WARNING:

UNCONTROLLED RADIOACTIVE RELEASES

BURIED BELOW IS A TANGLE OF CORRODED PIPES UNINSPECTED FOR DECADES NOW LEAKING RADIOACTIVE WATER

A Beyond Nuclear Report

BEYOND NUCLEAR

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Beyond Nuclear aims to educate and activate the public about the connections between nuclear power and nuclear weapons and the need to abandon both to safeguard our future. March 2015

TABLE OF CONTENTS

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LEAK FIRST, FIX LATER

Uncontrolled and Unmonitored Radioactive Releases from Nuclear Power Plants

A Beyond Nuclear Report
By Paul Gunter, Director, Reactor Oversight Project
Revised Edition: March 2015

INTRODUCTION

"Leak First, Fix Later" was first published in April 2010. Now nearly five years later, Beyond Nuclear takes another look at the problem of aging and deteriorating piping systems carrying radioactive liquids that still run under every nuclear power plant.

Nuclear power plants have an extensive network of piping systems dozens of which transport liquids that contain radioactive isotopes including tritium -- a radioactive form of hydrogen -- and long-lived strontium-90. These piping systems are not adequately inspected or maintained due to their inaccessibility.

U.S. reactors continue to experience leaks and spills of radioactive material into groundwater the unmonitored pathways from unknown and unanticipated sources.

The United States Nuclear Regulatory Commission (NRC) is the federal regulator charged by Congress with the oversight and enforcement of regulations governing these nuclear power plants.

The NRC defines "buried" pipe as a piping system that is in contact with soil. It defines "underground" pipe as a piping system that is contained within a vault underground. Both buried and underground piping systems at U.S. nuclear plants experience radioactive leaks that contaminate groundwater resources.

To date, the nuclear industry and the federal regulator have failed to focus action plans on how to prevent these leaks from occurring in segmented underground piping systems. Instead, despite broad uncertainties, the federal regulator and industry are using predictive and probabilistic models to estimate the remaining service life on uninspected and unmaintained pipes before leaks may be expected to occur. As late as June 2015, according to the Institute for Nuclear Power Operations (INPO), the industry's center for compiling operating experience and internal reporting confirmed that uncontrolled radioactive leaks continue to spring from unknown and unanticipated sources along largely still uninspected and unmaintained piping systems.[1]

Water is necessary to sustain all life. Water is a natural cycle of vapor, liquid and solid. New water is not created; it is recycled. This continuous cycle takes each water molecule through the processes of evaporation, condensation, precipitation and collection. Clouds, rain, snow, ice, fog and water vapor all converge into the collection of surface water in streams, rivers, lakes, and oceans, as well as within the movement of groundwater in deep and shallow aquifers to begin the cycle anew. Today's groundwater is tomorrow's drinking water. It is a vital resource for sustaining habitats, food and agriculture and recreation.

However, long-lived manmade radioactive toxins are being deliberately and accidentally released from nuclear power plants and are incrementally poisoning this natural water cycle.

In the course of normal operations, nuclear power plants both continuously emit -- and routinely batch-release -- radioactivity into the water and the air. While reactor operators are required annually to provide the NRC and the public with their calculations tallying radioactive releases,[2] these "controlled" releases of radioactivity are reason for concern for the public's health and safety.[3] In addition, a growing number of uncontrolled and unmonitored releases are occurring. These leaks and spills are attracting increasing attention from states and the public. The potential harmful impacts of radiation exposure caused by nuclear industry practices plus the inadequacy of federal government oversight and enforcement are of mounting concern.

A significant portion of the uncontrolled releases from nuclear power plants is in the form of the radioactive isotope of hydrogen called tritium.[4] Tritium also serves as a marker for many other radionuclides that escape into the environment.

As early as 1979, the NRC publicly identified the need for the nuclear industry to begin a proactive program of inspections and maintenance for the "Prevention of Unplanned Releases of Radioactivity" from reactors.[5] Now, more than three decades later, the call for preventive action remains totally ignored by both the nuclear industry and its regulator. The only apparent gain is that leaks are being reported. But the nuclear industry is self-reporting these repeated uncontrolled radioactive leaks to groundwater under an industry-led "voluntary initiative" program. In our view, voluntary reporting is not an effective or acceptable substitute for a comprehensive regulatory program aimed at protecting water resources. In June 2014, the NRC continued to indicate to the nuclear industry that the agency would continue to "Gather tritium and leak data" while "Seeking to understand [industry's] commitment to minimize leaks."[6]

Now, five years after our initial 2010 report, Beyond Nuclear has determined that the NRC has failed to mandate any corrective action programs that focus on inspection and maintenance programs aimed at groundwater protection by preventing ongoing radioactive leaks and contamination of water resources.

BURIED AND UNDERGROUND PIPES

Depending on the specific location of a nuclear power plant relative to its reactor cooling water source – a lake, river or ocean – the reactor site may have anywhere from two to 20 miles of buried and underground pipes intertwined beneath the power plant property. There are dozens of separate buried pipe systems carrying radioactive water under buildings and parking lots and penetrating building foundation walls below grade. These buried pipes connect reactor systems, including the steam supply for generating electricity, the emergency control and recovery following abnormal reactor events, and radioactive waste treatment and storage. Buried pipes can range in diameter from several inches to 16-foot-diameter re-circulating water lines.[7]

Radioactive plumes have migrated off site into groundwater and surface water resources, impacting neighboring properties.

According to the NRC, there are more buried and underground piping systems at Pressurized Water Reactors (PWR) than at Boiling Water Reactors (BWR) that can contain licensed radioactive materials.[8] A BWR will typically have 27 buried and underground systems that carry licensed radioactive material through more than 150 segments of pipe. A PWR will typically have 36 buried and underground systems that carry licensed radioactive material through as many as 306 segments (See Appendix B.)

This "*spaghetti bowl*" of pipes is fabricated of a variety of materials from fiberglass to corrosion-susceptible materials like coated carbon steel and aluminum to more corrosion-resistant stainless steel. Because the pipes at today's reactors are aging and corroding simultaneously on both exterior and interior surfaces, many are experiencing hidden, uncontrolled, unpredictable and unmonitored leaks of radioactive water that are contaminating underground water resources. Earthquakes have also caused buried pipes to leak. Leaking pipes have caused accidental radioactive releases both on and off nuclear power plant property.

These radioactive leaks have ranged from a few cupfuls to millions of gallons. In some cases, the radioactive water is pooling and accumulating in water tables deep below nuclear power plants and beyond. Underground radioactive plumes have migrated off site into groundwater and surface water resources, impacting natural resources as well as neighboring private and public properties. As more leaks occur at reactor sites, the plant owners are installing more, but a still limited number of, shallow onsite test wells to periodically sample groundwater for radioactive leaks. These test wells are used to extract water samples to determine the amount, type and radioactive count of isotopes that are already escaping and diffusing into the environment.

The nuclear industry readily admits that it is unable to access buried pipe systems for inspection and maintenance. Deteriorating pipes carrying radioactive water go uninspected until a leak percolates to the surface or is observed in periodic samples collected from sparse onsite and offsite test wells. The problem is compounded by the NRC's adoption of the industry's de facto "leak first, fix later" approach. The NRC typically claims that it has not identified any health or safety impacts from groundwater contamination by uncontrolled radioactive releases.

However, there is precedence in the nuclear industry for pro-active preventative upgrades that that can better serve to protect water resources from radioactive leaks. According to Exelon Corporation, the operator of the Oyster Creek nuclear power plant in New Jersey completed a 16-month program at the end of 2010.

Approximately 45 pipes that were previously directly buried or not easily accessible were "moved either above ground, into monitored concrete trenches/vaults, or some alternative protective measure to prevent potential leakage to the environment and insure consistent monitoring of the pipes."[9]

However, the rest of the industry, rather than similarly remediate vulnerable uninspected and unmaintained piping systems, continues to study plans that largely focus on predicting the remaining service life on inaccessible pipes before replacing them with more corrosive resistant materials and/or relocating them above ground for surveillance, inspections and maintenance. For the indefinite interim, industry and the NRC are content to continue with the "leak first, fix later" piecemeal approach to replace sections of pipes as the radioactive leaks percolate to the surface or are detected migrating into onsite test wells.

TRITIUM AND NUCLEAR POWER

In the normal course of operation, a nuclear power plant generates and releases tremendous amounts of heat through the fission process to boil water to generate steam to produce electricity. The fission process generates a wide range of radioactive wastes in the form of gas, particulate, liquid effluent and irradiated materials that emit radiation on a wide range of radioactive energies. In light water reactors, these radioactive products build up in the reactor coolant that courses through the reactor steam supply system. Radioactive fission by-products such as noble gases are entrained in the reactor coolant. These contaminants spread throughout the entire reactor steam supply system.

Starting with the fissionable enriched uranium in the nuclear fuel assemblies, defects in fuel rod cladding increase the amount and types of radioactive contamination escaping into the coolant water. No reactor is able to completely contain contaminants in its primary cooling system. More defects including tiny pinhole leaks and hairline through-wall cracks allow radioactive contaminants to escape from the reactor coolant system to other systems within the reactor. Even without defects, radioactive gas will permeate throughout reactor systems.

Tritium (^3H) is such a radioactive gas. Tritium is radioactive hydrogen, the smallest and lightest element of the Periodic Table. Tritium is extremely pervasive and easily permeates most kinds of materials including concrete and many grades of steel. Radioactive tritium readily diffuses through the steel alloy that constitutes the reactor's fuel rod cladding. In Pressurized Water Reactors, tritium is generated by the neutron activation of boron and lithium in the reactor coolant. Tritium readily diffuses through a reactor's fuel rod cladding and steam generator tubes into the cooling water. In Boiling Water Reactors, tritium is generated primarily through the neutron activation of the "burnable poisons" that are used to control fuel reactivity and by a process called "ternary fission" or the result of three fission fragments. With the exception of releases of noble gases, tritium is largest of the radionuclide emissions from the routine operation of nuclear power plants.

Tritium reduction in nuclear power plants has not been historically pursued by the industry primarily because of the difficulty, the cost and an industry-championed assumption that tritium can be diluted to inconsequential low-dose radiation exposure. In fact, chronic exposure to tritium releases is a universal health risk from every nuclear plant.[10]

Tritium has a half-life of 12.3 years, meaning that it can present risks as a biological hazard for at least 120 years (roughly ten half-lives). It is generated in nature by the interaction of cosmic radiation passing through the atmosphere. Naturally occurring tritium exists as part of background radiation and is ubiquitously found in water at very low levels (5 to 25 picocuries[11] per liter).[12]

However, tritium is also generated at much higher levels during the production of electricity by nuclear power plants as well as in the production and detonation of nuclear weapons. Tritium in its radioactive gas form (HT) is routinely vented from operating nuclear power stations as well as permeating through steel and concrete containment structures to escape into the atmosphere. Its liquid form, tritiated water (HTO), is chemically and physically identical to water in all its states including ice, rain, fog, and vapor. It can be commonly described as radioactive water. Tritium is routinely diluted and deliberately discharged by industry into adjacent surface water in rivers, reservoirs, lakes and the ocean.

While it is true that tritium is a low energy beta particle emitter, it is often mischaracterized by industry as a "weak" beta-emitting radioactive particle; disingenuously inferring that exposure is harmless. More accurately, tritium is a "low range" beta emitter. This is because, as ionizing radiation, gamma rays sparsely distribute their energy over a very long "track" before depositing damaging amounts of energy ultimately at their track end. Tritium disintegrations have only "track ends" delivering more energy per disintegration.

Once escaped, tritium is considered to be the most highly effective distributor of radioactivity in the environment because it is highly mobile, going anywhere the hydrogen molecule can go. Tritium is by far the largest volumetric routine radioactive release from nuclear power plants. A typical 1,000 megawatt electric (MWe) Pressurized Water Reactor will release nearly 800 curies of tritium per year, 85% of which is diluted and discharged as tritiated water. A typical 1,000 MWe Boiling Water Reactor will release 120 curies of tritium per year with 75% being released as a radioactive gas to the atmosphere and the remaining 25% in water.[13]

Tritium is a beta emitter with a specific activity of 9,800 curies per gram of the pure isotope.[14] Comparatively speaking, the specific activity or rate of decay of toxic radioactive isotopes such as strontium-90 is 140 curies per gram and 88 curies per gram for cesium-137. These two radioactive isotopes are common to atomic bomb fallout and are known to pose significant human health consequences with no known dose thresholds.[15]

Tritium is clinically shown to be more effective at damaging and destroying living cells even than gamma rays.[16] Precisely because isotopic tritium is identical to the hydrogen atom, it is able to incorporate itself at the most intimate biological levels where it effectively delivers its short ranged biologically destructive energy. Tritium rapidly exchanges with hydrogen atoms in nature including within the biological makeup of all organic life.

