contained approximately 1 00% and 50% greater tritium activities than the average in other tissues.

19 J.W. Lasky, and S.J. Bursian, *Radiation Research* 67, (1976) : 314.

Rats were exposed to constant tritium activities of 10 uCi/ml of body water for 42 days beginning first day of pregnancy or birth. In males exposed from birth or first day, there was a significant reduction in the testes weight and sperm content. In females exposed there was a significant reduction in F2 litter size and an increase in the number of reabsorbed embryos. The group most sensitive to low-level exposure was the one exposed from first day of pregnancy.

20 D.J. Mewissen, 'Cumulative Genetic Effects from Exposure of Male Mice to Tritium for Ten Generations.' IAEA Symposium on Biological Implications of Radionuclides Released from Nuclear Industries, (1 979).

Data established the existence of cumulative genetic injury and the existence of cumulative genetic injury at the 9th generation. Their F2 offspring (unexposed) exhibited a significant increase in dominant lethal mutations resulting in a decrease in litter size.

21 T. Straume, ' Health Risks from Exposure to Tritium.' UCRL-LR-105088, Lawerence LivermoreLaboratory, Livermore, California, US 94550, (1991).

Tritium is more hazardous to health than other types of low-level radiation. Tritium is about 1.5 times as carcinogenic, 2-5 times as mutagenic, and 2 times as teratogenic.

22 G. Tislajar-Lentulis, P.Hennenberg and L.E. Feinendegen, 'The Oxygen Enhancement Ratio for Single and Double Strand Breaks Induced by Tritium Incorporated in DNA of Cultured Human Tl Cells. Impact on the Transmutation Effect.' *Radiation Research 94,* (1983) : 41 -50.

Researchers found that a third of single strand DNA breaks caused by the decay of tritium in 6-thymidine were due to transmutation. This is over and above the radiational effect.

23 M. Van Hees, *et al,* 'Retention in Young Pigs of OBT Given During Pregnancy and Lactation.' *Radiat. Prot. dos.* 16, no 1-2, (1971) : 123-126.

Pigs fed with tritiated food themselves became tritiated. They passed on tritium to their offspring. The blood, heart, and kidneys of the young piglets were more tritiated than the tritiated foods fed their mother.

24 H. Wasserman, and K. Solomon, 'Killing Our Own," N.Y. Dell. (1982) :190-193.

There is a long residency period in the body of very low concentrations of tritium. A 1981 study of former American atomic workers showed a majority with tritium levels still ten times above normal. Study found that tritium can remain in the body for up to ten years.

Low-Level Radiation

25 K.F. Baverstock, D. Papworth, and J. Vennart, 'Risk of Radiation at Low Dose Rates." *Lancet, 1,* (1981) 430-433.

Researchers studied workers involved in assemblage of instrument-dials made luminescent with radium. Significance found for breast cancer induced by gamma radiation. Exposure at rate of 0.1 rad per 8 hours, allowing adequate time for repair from exposure. Although the luminizer appears to be a high dose study, it demonstrates the inability of the body to adequately repair after exposure to low-level radiation.

26 M.A. Bender, 'Significance of Chromosome Abnormalities.' (1984) :281-289 in boice.

Bender investigated the repair of chromosome breaks incurred through exposure to radiation. In discussing repair of chromosome breaks, he reports repair half-times which are 'typical of the order of 1 or 2 hours.'

27 L.W. Brackenbush, and L.A. Brady, 'Microdosimetric Basis for Exposure Limits." *Health Physics* 55, (1988) : 251-255.

Researchers state that 'Since most cells repair radiation damage with a characteristic time ranging from a few minutes to a few hours, it is evident that irreparable or mispaired damage must dominate the low-LET radiation effect at low dose rates.'

28 I.D. Bross, *et al,* 'A Dosage Response Curve for the One Rad range: Adult Risk for Diagnostic Radiation.' *Amer. Jour. Pub. Health,* 69, no. 2, (1979).