In the human body, all tissues and cells are composed of about 70% water. About 80% of the atoms are hydrogen atoms, a significant portion of which, with chronic exposure, can effectively be replaced by tritium.[17] Hydrogen is by far the most common element in the makeup of a DNA molecule. Tritium uniquely forms strong bonds with carbon to form organically bound tritium (OBT). Organically bound tritium is retained in the human body for a much longer period of time than tritiated water. Once ingested, inhaled and absorbed, tritium exposure closely follows a cellular distribution in the body. Tritium freely passes across the placental barrier from the mother to the fast growing cells of her fetus. Tritium is passed just as freely later to her infant through the mother's milk.[18] Clinical investigations have demonstrated that once mother and child are exposed, there is no difference between the tritium concentration in fetal tissue and in maternal tissue.[19]

Tritium in the form of tritiated water (HTO) is known to be much more radiotoxic than tritiated hydrogen gas, anywhere from 12,000 to 22,000 times.[20] Tritium is clinically known to cause cancers, mutations and birth defects.[21] According to the U.S. National Academies of Science, in its 7th *Biological Effects of Ionizing Radiation* (BEIR) report, any dose of radiation, no matter how low, still carries a risk.[22] Moreover, BEIR 7 discloses that women, pregnant women, their fetuses and children are more susceptible to the deleterious consequences of radiation exposures. A fetus can collect tritium at twice the concentration ratio in its tissues as compared to the mother, meaning that per mass, the fetus can become twice as contaminated as the adult female at a particularly vulnerable time of development.[23]

Protective standards for tritium, or "permissible" exposures, vary widely and remain embroiled in controversy. A permitted exposure arguably does not mean a safe exposure although it is generally misinterpreted as so. The United States Environmental Protection Agency (EPA) currently sets the federal protective limit for drinking water at 20,000 picocuries of tritium per liter.[24] However, the protective guideline for permissible levels of tritium in drinking water for the state of Colorado is now limited to 500 picocuries per liter and 400 picocuries per liter in California.[25] A Canadian government drinking water advisory council concluded in its 2009 report that "the requirements for an appropriate level of risk and public safety" from the permitted level of tritium discharged from Canadian nuclear power stations needed to be lowered to 540 picocuries per liter (20 Becquerel per liter) of drinking water.[26] The scientific trend strongly suggests that the current federal protective standard for tritium in drinking water is antiquated and the dated current federal standard for "*permissible*" releases from nuclear power stations needs to be dramatically reduced.

TRITIUM EXPOSURES TRIVIALIZED BY THE NUCLEAR INDUSTRY

While both NRC and the nuclear power industry admit that tritium exposure "health risks include increased occurrences of cancer and genetic abnormalities in future generations," they continue to trivialize how significant a health risk there is to neighboring populations from chronic tritium exposure and from ground- and surface water contamination.[27] The potential health risks and impacts are generally characterized as remote. The NRC has provided its evaluation of the health and safety significance of several "abnormal releases" of tritium from nuclear power plants in its U.S. NRC Fact Sheet, "Tritium, Radiation Protection Limits, and Drinking Water Standards."[28] The NRC writes that "Tritium is a weak form of radiation. The radiation emitted from tritium is a low-energy beta particle that is similar to an electron. Moreover, the tritium beta particle does not travel very far in the air and cannot penetrate the skin."[29]

All true, but the agency fails to mention how tritium once absorbed internally can effectively deliver damage to vulnerable biological targets including a fetus and the human DNA. The NRC fact sheet continues, "Once tritium enters the body, it disperses quickly and is uniformly distributed throughout the soft tissues. Half of the tritium [*biological half life*] is excreted within approximately 10 days after exposure."[30]

This is a disingenuously incomplete description of how tritium is biologically taken up by plants, animals and humans from radioactive releases. For its public audience, the agency leaves out the more critical description of how tritium releases will bond with organic molecules or "organically bound tritium (OBT)" and, as is generally accepted, will then have a biological half-life of between 21 and 76 days. Chronic environmental exposures increase the deleterious risks from the fixed binding of tritium to the carbon atom of DNA which is clinically documented with an even longer biological half-life of 280 to 550 days.[31] Further study finds that organically bound tritium can stay in the body for up to 10 years.[32]

Both NRC and industry further downplay tritium exposure by comparing it as significantly less of an exposure risk than medically accepted procedures like CT scans, dental x-rays, or natural radioactivity ingestion of radioactive potassium in bananas or Brazil nuts or even the temporary external exposures to cosmic radiation from a round trip airplane flight from New York to Los

Angeles.[33] All of these descriptions conveniently leave off the one critical and unique characteristic of radioactive hydrogen which can incorporate and cause damage at the most intimate levels of biology by replacing the most ubiquitous element in the human body, hydrogen.

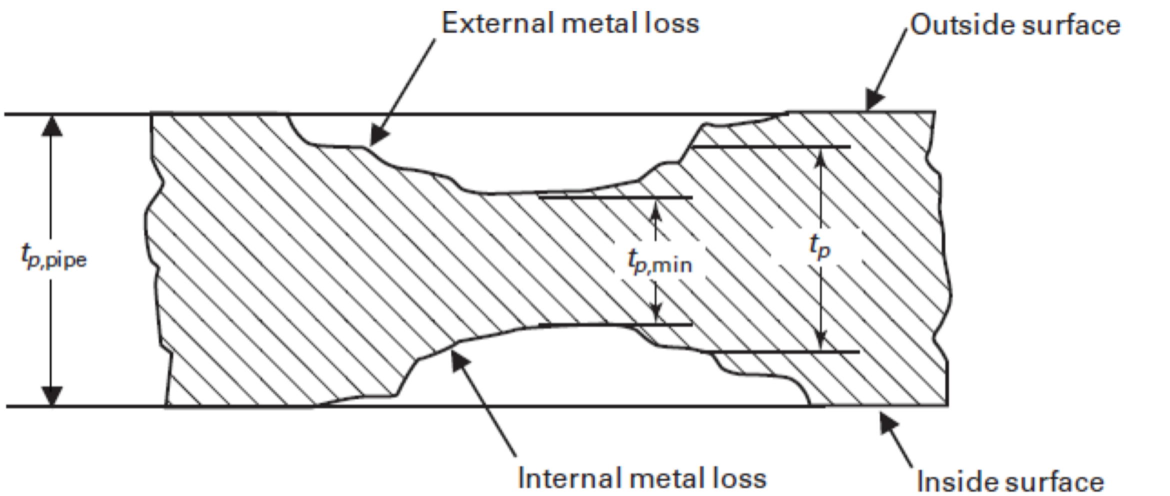
Scientific investigations into just how biologically damaging tritium exposures are continue to carry many uncertainties that warrant enforcement of a "precautionary principle" to limit exposures to the more vulnerable populations. Particularly revealing is how the 20,000 picocuries per liter "safe" drinking water standard was developed by the U.S. Environmental Protection Agency. According to Oak Ridge National Laboratories scientist, David Kocher, the current EPA standard was never based on any health studies, but rather on what the nuclear industry and regulators thought was affordable and where compliance was considered easy. Despite such broad health impact uncertainties, industry advocates continue to trivialize potential health and genetic impacts to more vulnerable populations like fetuses in pregnant woman and children. As Kocher told *Scientific American* in February 2014, "The good news about tritium is that: even if you inhale or ingest an awful lot, it is going to flush out of your body." He adds: "Just have a few beers and you're done."[34]

However, a recent review of more than 60 studies shows that childhood leukemia has increased by 37% within 5 kilometers (approximately 3 miles) of almost all nuclear power facilities in the United Kingdom, France, Germany and Switzerland.[35] One scientific hypothesis is that tritium in batch releases is partially responsible.[36]

RADIOACTIVE RELEASES WILL INCREASE AS UNINSPECTED SUSCEPTIBLE PIPES FAIL

Postings to the NRC website's "Event Notification Reports" readily reveal that there is no reliable trend that the number of unintended and uncontrolled radioactive releases to groundwater and surface water are increasing.[37] In part, this is because, since 2006, following numerous disclosures of previously unreported spills and leaks, the nuclear industry is now voluntarily reporting such accidents. However, without question, the numbers indicate that the location and timing of radioactive leaks cannot be predicted and continue to occur from aging, unmaintained and deteriorating buried and underground piping systems that carry radioactive effluent.

The nuclear industry admits that its primary challenge remains that making now inaccessible buried pipes and tanks accessible would incurr unwanted costs. Uninspected and unmaintained systems are consequently allowed to deteriorate. The pipes are made of materials with a range of durability – from very corrosion-susceptible aluminum and coated carbon steel to more corrosion-resistant stainless steel. The pipes deteriorate and fail by attack from within and without the pipe system – from corrosion and erosion.



There are no reliable tools for predicting the combined corrosion attacks on both the inside and outside walls of buried pipe. [Source: EPRI presentation to US NRC, 09/25/2014]

Seismic activity has also caused pipes at nuclear power plants to fail. Additionally, pipe coatings are damaged during installation during the backfill of pipe trenching by rocks and activity that exposes the base metal to accelerated corrosive conditions. "Holidays" or bare metal gaps in the original application of protective coatings during the pipe fabrication process leave installed pipes vulnerable later to accelerated corrosion and failure.

Many more different variables are known to influence how and when pipes carrying radioactive water can deteriorate and fail. Well-known variables include how wet and acidic the soil is in which the pipe is buried. Other less understood variables introduce more uncertainties. Tritiated water and tritium flowing within piping systems are known to accelerate corrosion by permeating coatings and attacking the molecular bonds in metals.[38] In fact, "The damaging action of tritiated water and tritium on the corrosion resistance of stainless steel is a very real problem," is one critical finding in the published study by G. Bellanger, "Corrosion Induced by Low-Energy Radionuclides: Modeling of Tritium and Its Radiolytic and Decay Products formed in Nuclear Installations."[39] As the study points out, tritium-induced damage can be severe and lead to pipe failure and radioactive releases.

As recent as September 25, 2014, the Electric Power Research Institute (EPRI) identified that there are no reliable tools for accurately predicting pipe corrosion. Corrosion rates cannot be reliably correlated with soil conditions and electro-chemical conditions. The combined attack of corrosion and erosion rates on buried pipe wall thickness from the internal fluid side and the external soil side surfaces cannot be predicted from an arithmetic sum. As a result, uninspected, unmaintained and aging buried piping systems at nuclear power plants continue to experience unanticipated and unpredicted radioactive leaks into groundwater.[40]

All of these uncertainties, shortcomings and the increase in radioactive leaks underscore the need for more proactive preventive measures for the protection of groundwater from the nuclear waste generated and flowing through nuclear power plants. The lack of nuclear industry and regulatory action will continue to lead to an increasing number of accidents once hidden from state authorities and the affected public but now voluntarily reported with immunity from federal enforcement actions.

A number of specific high profile events at reactors illustrate a recurring and growing problem and the unacceptable approach by NRC and industry.

BRAIDWOOD (IL) NUCLEAR GENERATING STATION

The Braidwood nuclear power station is located in Braceville, Illinois, approximately 20 miles from Joliet, Illinois.[41] It is operated by a limited liability corporation of Exelon Nuclear Corporation which is headquartered in Chicago, Illinois. Exelon operates 17 reactor units in the U.S. Braidwood is a two-unit Westinghouse Pressurized Water Reactor. Among the class of light water reactors, the PWR is the largest generator of tritiated liquid releases to the environment.

Radioactive leaks coming from Braidwood into the public right of way were suspected and documented as early as November 2000 when radioactive tritium and cobalt-60 were discovered in ditchwater running along the easement between Exelon's property and Smiley Road in the township of Godley Park District, Illinois.[42] The discovery prompted Godley town officials to press for an investigation that would eventually unravel a series of unreported tritium leaks from Braidwood nuclear station starting as early as 1996. Exelon finally disclosed the leaks in a December 2, 2005 press release and report to the NRC.[43]

What Exelon initially reported as “concentrations of tritium close to an underground pipe inside the plant’s northern boundary” was later revealed to be 22 unreported radioactive leaks from 1996 to 2000 occurring along a four and-a-half mile-long pipe running from the nuclear station to a dilution discharge point on the Kankakee River. Two of these radioactive spills of tritium-contaminated water were three million gallons each. Radioactively contaminated water flowed off site into the public right of way into ditches across roads and onto private property where ponds and shallow drinking water wells were contaminated. Millions of gallons of tritium-laced water pooled on company property and was quietly allowed to saturate into the groundwater table where it migrated out of sight offsite for years.

By December 6, 2005, Exelon’s story would change to "initial evaluation indicated that the tritium in the groundwater was a result of past leakage from a pipe which carries normally non-radioactive circulating water discharge to the Kankakee River, about five miles from the site. Several millions [sic] gallons of water leaked from the discharge pipe in 1998 and 2000. The pipe is also used for planned liquid radioactive effluent releases with the effluent mixing with the circulating water being discharged.”[44]

The failing pipe system in the Braidwood case was the Circulating Water Blow Down line. The nearly five-mile long pipe system connects the nuclear power plant and its cooling water reservoir to the Kankakee River. Exelon states “The primary function of the Circulating Water Blowdown System is to provide for lake turn over to prevent undesirable chemical buildup in the lake. The secondary function of the Circ Blowdown System is to provide dilution for liquid rad [radioactive] waste releases.”[45] Exelon states that they maintain water in the pipe to approximately 1,000,000 picocuries per liter.[46] The radioactive contaminated water is calculated to be below the 20,000 picocuries per liter permissible discharge limit once diluted in the Kankakee River.

In this case, the failure mechanism was not corrosion of the pipe itself. In order for the contaminated discharge water to flow freely through the blowdown line from the reactor site to the river, Exelon installed a series of eleven vacuum breaker valves along the pipeline. The vacuum breaker valves were not properly monitored and maintained and several valves cycled to failure, releasing fountains of concentrated tritiated water to the surface.

In 1996, Vacuum Breaker Valve-1 failed and leaked 250,000 gallons of radioactive water to the surface with the only documented response being to fix the valve but with no clean-up effort of the spill, thereby allowing the contamination to soak into the water table.[47]

In 1998, Vacuum Breaker Valve-3 failed, spilling approximately three million gallons of tritiated water to the surface. Once again, the only effort was to fix the valve with no documentation of a radioactive analysis being performed by Braidwood operators. In 2000, Vacuum Breaker Valve-2 failed, spilling approximately three million gallons of radioactive water to the surface. This time a local resident reported the spill to the operator. Braidwood operators took a sample of available surface water and found that tritium was greater than 20,000 picocuries per liter. The water was pumped back into the blowdown line with no further groundwater analysis for tritium.[48]

Exelon's Braidwood disclosures would be the beginning of an industry-wide unraveling of unreported leaks to groundwater.

In February 2006, following the disclosure of the Braidwood leaks, within minutes of a meeting where the county health department strongly recommended that residents stop drinking tap water, Exelon volunteered to purchase bottled drinking water for the approximately 600 residents of Godley, Illinois.[49] Exelon would supply the residents of Godley with bottled water for more than four years.[50] Exelon further provided the town with $11.5 million in funds to build a new municipal water system. In March, 2010, Exelon would further pay out a $1 million settlement with the State of Illinois for the undisclosed leaks at Braidwood and two other Exelon nuclear power plants.[51]

Exelon's Braidwood nuclear power station disclosures would be the beginning of an industry-wide unraveling of unreported leaks to groundwater.[52]

Exelon was able to claim that it has an effective groundwater remediation program in place at Braidwood by purchasing neighboring private properties to essentially move tritium contaminated land and groundwater to within the company-owned property boundary. One such property, a private horse pond, now owned by Exelon, was converted into a large sump pit to draw down the water table and pump the contaminated water into a series of storage tanks.[53] Ironically, the collection of tritium contaminated water was pumped back into the blowdown pipe for discharge into the Kankakee River.

The extent of Braidwood's uncontrolled radioactive releases and contamination in terms of both reach and depth into the surrounding water table may never be fully known. Spills along the radioactive waste discharge pipeline going down to the river have resulted in contamination of groundwater under the Braidwood Dunes and Savannah Nature Preserve two miles away where test wells indicated tritium concentrations ranging from 2,700 to 25,000 picocuries per liter.[54]

Many more residential property owners near the plant who have yet to be remunerated remain concerned about property values and health issues.

While uncontrolled leaks from Braidwood remain a potential public health concern and regulatory non-compliance issue, the routine "controlled" radioactive releases from the nuclear power plant should be raising more questions for downstream communities taking in their drinking water from the Kankakee River. In 2013 alone, the operator of the two Braidwood reactors deliberately discharged an estimated 4,500 curies of radioactive tritium into the Kankakee River.[55] The city of Wilmington, Illinois is two and-a-half miles downstream from the Braidwood radioactive waste discharge pipe. The 2008 Wilmington Annual Drinking Water Quality Report recorded tritium concentration levels as high as 1,850 picocuries per liter in grab samples at the city drinking water treatment facility's Kankakee River intake source.[56] While the recorded tritium concentrations remain well below the EPA permitted limit of 20,000 picocuries per liter, the samples indicate tritium in the city drinking water to be more than four times the State of California Public Health Standards for Drinking Water Goals and more than three times the safe drinking water goals for the state of Colorado.

OYSTER CREEK (NJ) NUCLEAR GENERATING STATION

The Oyster Creek nuclear plant is located in Forked River, New Jersey, on the Barnegat Bay and the Atlantic Ocean. It is operated by a limited liability corporation of Exelon Nuclear which is headquartered in Chicago, Illinois. It was the first of General Electric's Mark I Boiling Water Reactors to go critical in the U.S., beginning operation in 1969, and is the oldest currently operating nuclear power plant in the country. There are 22 GE Mark I reactors operating in the United States following the December 2014 closure of Vermont Yankee, all similar to the three Fukushima Daiichi reactors that melted down in Japan in March 2011. Among the light water reactor class, the Boiling Water Reactor is the largest generator of tritium gaseous releases that are not only deliberately vented to the air but permeate and seep unmonitored from reactor structures. Tritium generated in Boiling Water Reactors also chemically replaces hydrogen in the reactors' steam and water effluent.

Radioactive release pathways are open to both water and air. Over its operational history, Oyster Creek has released significant amounts of radiation to the air through its 300-ft vent stack towering over the reactor building. During its first years of operation between 1970 and 1993, Oyster Creek released approximately 5.5 million curies of radioactive gas and particulate through its vent stack.[57] More than 1 million curies of radioactive fission products were released to the atmosphere in 1979 alone following a May 3, 1979 loss of coolant accident that likely uncovered the reactor core just weeks after the more publicized Three Mile Island Unit 2 accident on March 28, 1979.[58] Given the high mobility of tritium and incorporation into water and water vapor, much of this radioactivity fell back to the ground as radioactive precipitation. While intentional gaseous releases from Oyster Creek have declined they remain significant. Future tritium and other radioactive isotopic releases depend on the condition of reactor barriers beginning with reactor fuel cladding, all of which can and have failed, resulting in higher routine releases and accidental radioactive releases to the environment.

As an example, on July 26, 2000 Oyster Creek experienced a multiple failed fuel pin accident.[59] Fuel pins, otherwise known as fuel rods, are bundled into fuel assemblies which make up the reactor core. The fuel pin cladding wall is credited as the first line of radiation dose reduction to the public from both gaseous and liquid radioactive effluents. As expected, Oyster Creek's damaged reactor fuel bundles caused an increase in radioactive effluent to be released from the reactor to the environment including radioactive noble gases, radioactive iodine and other radioactive particulate. In total, 182 curies of radioactive gas and particulate were reported released into the atmosphere during the third and fourth quarter of 2000 following this fuel damage event.[60] These releases constitute an ongoing, added and cumulative radioactive burden to the environment and biology.

Given the industry history of unreported and uncontrolled radioactive liquid releases to water, Oyster Creek is offered as an example of the need to investigate the unmonitored pathways for unreported radioactive gaseous releases as they constitute an additional risk to the biology by inhalation and by ingestion and absorption through water.

Oyster Creek plays a dominant role in focusing much needed attention on the disturbing lack of oversight, evaluation and management of deteriorating buried piping systems that carry radioactive waste in context of the Nuclear Regulatory Commission's 20-year license extension age management and environmental review process.

Oyster Creek had just completed a nearly four-year highly contested relicensing process when on April 15, 2009, seven days after receiving its 20-year license extension from the NRC, Exelon Nuclear announced the discovery of a leak involving thousands of gallons of water contaminated with radioactive tritium into a partially buried electrical cable vault room on the reactor site.[61] According to an NRC communication, the water was initially sampled and tritium was measured by the utility in concentrations as high as 102,000 picocuries per liter.[62] Approximately 3,000 gallons of radioactive water was pumped out into 55-gallon drums. However, the cable vault room had already leaked radioactive water into the surrounding water table estimated by the company at closer to 200,000 gallons.

Oyster Creek nuclear generating station is surrounded by a reactor cooling water canal system that takes in water from the Forked River and discharges it into Oyster Creek and Barnegat Bay.

Exelon offered a "summary" of its analysis in an opinion piece published in the local newspaper as its best effort at being forthcoming about the radioactive leaks from the reactor.

In an effort to discover the source of the leak, Exelon did further onsite monitoring well testing in late April and found that tritium in the onsite groundwater gathered from several of the onsite monitoring wells jumped to concentrations of 4.46 million, 5 million and 6 million picocuries per liter .[63] After excavating a series of onsite trenches, Exelon determined that two buried carbon steel pipes (8" and 10" in diameter) had corroded through-wall holes in the pipe walls of the Condensate Storage System. The radioactive underground plume then migrated into the nuclear power plant's intake and discharge cooling water canal which flows into the Bay.

Both the NRC and Exelon assured the public that once the radioactive groundwater plume was diluted into the discharge canal flow of billions of gallons of water per day into the bay, it raised no public health, safety or environmental concerns. Still, by June 12, 2009, a bottle sample that was taken by the company 25 feet from the southern bank of Oyster Creek's cooling intake canal (which draws 1.7 billion gallons of water into the plant each day) was analyzed and still found to be tritium "positive" at 16,600 picocuries per liter.[64]

Exelon initially announced that the company would withhold its original documentation on the root cause of the leaks, citing that the details were business proprietary.[65] Exelon instead offered a "summary" of its analysis in an opinion piece published in the local newspaper as its best effort at being forthcoming about the radioactive leaks from the reactor. [66] The company's locally published opinion piece attributed the leaks to improperly applied corrosion resistant pipe coatings during the 1990s and an "erroneous assumption" provided to the NRC in work completion orders. Exelon excavated and replaced the damaged sections of both pipes with 30-foot sections of corrosive-resistant stainless steel piping in what is typically an industry piecemeal approach that avoids more costly but proactive replacement of entire piping systems.

A subsequent Freedom of Information Request filed by Beyond Nuclear to the NRC disclosed the company's Root Cause Evaluation that revealed much more about the history of the April 15, 2009 leaks. The analysis confirmed that the 8-inch and 10-inch diameter carbon steel pipes were part of the Condensate Storage System and degraded by corrosion. The 8-inch line that had been "incorrectly identified" as a stainless steel pipe in the work order closure was found to be corrosive-susceptible carbon steel.[67] The NRC took no action to determine the nature of the false work order or what other Exelon work orders might be falsely completed.

The subsequent leaks resulted from a combination of mismanagement, a loss of design control, as well as misapplied and absence of protective coating on the piping. Between 1991 and 2009, Oyster Creek had several changes of ownership and management that affected how the reactor's buried pipes were to be managed including moving the pipes above ground, moving piping into concrete trenches and replacing piping with more corrosive-resistant materials in response to several previous leaks.[68] "However, most were not implemented."[69]

Most revealingly, the root cause of the leaks was attributed to "management decisions [that] were made in the mid-1990s to allow the station's operating license to expire. Modifications were not implemented, as well as cancelled maintenance and repair activities, should have been re-evaluated as vulnerabilities for long-term piping integrity."[70]

Exelon claimed emphatically that it was "confident no spill and/or discharge occurred".