Bross investigated the effects of diagnostic medical trunk X-rays on 220 men with non-lymphatic leukemia and 270 controls. Research suggests that most heart disease is 'prompted' by radiation exposure. The doubling dose of radiation for leukemia was determined to be 5 Rems.

29 Sidney Cobb, MD MPH., "Health in the Deerfield River Valley. Some Preliminary Looks,' (9/29/1992).

Dr. Cobb analyzed raw health statistics in the Deerfield River Valley to determine whether a full epidemiological investigation should be undertaken. Cobb investigated available data for cancer incidence, Down Syndrome, and mortality. He found a 50% greater overall mortality, a 50% greater mortality from cancer (5), a 40% greater mortality in heart disease, a 70% greater mortality from 'other' causes in the Deerfield River Valley. There was suggestive evidence that there might be an excess in Down's Syndrome. His conclusions were that the health problems deserve immediate attention. These problems were consistent with radiation injury incurred between 1960 and 1972.

30 H.J. Evans, K.E. Buckton, G.E. Hamilton and **A.** Garothers, 'Radiation-induced chromosome aberrations in nuclear-dockyard workers.' *Nature, 277,* (Dec. 1979) : 531 -S34.

Researchers demonstrated a significant dose-dependent increase in chromosome aberrations in peripheral blood leukocyte chromosomes in a population of monitored nuclear-dockyard workers, subject to occupational radiation exposure within maximum permissible limits 5 rem per year. The observed increase in dicentric aberrations is not large but is a direct expression of increased genetic damage caused by radiation exposure. It is possible to detect a biological effect at the chromosome level to ionizing radiation below the internationally agreed maximum permissible levels.

31 L.E. Feinendegen, *et al,* 'Biochemical and Cellular Mechanisms of Low-Dose Radiation Effects.' *Internationa Jjournal of Radiation, Biology* 53, no. 1, (1988) : 23-27.

Researchers studied the ability of irradiated cells to repair themselves. Feinendgen states, 'Whereas the majority of single-strand breaks and base changes are very efficiently and quickly repaired with half-times less than 1 hour, the reconstitution of a double-strand break probably lasts much longer, perhaps up to several hours, and not all double-strand breaks are fully repaired.'

32 J. Gentry, *et al,* 'An Epidemiological Study of Congenital Malformations in New York State.' *Amer. Jour. Pub. Health, 49*, no. 4, (4/1959).

Congenital malformation rates were studied in association with high and low background areas in New York State. The areas with the highest background radiation had the highest rates of malformations (1 7.5). For unlikely rural areas the rate was 12.5. There was a relationship between malformation rate and use of water from wells and springs as opposed to large surface areas (lakes and rivers). A doubling of the prevalence of severe mental retardation was found. There was also a sharp increase in the incidence of Down's Syndrome. AEC estimates that background radiation levels associated with igneous rock formations ranged from .07 to .11 Rems/yr.

33 D.T. Goodhead, 'Spatial and Temporal Distribution of Energy.' *Health Physics,* 55, (1988) : 231-240.

Goodhead studied the ability of cells to repair themselves after exposure to radiation. He suggests that the repair system may need a 'kick' to get started. He states: '...it is conceivable that the cell would repair relatively more efficiently if there were more damage to stimulate its repair process.'

34 A.J. Grosovsky, and J. Little, 'Evidence for linear response for the induction of mutations in the human cells by X-ray exposures below 10 rads.' *Proc. Natl. Acad. Sci., USA,* Genetics 82, (April 1985) 2092-2095.

The induction of thioguanine resistance was studied in continuous human lymphoblast cultures exposed to daily X-ray exposures of 1, 2.5, 5 or 10 rads for periods up to one month. The effects of small daily fractions were additive suggesting that doses as small as 1 rad are mutagenic in human lymphoblasts. A liner increase in mutation frequency was observed over this dose range with no apparent threshold. Results suggest that for human lymphoblasts, the mutagenic risk of low dose of X-rays can be accurately estimated by linear extrapolation from high dose effects.