Exelon further identified that the non-intrusive inspection techniques available to industry (including visual inspection, Ultrasonic Testing and Guided Wave technology) all have limitations stating, "Since 100% verification of pipe integrity is not practical, even these extensive measures leave the site vulnerable to localized corrosion because the methodologies used by the buried pipe program do not, in all instances, locate defects, and cannot assess entire continuous full lengths of pipe."[71]

In March 2009, the NRC issued its investigative report on the Oyster Creek tritium spills into groundwater from buried pipes but required no action to be taken.

Then on August 25, 2009, Exelon discovered a second leak involving tritium-contaminated water leaking from an aluminum condensate transfer pipe located within a penetration through a wall of the turbine hall foundation. The pipe was inaccessible and uninspectable at the penetration of the foundation wall. Radioactive water flowed both into the turbine building interior and outside the building through the penetration sleeve and seeped into the groundwater. The leak was estimated to be about eight to 12 gallons per minute and when sampled by Exelon was determined to contain approximately 10 million picocuries per liter of radioactive tritium. Exelon excavated the buried portion of the aluminum pipe that was outside of the turbine hall and found that the buried portion of the pipe outside was also leaking to the outside of the turbine building. A temporary modification of the condensate storage system made by Exelon allowed the leakage to be stopped on August 26 and by August 29 it had completed the pipe replacement. Again, NRC and the company assured the public that there was no radiation impact to the public.

Even earlier in 2008 in the midst of the license renewal process itself, the state of New Jersey had disclosed that Exelon had an "apparent lack of attention to detail with regard to laboratory protocols and procedures" for sampling and testing for radioactive tritium in water coming from buried pipe.[72] While Exelon emphatically claimed that it was "confident that no spill and/or discharge occurred" the state replied "We do not agree" and further noted that discrepancies in the company's radiation sampling protocol "raised serious concerns regarding your onsite laboratory practices and environmental sampling protocol."[73]

The management, oversight and evaluation of the potential radiological impacts on the environment from these falsely documented and deteriorated pipes and other degraded pipe systems carrying radioactive water completely escaped the 20-year relicensing review process before the Nuclear Regulatory Commission. This raises serious questions and doubts about the thoroughness, adequacy and veracity of the relicensing review process and current operating systems at reactors.

Following the discovery that the Oyster Creek tritium leaks had contaminated the Cohansey Aquifer, a major drinking water resource for Southern New Jersey at 1.05 million pCi/L, 50 times higher than the State standard, the New Jersey Department of Environmental Protection issued a directive to Exelon to participate in an expanded investigation and drill more test wells for groundwater sampling and monitoring.[74] The directive stated that if Exelon did not cooperate, then the State would intervene with public funds for the cleanup and hold Exelon liable for three times the cost.

By October 2010, using the classic "solution to pollution is dilution," Exelon began pumping up the small amounts of contaminated water from the aquifer system to circulate in the reactor's cooling system. This water was then diluted with a flood of cooling water before being released into Barnegat Bay.[75]

However on March 10, 2011, in a public meeting with NRC officials, Exelon announced that the corporation would spend more than $13.3 million and take 16 months to transfer all of Oyster Creek's pipe systems carrying radioactive water into concreted vaults or bring them above ground where they could be monitored for deterioration and maintained in advance of radioactive leaks.[76] With the Oyster Creek pipe retrofit now completed, the precedent has not been applied to any of Exelon's other reactors nor has any other nuclear utility taken up such a replacement initiative.

By 2013, the tritium contamination was still lingering on in the groundwater sampled from Oyster Creek's limited number of onsite test wells.[77] The concern remains where the tritium contamination has moved offsite into the flow of the public drinking water supply.

As the result of separate violations of the Clean Water Act for thermal pollution from Oyster Creek's cooling system discharges into Barnegat Bay, on December 8, 2010, Exelon announced that it had negotiated with the State of New Jersey to close the reactor early on December 31, 2019, 10 years sooner than provided by the NRC in a 20-year license extension.

VERMONT YANKEE (VT) NUCLEAR POWER PLANT

On December 29, 2014, after 42 years of operation and only two years into its 20-year federal license extension, the Vermont Yankee nuclear power plant was permanently shuttered. Entergy Corporation, the power plant's owner, claimed that bad economics was the sole reason for the closure. But contributing factors were the public mistrust of the corporation and ultimately the State of Vermont's refusal to purchase power from the reactor, prompted by a series of mishaps including the January 2010 discovery of radioactive contamination of groundwater from leaking below-grade pipes.

These radioactive leaks continue to impact the quality of the environmental cleanup and the eventual associated costs of site decommissioning. On February 9, 2015, the State of Vermont learned that the radiological monitoring of the groundwater under the now closed nuclear power plant had revealed the presence of radioactive strontium-90, a known cancer-causing radionuclide.[78] The Vermont Department of Public Health concluded that "it is likely that Sr-90 in groundwater and soils at Entergy Vermont Yankee are the result of past leaks and fallout from air releases at the station during its years of operation."[79] While there may be no immediate impacts, the state findings underscore the seriousness of lasting impacts, increasing costs and uncertain consequences of unmitigated radioactive leaks into the environment.

The now-closed Vermont Yankee is a General Electric Mark I Boiling Water Reactor located in Vernon, Vermont, on the banks of the Connecticut River closely bordered with New Hampshire and Massachusetts. Vermont Yankee began operation in 1972.

Vermont Yankee has a history of large radioactive spills. The plant experienced its first such substantial radioactive spill in 1976 when, from July 18 until July 20, 1976, Vermont Yankee operators inadvertently pumped approximately 83,000 gallons of tritium contaminated water through the overflow line of the waste condensate storage tank that overflowed through an open electrical conduit box, flowed into a storm drain and into the Connecticut River. The leak was estimated to be 1.3 times over the regulatory limit for tritium discharge into the environment.[80]

Television and radio stations as well as newspapers warned neighboring and downstream communities in Vermont, New Hampshire and Massachusetts not to swim, fish or recreate in the river until the radioactive contamination had washed and diluted further down river. The condensate storage tank spill was confirmed to have released not only tritium but also traces of cobalt-60, cobalt-57, cesium-137, cesium-134 and other isotopes.[81]

In January 2006, Entergy made application to the NRC for a 20-year license extension of an already controversial and long-contested reactor. The license renewal request was legally challenged before the NRC licensing board by intervenors. The state of Vermont enacted a series of legislative acts to examine and decide upon the reliability of Vermont Yankee during the proposed license extension before the state Public Service Board could issue a certificate in the public good for the reactor's continued operation. [82] The state of Vermont established the Vermont Yankee Public Oversight Panel to guide, evaluate and inform its decision.

The panel of experts included in its overall evaluation Vermont Yankee's underground piping systems that carry radioactive water.

On January 6, 2010, Entergy was notified by its contract laboratory that results from its 2009 4th quarter groundwater sampling program for Vermont Yankee "identified a very low concentration of tritium in one well that is used to monitor station ground water." [83] The tritium leak was discovered via a water sample taken from a 36-foot deep monitoring well just 30 feet from the Connecticut River.[84] The initial test results spiked from a "low level" of 700 picocuries per liter to 17,000 picocuries per liter in a subsequent laboratory analysis.[85]

As Entergy dug more test wells and unearthed buried systems in the hunt on the reactor site to find which pipe or pipes were leaking, the radioactive sampling of groundwater test results ranged widely from 22,300 picocuries per liter, to 720,000 picocuries per liter and up to 2.7 million picocuries per liter.[86]

Additionally, trace amounts of cobalt-60 and radioactive manganese and zinc were discovered in the leak path. Radioactive cesium-137 was additionally discovered in soil at the reactor site which Entergy public relations immediately said was decades old from radioactive fallout from the 1986 Chernobyl nuclear power accident in Ukraine and atmospheric weapons testing through the 1950s. Contrary to the Entergy public affairs claim, the test results confirmed that cesium-137 (10,260 picocuries per gram of soil), ten times the background level for the area, pointed to the contamination coming from leaky fuel rods in the reactor core that had migrated into the environment.[87] In addition to escaping through the liquid effluent pathway, cesium-137 leaking from fuel rods can contaminate routine gaseous releases to the atmosphere through a 300-feet tall vent stack and deposit radioactive fallout beyond the reactor site.

Following discovery of the leak, Entergy sunk two dozen tests wells into the ground in its effort to determine the direction of the flow, levels of radioactivity and the reach of the contamination.[88] Entergy has argued that the tritiated groundwater plume is flowing down into the Connecticut River.

> ***Entergy management officials made false representations to the review panel, the Public Service Board, and the state legislature that there was "no underground piping carrying radioactive water."***

The initial discovery of the tritium leak quickly escalated to questioning the trustworthiness of Entergy officials when the company was revealed to have falsely reported to the state that there were no buried pipes carrying radioactive water in use under the Vermont Yankee site.[89] When Entergy tried to downplay the discovery as a mistake, a member of the state's Public Oversight Panel revealed a deliberate pattern of deception.[90] Beginning in October 2008, Entergy management officials made false representations to the review panel, the Public Service Board, and the state legislature that there was "no underground piping carrying radioactive water." The claim to not have any high-risk buried pipes would be repeated, provided in pre-filed testimony and in responses to direct questioning sworn under oath to state regulatory authorities.[91] The Vermont Attorney General launched a formal criminal investigation into perjury by Entergy management officials and local groups have made a complaint to the United States Department of Justice.[92]

Throughout January, February and March 2010 Entergy searched for the radioactive leak. It began to focus on a 30-foot-wide alley between the reactor and the turbine hall. Because of the congested location and the tangle of overlapping buried pipe systems, Entergy used a high pressure stream of water to dig a 15 to 17 feet-deep trench around the underground systems eventually exposing a concrete pipe tunnel. The operation not only dug the hole but flushed away much of the contamination deeper into the groundwater and into the river.

On March 25, 2010, Entergy announced that it had found the source of the radioactive leakage from two of the pipes. The two pipes were enclosed in concrete pipe. One pipe carried liquid and the other steam to Vermont Yankee's off-gas building where impurities are removed from steam to be condensed and routed back to the reactor. Both pipes had deteriorated and leaked their radioactive contents. Estimates of the amount of radioactive water that had leaked from the degraded reactor system range from 300,000 to one million gallons. Entergy officials say that the radioactive water will be collected back up, filtered, cleaned and recycled back into the reactor system. The tritium will likely be released later into the atmosphere along with Vermont Yankee's routine radioactive releases through its vent stack.

"The systems failed," said Neil Sheehan, spokesman for the Nuclear Regulatory Commission's Northeast regional office.[93] More to the point, Entergy management and the NRC oversight process failed to assess a degraded radiological system buried under an aging reactor seeking a 20-year license extension. Entergy officials failed to accurately convey to state regulators Vermont Yankee systems that radioactive leaks carry potentially harmful consequences now and into the future. Further, NRC failed to take decisive licensing and enforcement action at this reactor site as the agency has similarly failed at the growing number of leaking reactor sites around the country.

Vermont Yankee's initial 40-year operating license expired in March 2012. As the direct result of Vermont Yankee's radioactive leaks and Entergy's repeated misrepresentations made to state legislators, regulators and their consultants under state law, on February 24, 2010, the Vermont State Senate voted 26 to 4 to close Vermont Yankee at the end of its current license.[94] Ignoring the state's concerns, the NRC granted the reactor a 20-year license extension on March 10, 2011 which was then affirmed by the Commission ten days after the Fukushima nuclear accident in Japan. However, within weeks of the Vermont Yankee relicensing and the Fukushima nuclear accident, the Vermont Electric Cooperative, the third largest electric utility in the state, voted to reject its power contract with Vermont Yankee. This decision accelerated the already eroding confidence in a long-term contract, a deterioration set in motion by Entergy's misadventures that "included leaking pipes that spewed radioactive fluids into the ground."[95]

Uncontrolled and unmonitored radioactive releases will have direct impact on increasing the reactor's decommissioning costs following permanent closure and the quality of site cleanup. Entergy has submitted to the NRC that it will wait 60 years to finish the dismantlement of the reactor and site cleanup. This decommissioning option known as "SafeStor" demonstrates a cause for concern where the company currently has only half the required funds for the estimated $1.24 billion cost of dismantlement and environmental cleanup.[96] The degree of contamination from unmonitored leaks may not be known for years, even decades.

Yet ultimately who bears the liability for the consequences of potentially unfunded and unfinished clean up from uncontrolled radioactive contamination is yet to be determined.[97] Entergy is already saying that it is not offering any guarantees that it will be the operator.[98]

PALISADES (MI) NUCLEAR POWER PLANT

The Palisades nuclear reactor is a Combustion Engineering Pressurized Water Reactor located in Covert, Michigan, on the southeastern shore of Lake Michigan. It is owned and operated by Entergy Corporation headquartered in New Orleans, Louisiana. Palisades began operating in 1971. In early 2007, Palisades obtained a 20-year license extension from the NRC, despite significant safety concerns about age-degraded systems, structures, and components. For example, Palisades is described as having the most embrittled reactor pressure vessel in the U.S. Its steam generators need to be replaced for the second time. Its reactor lid is seriously corroded, but Entergy has no plan to replace it. An environmental coalition, including Beyond Nuclear, objected to the license extension at this dangerously deteriorated reactor.[99]

In December 2007, Palisades, as with a growing number of operating reactors in the U.S., disclosed that it was leaking tritium into groundwater on the site.[100] Entergy could not identify when the leak began so it was assumed to have occurred throughout 2007. Palisades determined that the leaks were coming from a failed storage tank and connected underground pipes.[101] Tritium was reported in an onsite groundwater test well at 34,000 picocuries per liter.[102] Entergy estimated that a total of 8.33 curies of tritium was leaked into groundwater with about 1% of the failed tank and piping's tritium contents leaking out.[103] For this same period, the Palisades nuclear power station deliberately released 839 curies of radioactive tritium as liquid effluent into Lake Michigan and 341 curies of radioactive fission and activation gases at ground level.[104]

> ***Palisades and NRC officials downplay the health and safety significance of these radioactive releases.***

Palisades and NRC officials downplay the health and safety significance of these ongoing radioactive releases and concentrated contamination. For its part, Entergy emphasized that the discovery of tritium leaks in groundwater was made at a test well on the company's property that is not used for drinking water.[105] This same false argument is used repeatedly at every nuclear power plant experiencing uncontrolled radioactive leaks to groundwater. Samples taken from onsite test wells are only indicators that highly mobile tritium has escaped into the movement of groundwater tables that can transport tritium offsite into Lake Michigan and potentially to deeper water tables and aquifers.

While the leaking damaged pipe was supposedly excavated, drained, and repaired in 2008,[106] tritium levels continued to spike in Palisades' groundwater,[107] raising concerns that leaks of unknown origin continued.[108] Entergy Nuclear spokesman Mark Savage announced that the leak was caused by a failed weld at a turn in a stainless steel pipe installed during original construction, and claimed that this flaw had also been repaired.[109]

To the immediate north of Palisades is the Van Buren State Park.[110] Visitors at the State Park campground use well water for drinking, cooking, and washing. To the immediate south of Palisades nuclear power plant is Palisades Park, a private, more than century-old resort community with 200 cabins. Portions of the Palisades Park resort community, inhabited mostly during warm weather months, also use well water. The shoreline beaches and waters are popular for boating, swimming and fishing.

Beyond Nuclear continues to advocate for the routine radiological sampling of area drinking water supplies, to monitor the concentration of tritium, and possibly other harmful radioactive substances, found therein. Given the intensive use of the area for residency and recreation, it is valuable to test the radiological and chemical content of area flora and fauna (such as edible sports fish, and edible wild or cultivated plants and animals), to determine human and ecosystem exposure to harmful radioactivity and toxic chemicals emanating from Palisades and concentrating in the local food chain.

In addition to the acute risks from tritium described above are the chronic risks downstream. Just a few hundred yards of loose sand beach separate the Palisades nuclear power plant from the waters of Lake Michigan. Thus, contaminated groundwater can readily pass through this land form and discharge directly into Lake Michigan. Palisades routinely discharges tritium and other radioactive isotopes directly and intentionally into Lake Michigan. In fact, 31 reactors are now routinely and accidentally releasing radioactive discharge resulting in the bioaccumulation and biomagnification of radioactivity in the biology of the Great Lakes.

Both routine and uncontrolled releases of tritium into Lake Michigan are cause for concern. The Great Lakes represent 20% of the surface fresh water on the planet, and Lake Michigan is one of the Great Lakes' primary headwaters for points downstream. As a whole, the Great Lakes supplies drinking water to more than 30 million people downstream, in the U.S., Canada, and to numerous Native American and First Nations communities.

Whether the tritium releases from Palisades into Lake Michigan are permitted, direct and intentional, or unpermitted and due to leaking pipes, health concerns are raised downstream due to chronic exposure to even dilute concentrations of tritium.

High levels of radioactive tritium were discovered leaking into groundwater from a crack in the 400,000-gallon onsite nuclear waste storage pond.

In February 2010, Entergy was quoted in the *Herald-Palladium* newspaper as taking the proactive approach, claiming "we have since replaced all underground pipes."[111] However, when asked by Beyond Nuclear staff at a public meeting on February 24, 2010, the NRC staff could not verify if Entergy was claiming to have replaced "all" buried pipes that carry radioactive water or just those pipes that carry water related to safety-related functions of the reactor. [112] In follow-up, Beyond Nuclear would subsequently find that the company would later claim that Entergy spokesperson's statement was taken out of context by the newspaper when in fact Palisades has not replaced "all" of its buried pipes to "head off" the corrosion problem.[113] Beyond Nuclear conversations with NRC staff reveal that Palisades has applied "cathodic protection" to its remaining high-risk buried and underground piping systems. Cathodic protection is described as a protective process where the flow of Direct Current electricity is introduced underground and directly to the buried pipes to inhibit the corrosion process. However, the actual NRC inspection report for Palisades and other U.S. reactors is not at present publicly available.

On June 11, 2014, Beyond Nuclear participated in an Entergy-guided tour of the Palisades nuclear power plant. At that time, Entergy announced that there were no active leaks from buried pipes currently on the site.

However, in the previous years of 2012 and 2013, workers tried unsuccessfully to repair repeated tritium leaks occurring from an above-ground safety injection refueling water tank. On May 5, 2013, Palisades was manually shut down due to exceeding the "allowable" leak rate from the storage tank. The tank contains up to 300,000 gallons of borated water with low levels of tritium contamination that is used during refueling outages or in case of emergency. During that time, workers found numerous cracks and tried again to stop the tank from leaking.[114]

Entergy was criticized at the time by the Union of Concerned Scientists (UCS) for its "patch and restart" approach to fixing radioactive leaks from degrading systems. UCS called for more permanent fixes to be put into place. [115] When Entergy eventually did replace the entire bottom of the tank, it was discovered that a protective sand bed barrier had not been installed as credited in the plant's original blueprints. [116]

Since June 2013, Entergy reports the tank has not leaked. That same year, NRC inspectors at Palisades report that all the corroded pipes had been repaired, replaced or reinforced with sleeving.[117] In a February 2015, the NRC reports that Entergy has taken further corrective actions to provide "cathodic protection" to at-risk buried pipe.[118] According to the Electric Power Research Institute, "None of these protective measures, however, are foolproof, and over time they tend to degrade."[119] Beyond Nuclear continues to monitor the situation but remains concerned with the inconsistent manner of application of such protection actions from one reactor site to another.

On March 19, 2015 Entergy reported that radioactive tritium had been discovered on February 26, 2015 in two temporary onsite test wells. At the time, Entergy was unable to identify the exact location of the pipe leak or the leak volume rate. The Entergy report to the NRC suspected the radioactive leak originated from the reactor's steam generator inside containment which leaked out into the turbine building and through failing buried piping systems for the turbine sump oil separator to the turbine building drain tank.[120]

INDIAN POINT (NY) NUCLEAR POWER PLANT

The three-unit Indian Point nuclear power station (two operational units and one closed unit) is located in Buchannan, New York, on the Hudson River 24 miles north of New York City. Indian Point Units 2 and 3 are both operating Westinghouse Pressurized Water Reactors. Unit 1 was permanently closed in 1974 and stores all of its nuclear waste in an onsite pool. Entergy Corporation is the parent company. The current 40-year operating license for Units 2 expired in September 2013. The Unit 3 license will expire in December 2015. The NRC received Entergy's application for the 20-year license extension of Units 2 and 3 in April 2007 and, as of March 2015 both units both are still being contested by the New York State Office of Attorney General and public intervenors before the NRC Atomic Safety Licensing Board.

Entergy reports that the Indian Point reactor site intentionally released 877 curies of liquid radioactive effluent containing tritium and traces of other radioactive isotopes into the Hudson River in its 2008 annual radioactive effluent release report.[121]

In early September 2005, high levels of radioactive tritium were discovered leaking into groundwater from a crack in the 400,000-gallon onsite nuclear waste storage pond for the closed Unit 1. The time that the leak began could not be determined but the NRC assumed it had been going on for a long time. The leak prompted Indian Point operators to dig dozens of test wells to determine the extent and reach of the leak. Additional radioactive isotopes were found leaking from the reactor site including nickel-63 and strontium-90.

By 2008, strontium-90 had been discovered in several test wells on and off the site with radioactivity readings as high as 26.4 picocuries per liter – more than three times the EPA permissible limit for drinking water. The radioactive plume was moving into the Hudson River. In fact, the radioactive leaks under Indian Point have created at least two large underground radioactive "lakes" containing concentrations of tritium, strontium-90 and likely other longer lived-isotopes. The radioactive lakes were reported in a study to have leaked from both Indian Point Unit 1 and Unit 2 nuclear waste storage ponds.[122] [123] A controversial study conducted by GZA Geoenvironmental, Inc. suggests that Entergy leave these underground radioactive lakes undisturbed until taken up as part of the decommissioning of the Indian Point reactor site.

In February 2009, 100,000 gallons of water containing radioactive tritium at 2,000 picocuries per liter leaked onto the floor at Indian Point through a one-and-a-half-inch hole made by corrosion through an uninspectable pipe buried eight feet underground.[124] The fact that the pipe had not and could not be inspected or maintained raised concerns within and beyond the state of New York as it represented yet another in a series of uncontrolled and unmonitored radioactive leaks springing from nuclear power plants. The leak was again accompanied by trivializing responses from Entergy and the NRC despite the fact that many of Entergy's nuclear power plants were by now springing radioactive leaks and none of the nuclear giant's 11 reactors to date have a management plan for the leaks.

On August 12, 2009, the NRC staff found that there were no issues to stop a relicensing of Indian Point for another 20 years. This staff finding and recommendation to the licensing board comes despite the evidence of deterioration of these systems carrying radioactive effluent, inadequate federal oversight and the lingering absence of a company management plan to effectively monitor, maintain and contain future radioactive leaks.[125]

In January 2010, in comments to the NRC submitted by Riverkeeper, one of the legal intervenors in the Indian Point license extension application before the NRC, the environmental organization pointed to the ongoing inadvertent radioactive releases to the environment from nuclear power plant buried pipes and structures.[126] Among the many salient points, Riverkeeper challenged the NRC and industry effort to continually trivialize the known adverse biological impacts of tritium and their assumption that radioactive contamination will be confined on site, disregarding the highly mobile nature of tritiated water.

In June 2014, elevated levels of radioactive tritium were once again spiking in groundwater monitoring wells near Indian Point nuclear power station.[127] The NRC was first made aware of the radioactive leak issue in an onsite groundwater monitoring well in 2005.[128] Ten years later, radioactive leaks from underground pipes continue to plague the site without discovery of the source or mitigation of the leak. As the event report states, the water sampling was then part of an "ongoing investigation to verify and quantify previously identified leakage, potentially from the spent fuel pool."[129]

The source of the radioactive leak that spiked in the monitoring well in March 2014 continues to be evasive. In July 2014, Entergy plans to employ a robotic crawler for surveillance of the interior wall of buried piping in an effort to find the source of the leak. However, no findings or results of the inspection have been made public that would identify the location of the leak or its status.

Other than the industry voluntary reporting, the ongoing and unmitigated radioactive leaks at Indian Point serve as an example of an ineffective NRC policy and industry action to locate and reliably stop groundwater contamination.

AN EPIDEMIC OF RADIOACTIVE LEAKS

Appendix A of this report documents that since 1963 more than 102 reactor units have leaked radioactive contamination in recurring events into highly mobile groundwater that carried radioactive tritium farther and deeper into underground water resources. Under current lax federal oversight and regulation, aging nuclear power plants will continue to experience new and possibly larger leaks.

Uncontrolled and unmonitored radioactive leaks from nuclear power plants in the United States are now ubiquitous.