35 M. Otake, and W. Schull, 'In utero exposure to A-bomb radiation and mental retardation; an assessment.' *British Jour. Radiol.,* 5 7, (May 1984) : 409414.

Otake and Schull studied the incidence of mental retardation in Japanese A-bomb survivors. They found that the 8th through the 15th week of gestation was especially significant. Implication that 1 rad absorbed by the fetus during this period may double the rate of mental retardation.

36 A. Upton, "Prevention of Work-Related Injuries and Disease: Lessons from Experience with Ionizing Radiation." *Amer. Jour. Indust. Med.,* (1987) : 300-301.

Upton analyzed the effects of ionizing radiation and the incidence of breast cancer in women from different sources, i.e., A-bomb radiation, therapeutic irradiation for postpartum mastitis, multiple fluoroscopic examinations, and exposure occupationally to external gamma radiation in the painting of luminous clock and dials. Upton states that "The similarity of the dose-incidence relationships in all four groups of women, in spite of marked differences .... in the duration of exposure, implies that the carcinogenic effect of a small dose on the breast is largely irreparable and that the effect of successive doses are additive.' He states '....there may be no threshold in the dose-incident relationship.'

37 C. Waldren, *et al,* "Measurements of low-levels of X-ray mutagenesis in relation to human disease." *Genetics, 83* : 4839-4843.

Waldren and coworkers studied the direct measurement of the effects of low doses of radiation and other mutagens. Extrapolation procedures were not used to estimate effects. The data demonstrate 'that the true mutagenesis efficiency at low doses of ionizing radiation that approximate human exposures is more than 200 times greater than those obtained with conventional methods.' With increasing dose, a point reached, where the mutational effect can not be detected in the chromosomes because the cell is killed off. Unequivocal mutagenesis took place for dose as low as 2.4 rads. Waldren states that 'observed mutational efficiency at low doses is considerably higher than that observed at higher doses.'

A

activity - The number of atoms of a radioactive substance that disintegrate per unit of time.

air Inversion - A condition in which a dense substance lies over a less dense substance. In an atmospheric temperature inversion, the air temperature increases and therefore the density decreases with height. Such inversions occur locally in very still air and tend to be stable because rising air, warmed at the surface, loses its buoyancy and is trapped when it meets air at the same temperature and density as itself so tending to reinforce the inversion. Pollutants entering the air close to the ground level are similarly trapped, and so temperature inversions are sometimes associated with severe pollution incidents.

alpha particle - A positively charged particle emitted by certain radioactive material consisting of two neutrons and two protons. A dangerous carcinogen when inhaled or ingested.

atom - The smallest unit of an element, consisting of a dense central, positively charged nucleus surrounded by a system of electrons. The structure is usually electrically neutral and is indivisible by chemical reactions.

atomic nucleus - The core of an atom, composed of protons and neutrons.

atomic waste - Radioactive solids, gases and contaminated liquids produced by nuclear reactions. Generally classed as high, intermediate, or low-level waste, dependent on curie per liter count.

B

background radiation - Ambient radiation from outer space [cosmic] and materials found at the surface of the earth.

beta - A type of radiation

beta-emitter - A radioactive element characterized by its beta radiation.

beta particle - A high energy electron emitted by decay in a radioactive nucleus. Can cause skin burns and, when ingested, cancer.

C

carcinogen - A cancer causing substance or agent.

chromosomal strands -

curies - (radiation units). Units of measurement used to express the activity of a radionuclide and the dose of ionizing radiation.

D

decay - Gradual disintegration of radioactive material over time.

DNA - (deoxyribonnucleic acid). The genetic material of most living organisms which is a major constituent of the chromosomes within the cell nucleus and plays a central role in the determination of hereditary characteristics.

dose - The amount of energy absorbed in a unit mass, organ, or individual from irradiation.

Down's Syndrome - A congenital condition characterized by mental deficiency and related to the tripling of certain human chromosomes.