On April 6, 2010, the Public Service Electric & Gas management was notified that its Salem nuclear power plant on Artificial Island in New Jersey tested positive for tritium contamination in a storm drain system that was confirmed at about 1 million picocuries per liter.[130]

On April 6, 2010, Tennessee Valley Authority's Browns Ferry nuclear power station in Alabama spilled 1,000 gallons of tritiated water (2,050,000 picocuries per liter) during a transfer operation from one tank to another when plant personnel were unable to close an open test valve for nearly two hours.[131]

On February 9, 2010, Duke Energy's Oconee nuclear power station in South Carolina tested positive for tritium in two new groundwater test wells onsite at 24,400 picocuries per liter and 35,400 picocuries per liter.[132]

On January 10, 2010, Progress Energy's Shearon Harris nuclear power station in North Carolina discovered a leak in an eight-inch diameter underground fiberglass pipe of approximately 1,000 gallons of tritiated water at 5,590 picocuries per liter that had saturated soil.[133]

On January 6, 2010, Entergy's Vermont Yankee nuclear power station in Vernon, Vermont, was notified that a 2009 fourth quarter groundwater sample from an onsite test well was positive for tritium with readings which would range between 7,000 picocuries per liter and 2.7 million picocuries per liter from buried pipes that Entergy officials had denied existed while under oath to state regulators.[134]

On December 28, 2009, Entergy's Fitzpatrick nuclear power station in Oswego, New York, was notified that the west storm drain tested positive for tritium at 938 picocuries per liter. Entergy further disclosed that on November 3, 2009, the reactor building perimeter sump, which communicates with the west storm drain, had tested positive for tritium at 1,474 picocuries per liter but had not been previously reported because there was no evidence of tritium in the storm drain or groundwater test well at the time.[135]

On November 19, 2009, Constellation Energy's Ginna nuclear power plant in Ontario, New York, notified the state Department of Environment Protection when sediment contaminated with an undisclosed amount of cesium-137 fell into an excavation hole from a section of buried pipe that was being replaced. "The section of piping being replaced was between the plant storm drain system and the discharge canal. The radioactive material was identified as Cs-137 but was not quantified at the time of this report." This discharge canal flows into Lake Ontario.[136]

On September 10, 2009, Northern States Power's Monticello nuclear power plant notified the state of Minnesota that samples from a new groundwater test well near the reactor building sampled positive for tritium in groundwater at 21,300 picocuries per liter.[137]

On August 25, 2009, Exelon's Oyster Creek nuclear power station in Lacey Township, New Jersey, notified the state of New Jersey of a tritium leak to groundwater from a buried condensate pipe in concentration of 10 million picocuries per liter. [138]

On July 10, 2009, Exelon's Peach Bottom nuclear power station in Delta, Pennsylvania, issued a news release that an onsite exploratory well tested positive for tritium in groundwater at 123,000 picocuries per liter.[139]

On June 6, 2009, Exelon's Dresden nuclear power station in Morris, Illinois, reports as "part of the Station's continuing environmental monitoring and sampling program sample results from some of the monitoring wells indicated tritium at elevated levels." The event notice further stated "The IEPA/ IEMA regulation requires notification when a release to soil, groundwater, or surface water goes offsite at greater than 200 pCi/l [picocuries per liter] or remains onsite greater than 0.002 Curies. Based upon the monitoring well results and the volume and concentration of groundwater infiltration into the nearby storm sewer, it is likely that the 0.002 Curie onsite threshold has been exceeded." The event report does not indicate by how much more, however. An excess of an "onsite threshold" of 0.002 Curie converts to more than 2 billion picocuries.[140]

On May 11, 2009, Southern Nuclear Operating Company's Hatch nuclear power plant in Baxley, Georgia, reported that on May 5, 2009 the operators were notified that a groundwater test well sampled positive for tritium at 36,300 picocuries per liter. This sample was confirmed to represent an increase in the levels of tritium in the same test well last sampled on March 16, 2009 at 5,400 picocuries per liter.[141]

On April 15, 2009, seven days after receiving a 20-year license extension from NRC, Exelon's Oyster Creek nuclear power station in Lacey Township, New Jersey, notified the state of New Jersey of a "potential" release of tritium in a cable vault. A leak to groundwater was later confirmed to be approximately 200,000 gallons of radioactive water as high as 6 million picocuries per liter.[142]

On April 1, 2009, Progress Energy's Shearon Harris nuclear power plant in North Carolina reported that as part of its ongoing voluntary Groundwater Protection Initiative a leak had occurred in the buried Cooling Tower Blowdown line and was releasing water contaminated with tritium at 2,120 picocuries per liter into the surrounding soil. The buried pipeline is used to routinely discharge diluted tritium releases into Harris Lake.[143]

On March 3, 2009, Dominion Energy's Surry nuclear power plant near Williamsburg, Virginia, reported that an onsite relief valve opened for about 20 minutes before it was identified and closed down. About 400 gallons of water contaminated with tritium at 4,810 picocuries per liter and cesium-137 at 25.1 picocuries per liter was spilled into soil.[144]

The compendium of radioactive leaks from reactors to groundwater is long and continually growing as new leaks and spills will be added to the list. Appendix A of this report provides the Union of Concerned Scientists' comprehensive tally of radioactive leaks involving groundwater at U.S. reactor sites from 1963 through February 28, 2009.[145]

As recent as January 21, 2015, the Institute for Nuclear Power Operations (INPO), the industry's non-public self-police force, confirmed that U.S. reactors still have "Leaks occurring and the source is not determined."[146] Beyond Nuclear reviewed industry voluntary reports posted to the NRC "Event Notification Reports". A sampling of radioactive leak reports to the NRC from 2010 [147], 2011[148], 2012[149], 2013[150], 2014[151] and the beginning of 2015[152] demonstrates that unanticipated radioactive leaks continue to occur from unmaintained and still inaccessible buried pipes at reactor sites.

A LACKADAISICAL REGULATORY RESPONSE

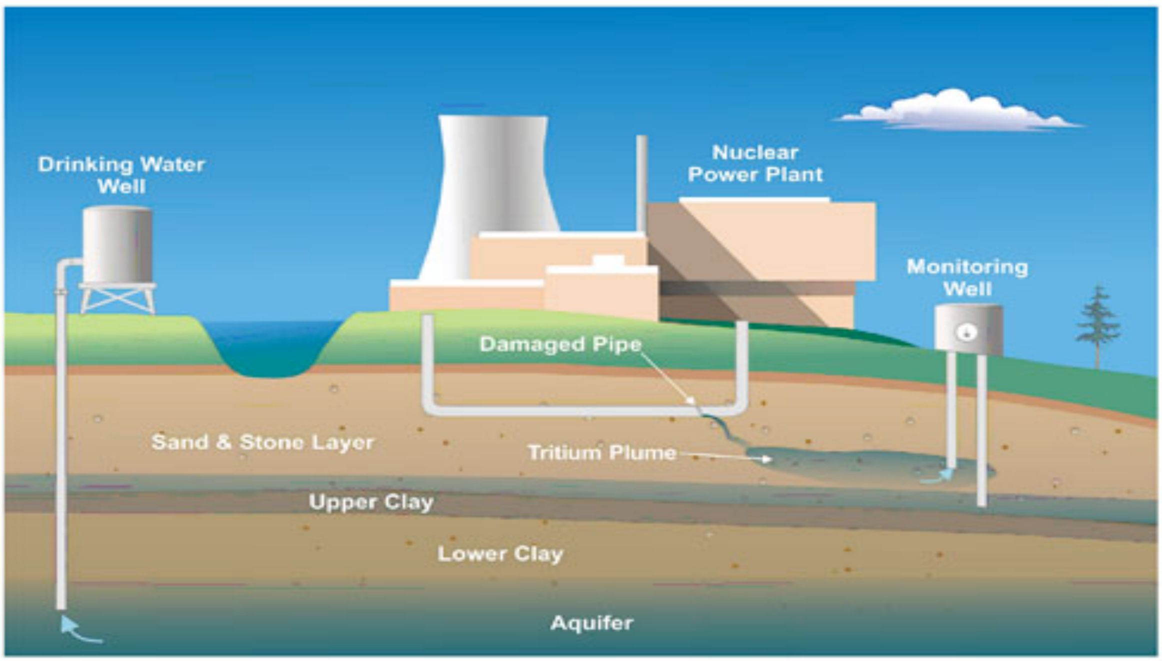
A national crisis of public confidence arising out of uncontrolled and undisclosed radioactive leaks from nuclear power plants has pushed both the NRC and the industry into damage control, arguably as much for rebuilding public image as actually addressing the radioactive pollution issue. Industry and the NRC have resolved that simply disclosing the radioactive leaks, without concrete action plans and enforcement requirements to prevent them, is sufficient to bolster public trust. The nuclear power plants continue to leak radioactivity into the environment from underground pipes and tanks and many of the sources still remain unknown. What is consistently left unaddressed is that nuclear power plants by regulation and licensing agreement are not allowed to have uncontrolled and unmonitored radioactive releases.

Instead, in public statements once buried pipe leaks are discovered,the NRC and industry have consistently ignored a fundamental issue of non-compliance and trivialized any concern for public health and safety.[153] NRC comments routinely fail to acknowledge that the full extent of the agency's regulatory responsibilities includes both reactor safety and the radiological control of releases at nuclear power plants not only through monitored paths but also through uncontrolled and unmonitored release pathways. Radioactive leaks from unmaintained and inaccessible buried pipes contaminating soil and water *at any level* constitute uncontrolled and unmonitored release pathways.

The NRC fact sheet on tritium leaks from buried pipes states at the outset: "Over the past several years, minor corrosion incidents have caused leaks in buried pipes and related systems at several U.S. nuclear power plants, contaminating groundwater with minor levels of radioactive material. The plants' safety systems continue to function properly despite these leaks. The types and amounts of radioactive material involved in the leaks have represented a small fraction of limits the NRC sets to maintain public health and safety, so the leaks do not present a risk to the public."[154]

The NRC continues to assure the public that there is no nexus between uncontrolled radioactive leaks and public health and safety. The diagram below. from the NRC fact sheet on "*Buried Pipes from Nuclear Power Plants,*" graphically illustrates how the agency depicts that there is no connection between drinking water, agriculture, irrigation water and other potential biological radioactive exposure pathways coming from a leaking buried pipe.[155]

By viewing this agency diagram, a member of the public could assume that tritium plumes run



NRC diagram misleadingly attempts to show there is no connection between drinking water, agriculture, irrigation water and other potential biological radioactive exposure pathways coming from a leaking buried pipe.

shallow and that drinking water aquifers are universally protected. One could further assume that tritium plumes are effectively monitored by a series of onsite monitoring wells.

In fact, federal regulations have established "*minimum requirements*" not only for the safety performance of reactor systems, structures and components but also for the radiological consequences of reactor operations and occurrences to assure and demonstrate that radioactive effluents to the air and water are controlled and monitored. The Code of Federal Regulations Chapter 10 Part 50 Appendix A General Design Criteria of a reactor's licensed condition requires in Section VI Fuel and Radioactivity Control: "Criterion 60 – Control of releases of radioactive materials to the environment.

"The nuclear power unit design shall include means to control suitably the release of radioactive materials in gaseous and liquid effluents and to handle radioactive solid wastes produced during normal reactor operation, *including anticipated operational occurrences* [emphasis added]. Sufficient holdup capacity shall be provided for retention of gaseous and liquid effluents containing radioactive materials, particularly where unfavorable site environmental conditions can be expected to impose unusual operational limitations upon the release of such effluents to the environment." [156]

The same General Design Criteria goes on to require that the radiological effluent path is to be monitored under a separate Criterion 64 requiring each licensee to adhere to maintaining that, "Means shall be provided for monitoring the reactor containment atmosphere, spaces containing components for recirculation of loss-of-coolant accident fluids, effluent discharge paths, and the plant environs for radioactivity that may be released from normal operations, *including anticipated operational occurrences* [emphasis added], and from postulated accidents."[157] Additionally, Code of Federal Regulation Chapter 10 Part 20 requires that each reactor operator shall conduct its operations so that the total effective radiation dose equivalent to individual members of the public does not exceed 0.1rem (1mSv) in a year.[158]

The federal requirement is explicit to say that the design criteria include "*anticipated operational occurrences*." It is not a question of a licensee complying with one or two out of these three licensing criteria. A nuclear power plant operator that has lost control of the radioactive effluent pathway by releasing contaminants into groundwater and is no longer able to monitor that radioactive effluent pathway has also lost control of reasonably and reliably calculating potential radiation exposures to the public now and into the future. Radioactive plumes once in the environment will move with the groundwater. The radioactive plumes can be evasive and difficult to detect, isolate and mitigate. Once the radioactive effluent previously controlled in a pipe has escaped, it also bypasses established radiological monitors in that pathway system. While nuclear power plants typically have several test wells on site to periodically sample groundwater for radioactivity, they are often too few and far between to constitute a reasonable and reliable monitoring program for contamination moving in unconstrained groundwater at varying depths.

Federal regulation provides that a license may be revoked, suspended, or modified, in whole or in part, for failure to operate a nuclear power plant in accordance with the terms of its licensed condition or for failure to observe any of the terms and provisions of the act, regulation, license, permit or order of the Commission.[159]

The NRC would not grant an initial license to an operator who displayed the potential for repeated uncontrolled and unmonitored radioactive releases of million gallons of radioactively contaminated water to the local environment. Yet the agency to date has deferred its enforcement responsibilities to just such repeated and recurring radioactive leaks to ground- and surface water from buried pipes. Operators have allowed radioactive leaks to disappear into the groundwater table around many nuclear power stations. However, the disappearance does not necessarily mean that there is no contamination. Instead it places neighboring communities into a game of "hide and go seek" with deleterious radioactive contamination that may not be found for decades rather than maintaining and enforcing proactive and preventative regulatory oversight. Federal law was not promulgated to selectively address the least limiting regulations to accommodate its licensees but rather to be applied on the whole for the protection of the public now and into the future from radiation generated within nuclear power plants. However, the NRC has chosen to selectively ignore its own radioactive effluent control and monitoring regulations in acquiescence to industry financial and production interests at the expense of undue risk to the public health and safety.

ILLEGAL RADIOACTIVE TRESPASS AND AN INDUSTRY ABOVE THE LAW

Groundwater is a protected public resource. A number of controversial accidental radioactive releases to ground- and surface water from reactors like the Braidwood and Dresden nuclear power plants in Illinois, Indian Point in New York, Oyster Creek in New Jersey and Vermont Yankee in Vermont have drawn high profile attention from state authorities and the public alike. The nuclear industry looks to distance itself from any and all liability from the known health risks and consequences to neighboring communities potentially caught in the path of radioactive discharge. Still, reactor operators like Constellation Energy acknowledge that "The true risk is legal. The plants do not have legal authorization to release radioactive material to the groundwater. Groundwater flows through and off the plant property, potentially contaminating private property."[160] Constellation Energy, the operator of five reactor units at three sites in Maryland and New York recognizes that an uncontrolled radioactive leak means *"You have put your radioactive waste on my property and damaged my property value."*[161] In fact, such discharges constitute a radioactive trespass that negatively impacts property values and places public health at increased risk to the known biological hazards of radiation exposure.

This acknowledged legal risk became reality in March 2006 when a complaint, seeking $36.5 million in fines and restitution, was brought by impacted citizens through the Illinois Office of the Attorney General and the State's Attorney for Will County, Illinois and filed before the

Circuit Court for the Twelfth Judicial Circuit in Will County, Illinois.[162] The complaint related to the series of undisclosed spills of tritiated water from the Braidwood nuclear station.

By March 2010 a $1.13 million settlement was reached between Exelon and the state of Illinois for groundwater contamination stemming from three civil complaints as the result of uncontrolled releases from three of its atomic reactors in Illinois.[163] The legal settlement was reached in addition to the $11.5 million that Exelon had already agreed to pay in 2006 for a new water treatment facility for the Godley Township District.[164]

Subsequently, the complaint was broadened to include radioactive spills from two more Illinois nuclear power plants, Byron and Dresden. The complaint contended that Exelon violated eight counts of Illinois water protection statutes governing: 1) water pollution; 2) exceeding groundwater standards; 3) violation of non-degradation provisions; 4) discharging wastewater without a National Pollution Discharge Elimination Systems (NPDES) permit; 5) failure to comply with NPDES permit reporting requirements; 6) failure to ensure proper operation and maintenance and failure to mitigate; 7) water pollution hazards, and; 8) common public nuisance.[165]

The legal resources of the nuclear industry are admittedly immense given the example that Exelon was able to deny any guilt in all of the alleged violations and settle with the state for a small fraction of the originally levied fines and restitution.

LEAK FIRST, "VOLUNTARILY" REPORT LATER

The 4.5 Magnitude earthquake that shook the U.S. Midwest on June 28, 2004 was perhaps the sentinel event for revealing that groundwater contamination from uncontrolled and unmonitored radioactive releases was going unreported to impacted communities by the nuclear power industry. The quake was felt at nuclear power plant sites in Illinois and prompted Exelon to declare an unusual event at several of its reactors.[166] Water was later found pooling on the surface at Exelon's Dresden nuclear power station prompting workers to excavate an area on site to find a leaking buried pipe, possibly already degraded, that had broken open during the tremor. The nuclear workers took samples of the water to look for radioactivity and discovered that it contained high levels of radioactive tritium measuring at 10,000,000 picocuries per liter at one location in a storm drain that communicated offsite into the Kankakee River.

A whistle-blowing worker at the Dresden nuclear power plant anonymously called the Union of Concerned Scientists in the Fall of 2004 to report the radioactive leak and to inform David

> ***The industry voluntary actions are focused on fixing and mopping up after a leak to groundwater has occurred.***

Lochbaum, the UCS Senior Reactor Safety Engineer, that both the former operator Commonwealth Edison and Exelon had discontinued the site's routine radiological groundwater sampling program in 1993, likely as a cost-saving measure. Even more disturbing was the fact that the NRC had allowed Exelon and others to discontinue their groundwater monitoring programs.[167]

An unraveling of the lack of Exelon's public reporting of radioactive leaks and the NRC regulatory permissiveness would eventually lead to the company's admission in 2005 that many more unreported radioactive leaks had been spilling into groundwater from nuclear power plants around the country, most notoriously at Exelon's Braidwood nuclear power plant. It would also expose the federal agency's lackadaisical oversight of groundwater protection from these radiological releases springing from aging nuclear power plants. Public confidence in the trustworthiness of the nuclear power industry and the adequacy of NRC oversight plummeted.

The pressure upon the NRC and the industry was clearly mounting. Then freshman Illinois Senator, Barack Obama, had drafted federal legislation to require the NRC to mandate the nuclear industry to immediately report not only to the NRC, and to the state but also to the local communities potentially in the pathway of the radioactive plume. The mandatory reporting requirement measure would eventually stall in committee and Senator Obama failed to follow through for his Illinois constituents.[168] The nuclear industry, faced with both growing public and political pressure, concluded that either they were going to take the initiative or the NRC was going to have to become a regulator. By 2006, the Nuclear Energy Institute (NEI), the nuclear industry's chief lobbing and troubleshooting organization, seized the opportunity from an all-too-willing and accommodating federal regulator to defer agency oversight and enforcement by introducing its "Voluntary Initiative for Groundwater Protection" to the NRC.[169]

Ralph Andersen, NEI's Chief Health Physicist was quoted as saying: "Tomorrow we're going to meet with the NRC in a public meeting and commit our industry to doing this. Whether it's writ [sic] on a piece of paper that the lawyers can work with or not, I believe that our industry and anybody else who attends that meeting is going to understand that we either do it or we're going to have a serious problem. The reason is because NRC certainly will be taking into consideration our initiative when they review whether they need to do other things in terms of regulations or requirements."[170]

The NEI-led project is recognized as the "Ground Water Protection Initiative." It is focused on "improving the management of situations involving inadvertent radiological releases that get into groundwater and the communications with external stakeholders about those events."[171] In January 2013, the Nuclear Strategic Issues Advisory Committee (NSIAC), represented by every U.S. nuclear power company's Chief Nuclear Officer, adopted the "Underground Piping and Tanks Integrity Initiative" for the self-oversight buried pipes and tanks at the reactor sites. Each nuclear power plant is responsible for self reporting to the NSIAC any leak incidents, condition assessments (including material composition) of underground pipes and tanks, management and implementation plans and schedules along with documentation and the description of deviations that do not meet the intent of the initiative. It includes risk ranking for piping systems that are safety-related and carry licensed radioactive materials. This information is proprietary and not available for public review.

The NRC response to industry's voluntary initiative was to develop a "temporary instruction" (TI 2515-182) for issuance to federal inspectors on how to determine whether reactor operators were implementing the initiative and whether they had successfully completed commitments described in the "Underground Piping and Tanks Integrity Initiative."

The temporary instruction's inspections were conducted in two phases; Phase 1 for the assessment of plant programs and schedule compliance and; Phase 2 for assessing program quality. As of January 21, 2015, the NRC reported that both inspection phases were complete.

The NRC has no plan to compile and publish the inspections findings of TI 2515-182. A January 21, 2015 agency briefing included an overview and summary of the inspection results that identified that the quality of implementation was inconsistent across the industry. The inspections further identified that in general the nuclear industry had no procedures or programs to confirm the "as-built locations" of buried pipes and tanks.[172] While the agency was quick to state that the industry had shown the ability to find and excavate the pipes and tanks, it identified a general lack of care for these structures, potentially raising the risk of their damage in the future. The briefing provided no insights into any other significant findings.

From the public interest and environment protection perspective, the chief concern for efforts to protect communities and water resources remains focused on the need for enforcement of the "minimum requirements" to maintain a controlled and monitored pathway for all radioactive releases as originally licensed. It is of additional concern that the NRC has enforceable requirements for prompt and accurate reporting of groundwater contamination events when they occur in contrast to voluntary industry initiatives. The NEI program as currently in place, and supported by the NRC, provides that a nuclear power plant operator can voluntarily take action to detect and respond to uncontrolled leaks; voluntarily report to NRC any radiological sample from onsite groundwater; and voluntarily notify state and local officials "as appropriate" for onsite leaks and spills to groundwater and onsite or offsite water sample results exceeding established criteria in the radiological monitoring program.

The NRC has deferred its oversight and enforcement tools in a trade-off for industry good faith efforts to self-report compliance issues originating from industry non-disclosure and obfuscation.

There is nothing in NEI's "Groundwater Protection Initiative" that proactively protects the groundwater flowing onto, under and off nuclear power plant sites from uncontrolled and unmonitored radioactive releases. The industry voluntary actions remain focused on radioactive leak detection, fixing and mopping up after a leak to groundwater as opportunities occur. In fact, the initiative serves more to protect the industry from liability than to protect the water. One needs to only briefly ponder the thought of "voluntary" payment of taxes to understand the federal loophole that is provided to the nuclear industry for preventing future groundwater contamination from uncontrolled and unmonitored radioactive releases as stipulated in federal licensing agreements.

The failure of the NRC to regulate the nuclear industry in response to radioactive releases was explicitly articulated by the New Jersey Department of Public Health in comments to the agency in 2010 in response to contamination of the Cohansey aquifer system by Oyster Creek nuclear power station. The State voiced its concerns that the NRC needs to effectively enforce its regulations rather than acquiesce to the industry agenda particularly where maintaining barriers as designed to contain licensed materials (radioactivity) as per licensing agreements. "This is the area where the NRC can make real changes that can be most beneficial. There is no doubt that the best way to protect groundwater and other natural resources from unintentional contamination is prevention."[173] State authorities pointed out that such regulatory deficiencies in this area can "lead to serious environmental impacts like the contamination of groundwater, potentially denying its use as a drinking water source."[174] More importantly, the New Jersey state authority recognized that not unlike voluntary speed limits for traffic control lacking any enforcement criteria, "Voluntary reporting is not an acceptable substitute for a comprehensive regulatory program."[175]

A NOTE ABOUT ROUTINE RELEASES

Every nuclear power plant releases radioactive waste to the environment as a part of its routine operation. It does not take an accident. Radioactive leaks from buried pipes, as described in this report, added to these routine releases permitted by the NRC, impose a cumulative radioactive burden on the populations living downstream and downwind. That is, radioactive trespass includes not only leaks to the groundwater from inaccessible pipes, but also the routine releases of radioactivity to surface water and the atmosphere.

Routine releases are the result of radioactive products that build up in the reactor fuel and in the reactor's cooling water and steam. The metal tubing of the uranium fuel rods and the welds at the top and bottom of the rods may develop leaks or defects through which radioactive fission products can escape into the cooling water. The reactor vessel and related equipment become irradiated; radioactive rust sloughs off into the cooling water. Some contaminated cooling water may periodically be removed, stored and demineralized before being returned to the reactor vessel. Some of the cooling water is filtered and then released in batches to the river, lake or ocean. Some radioactive gases are released as steam; some are stored in tanks and then are filtered and released; some gases are merely vented or purged directly to the atmosphere.