E

effluent - Liquid or gaseous radioactive discharge from a nuclear reactor.

effluent pathway - the pathway that radioactive waste travels after it is emitted from a nuclear reactor.

electron - A negatively charged atomic particle, lighter than a proton or neutron.

epidemiology - A branch of medical science that deals with the incidence, distribution and control of disease in a population.

etiology - All of the causes of a disease or abnormal condition.

exposure - Being exposed to radiation.

F

fission - The splitting of a nucleus into two lighter fragments, accompanied by the release of energy and generally one or more neutrons. Fission can occur either spontaneously or as a consequence of absorption of a neutron.

fluoroscope - An instrument used chiefly in industry and medical diagnosis for observing the internal structure of opaque objects (as the living body).

fuel rod - A single tube of cladding filled with uranium fuel pellets.

G

gamma ray - High energy, short wavelength, electromagnetic radiation emitted by a nucleus.

H

half-life - The time it takes for half of any radioactive substance to disintegrate. Half-lives range from seconds to millions of years.

I

ion - An atom, molecule, or elementary particle that has lost or gained one or more electrons, therefore taking on an electrical charge. **A** positive ion has lost one or more electrons; a negative ion has gained one or more electrons.

ionization - The process of adding or removing electrons so as to form ions. Ionization can be caused by high temperatures, electrical discharges, or nuclear radiation.

ionizing radiation - Alpha, beta, or gamma radiation, which, when passing through matter can ionize it. Ionizing radiation can cause cell damage as it passes through tissue.

irradiated - Having been exposed to or treated with radiation.

isotope - A radioactive variant of **a** common element with a different atomic weight but equivalent atomic number. Isotopes are generally created by the fission process.

L

latent period - The amount of elapsed time between exposure and the first sign of disease symptoms.

low-level - Refers to radioactivity of low intensity.

M

Micro-dosimetry - Dosimetry involving micro-doses of radiation or minute amounts of radioactive materials.

millirem [mr] - One thousandth of a rem.

molecule - A group of atoms held together by chemical forces.

mongolism - See Down's Syndrome. **A** sudden variation; offspring differing from its parents in one or more heritable characteristics

mutation - changes within the chromosome or the gene.

N

neutrino - A subatomic particle of negligible mass, named by Enrico Fermi.

neutron An uncharged particle in the nucleus of every atom heavier than hydrogen. A free neutron is unstable. with a half life of 13 minutes, it will decay into a proton, electron and a neutrino.

nondisjunction - Failure of two chromosomes to separate subsequent to meta phase in meiosis or mitosis so that one daughter cell has both/and the other, neither of the chromosomes.

nuclide - Any atom that exists for a measurable length of time. A nuclide can be identified by its atomic weight, atomic number, and energy state.

O

oocyte - An egg before maturation: a female gametocyte.

organically bound - Held in chemical or physical combination.

P

photon - A 'packet' of energy with no mass, which travels at the speed of light. Photons range from very low energies [such as infrared and visible light], moderate energies [ultraviolet and X-rays] to high energy [gamma].

pressurized water reactor (PWR) - A reactor in which the heat from the nuclear core is transferred to a heat exchanger under constant pressure to achieve a high water temperature without boiling. A secondary circuit produces steam for the generators.

proton - A elementary particle with a single positive charge that is a part of all nuclei.

R

Rad - A measure of exposure to, or the absorbed dose of radiation.

rad waste - radioactive waste.

radiation - The emission of neutrons, alpha particles, beta or gamma rays from a radioactive source.

rem - The unit measuring an absorbed dose of ionizing radiation in biological matter; abbreviated from 'Roentgen Equivalent, Man.'

S

soft x-rays - (soft radiation) Ionizing radiation of low penetrating power, usually used in reference to x-rays of long wavelength.

T

teratrogenic (teratogen) **-** Any environmental factor that acts on a fetus to cause congenital abnormality.

transmutational - The transformation of one element into another by bombardment of a nucleus with particles. For example, plutonium is obtained by the neutron bombardment of uranium.

tritium - A radioactive nuclear by-product, also known as H3, consisting of a hydrogen nucleus, or proton, with two additional neutrons.