No economically feasible technology exists that can filter out some of the isotopes, like tritium. No nuclear power plant can operate without the routine release of radioactive waste to the environment. Therefore, the NRC permits these radioactive isotopes to be released.

Long-lived radioactivity generated by the nuclear industry is being passed along to future generations that will receive not one watt of benefit.

Hannes Alfvén, a 1970 Nobel Laureate in physics encapsulated the issue when he famously stated: "The fission reactor produces both energy and radioactive waste; we want to use the energy now and leave the radioactive waste for our children and grandchildren to take care of. This is against the ecological imperative: Thou shalt not leave a polluted and poisoned world to future generations."

CONCLUSIONS AND FINDINGS

Study now (and for years to come); fix later

The industry's underground pipe and tank integrity program is a contradiction in terms. Once piping and tanks are buried, and made inaccessible to monitoring the effects of aging, corrosion and other forms of attack, the reliability of determining their future integrity is significantly diminished. If the nuclear industry priority was to comply with their licensing agreement to maintain control of licensed radioactive materials like tritium and strontium-90, reactor operators would make pipes and tanks accessible for inspection and preventative maintenance. Without effective federal oversight and regulation that remains not to be the case.

The Electric Power Research Institute (EPRI), American Society for Mechanical Engineers and the NACE International (formerly the National Association of Corrosion Engineers) are working collaboratively with the nuclear industry to better understand pipe corrosion and develop more reliable nondestructive evaluations of buried pipes and tanks are still ongoing with still limited success. But after the five years since "Leak First, Fix Later" was first published, such nondestructive evaluations have still not arrived on an economically affordable scale for commercial application at the nation's nuclear power plants.

Meanwhile, the nuclear industry is burying portions of their own root cause evaluations of these leaks from public disclosure and independent review. This effectively hides the causes, the extent and direction of their analysis of the problem and the basis for prospective corrective actions. The protection of groundwater and public health is too important to be left to industry summations.

Central to any future pipe integrity program, NRC and industry need to devote significant resources to better understand how corrosion is accelerated by exposure to tritium and tritiated water.

Scientific research indicates that radioactive hydrogen in the form of tritiated water and tritium gas accelerates the corrosion of metal. The tritium-induced corrosion damage even to stainless steel can be severe.[176] The contribution of tritium exposure to accelerated corrosion is not being adequately evaluated by the NRC or the nuclear industry.

Main Findings

- The number of unintended and uncontrolled radioactive releases to groundwater and surface water are increasing. Uninspected, unmaintained and aging buried piping systems at nuclear power plants continue to experience unanticipated and unpredicted radioactive leaks into groundwater.

- Nuclear power plant operators have allowed radioactive leaks to disappear into the groundwater table around many nuclear power stations.

- The NRC has failed to mandate any corrective action programs that focus on inspection and maintenance programs aimed at groundwater protection by preventing ongoing radioactive leaks and contamination of water resources.

- The nuclear industry and the federal regulator have failed to focus action plans on how to prevent these leaks from occurring in segmented underground piping systems. Instead, the federal regulator and industry are using predictive and probabilistic models to estimate the remaining service life on uninspected and unmaintained pipes before leaks may be expected to occur.

- The industry "voluntary" actions remain focused on radioactive leak detection, fixing and mopping up after a leak to groundwater as opportunities occur. In fact, the initiative serves more to protect the industry from liability than to protect the water.

- The NRC has chosen to selectively ignore its own radioactive effluent control and monitoring regulations in acquiescence to industry financial and production interests at the expense of undue risk to the public health and safety.

- Tritium reduction in nuclear power plants has not been historically pursued by the industry primarily because of the difficulty, the cost and an industry-championed assumption that tritium can be diluted to inconsequential low-dose radiation exposure. In fact, chronic exposure to tritium releases is a universal health risk from every nuclear plant. Furthermore, the contribution of tritium exposure to accelerated corrosion is not being adequately evaluated by the NRC or the nuclear industry.

RECOMMENDATIONS

1. Regulatory oversight, authority and enforcement must be strengthened

- A prompt and fundamental shift in focus for federal oversight and enforcement is necessary. The prevention and containment of both routine and accidental radioactive releases must supersede the nuclear industry's economic considerations that presently rely on a "leak first, fix later" approach with the piecemeal replacement of damaged sections of buried and underground pipe essentially as leaks occur followed by mopping up as best as the industry is willing to afford;

- Nuclear industry "voluntary initiatives" for groundwater protection and the integrity of buried pipes and tanks is not an effective or acceptable substitute for a comprehensive regulatory program aimed at protecting water resources. The initiative should be suspended and supplanted by NRC mandatory prescriptive requirements to regain federal regulatory oversight and enforcement authority as promulgated in 10 CFR 50 Appendix A, General Design Criteria

60 for the control of radioactive effluent and General Design Criteria 64 for the monitoring of radioactive effluent in nuclear power plants;

- NRC should require all nuclear power plant operators to reconstitute the history and as-built configuration of all buried, underground and above-grade pipe systems identifying all on- and offsite locations and the material susceptibility of all systems that currently carry and have carried radioactive effluent;

- The current federal protective standard for tritium in drinking water is antiquated and the dated current federal standard for "*permissible*" releases from nuclear power stations needs to be dramatically reduced;

- There should be mandatory routine radiological sampling of area drinking water supplies around leaking nuclear power plants in order to monitor the concentration of tritium, and possibly other harmful radioactive substances;

- Central to any future pipe integrity program, NRC and industry need to devote significant resources to better understand how corrosion is accelerated by exposure to tritium and tritiated water.

2. Standardized NRC regulations should require that underground pipes and tanks be promptly replaced so that systems carrying radioactive effluent can be inspected, monitored, maintained and contained in the event of leaks

- Nuclear power plants must be universally required to promptly replace all of their buried piping systems carrying radioactive water during sequential outages with newly-installed above ground systems in vaulted corrosion-resistant materials. Above-grade and vaulted pipes and tanks can be proactively inspected, monitored, maintained and, should a radioactive leak occur, contained in isolation from water, air, soil and the biology

3. The nuclear industry must be held accountable for radioactive releases to air, water and soil

- Nuclear industry "voluntary initiatives" for reporting inadvertent radioactive releases should be replaced with an immediate mandatory reporting requirement of all inadvertent radioactive releases directly to the NRC, the state and potentially affected communities. The NRC should assert its oversight responsibilities to initiate investigations and take meaningful enforcement action for design requirements when violations occur;

- The nuclear industry should be mandated to reorient its commitments from post-radioactive leak management to radioactive leak prevention;

• All industry commitments regarding the protection of ground- and surface water from radioactive releases must be in the form of legally binding written commitments made to state and federal authorities;

• A nuclear industry-wide scientific assessment should commence immediately with independent oversight of the accelerated corrosive effects of tritium and tritiated water attack on reactor systems including buried pipes that carry radioactive effluent.

4. There must be more public transparency describing the source, cause and extent of radioactive releases from nuclear power plants

• The nuclear industry should be required to make the Root Cause Evaluations of radioactive leaks and spills from nuclear power stations a public record. Mistakes, accidents and events affecting the protection and quality of water resources under and near nuclear power plants should not be withheld from public disclosure as "proprietary" and "trade secret" company documents;

• NRC needs to require all nuclear power operators to make public all "Condition Reports" describing and evaluating inadvertent radioactive leaks and spills as a disclosure under the "Abnormal Occurrences" section of the publicly available Annual Radiological Effluent Release Report currently required of nuclear power plant operators.

5. Radiation protection standards must be strengthened and applied consistently nationwide

• Consistent radiation protection standards need to be promulgated and applied in updated federal standards;

• Radiation protection standards need to be updated to be more protective of the most vulnerable in our populations as expertly presented by Dr. Arjun Makhijani and described in his Institute of Energy and Environmental Research's "Healthy from the Start Campaign." The campaign aims to shift the focus of radiation exposure standards from "Reference Man" to those most at risk, namely, the developing fetus and infants and their pregnant and lactating mothers;[177]

• Further toward these goals, NRC should adopt the conclusions and recommendations authored by Dr. Makhijani, as they pertain to both routine and accidental discharges of tritium:[178]

> a) The NRC should develop a policy of keeping tritium releases as low as reasonably achievable as a supplement to its dose guidelines;

b) The upper limit for environmental concentrations for tritium should be tightened to no more than 400 picocuries per liter on an annual average basis;

c) Nuclear plant licensees should be required to monitor rainwater and offsite groundwater in a manner designed to detect rainwater and groundwater contamination and the results should be reported to the NRC by licensees as part of their annual environmental reporting;

d) There should be significant penalties for failure to disclose offsite migration of radionuclides due to leaks and accidents or contamination of offsite rainwater, groundwater, or drinking water above 400 picocuries per liter;

e) The lower limit of detection should be lowered to 200 picocuries per liter;

g) The NRC should require licensees to make public all health and environmental documents, including all raw measurement data and times of discharges.

Appendix A

List of reactors known to have leaked radioactive effluent

Compendium of Groundwater Events at U.S. Reactors, 1963 through February 2009, David Lochbaum, Union of Concerned Scientists:
http://www.beyondnuclear.org/storage/tritium_buriedpipes_groundwater_compendium_events_sorted_by_site.pdf [179]

Also see: Union of Concerned Scientists Leaks Tracker: http://www.ucsusa.org/nuclear_power/reactor-map/embedded-flash-map.html

Appendix B

Boiling Water Reactor buried and underground systems

According to the NRC, a BWR will typically have 27 buried and underground systems that carry licensed radioactive material in more than 150 segments. These are:

-Condensate System (17)

-Condensate Demineralizer System (1)

-Demineralized Water Storage and Transfer System (1)
-Diesel Fuel Oil System (1)
-Equipment and Floor Drains System (7)
-Feedwater System (3)
-Fuel Oil Storage and Transfer System (2)
-High Pressure Core Spray System (8)
-Liquid Waste Management System (15)
-Lube Oil System (1)
-Nonessential Service Water System (1)
-Offgas System (16)
-Plant Hot Water System (2)
-Reactor Core Isolation Cooling System (6)
-Sanitary Waste Processing System (1)
-Residual Heat Removal/Low Pressure Coolant Injection System (5)
-Turbine Building Closed Cooling Water System (2)
-Yard Handling and Maintenance System (4)

Other BWR systems that may carry licensed radioactive material

-Condensate Storage and Transfer System (20)
-Fuel Pool Cooling and Purification System (3)
-HP Heater and MSR Drains and Vents System (1)
-Low Pressure Core Spray System (4)
-Lube Oil Storage and Transfer System (3)
-Plant Exhaust System (4)
-Sludge Waste Dewatering System (1)
-Steam Extraction System (3)
-Ultimate Heat Sink System (2)

Pressurized Water Reactor buried and underground systems

The NRC identifies that a Pressurized Water Reactor will typically have 36 buried and underground systems that carry licensed radioactive material made up of as many as 306 segments that include:

-Auxiliary/Emergency Feedwater System (12)
-Auxiliary Steam System (8)
-Chilled Water System (4)
-Closed/Component Cooling Water System (5)
-Cooling Tower Blowdown (5)
-Condensate System (20)
-Condensate Demineralizer System (8)
-Condensate and Feedwater Chemical Control System (3)
-CVC/Makeup and Purification System (9)
-Demineralizer Water Storage and Transfer System (3)
-Equipment and Floor Drains System (16)
-Emergency/Standby Gas Treatment System (1)
-Essential Service Water System (10)
-Feedwater System (3)
-Fuel Oil Storage and Transfer System (2)
-Gaseous Waste Management System (6)
-High Pressure Spray Injection System (7)
-Insulating Oil System (1)
-Liquid Waste Management System (46)
-Nonessential Service Water System (9)
-Plant Hot Water System (2)
-Residual Heat Removal /Low Pressure Spray Injection System (12)Steam Generator Blowdown System (15)
-Turbine Drains and Misc. Piping Sys (8)

-Wastewater Disposal System (14)
-Yard Handling and Maintenance System (12)

Other PWR piping systems that may carry licensed radioactive material

-Condensate Storage and Transfer System (10)
-Fuel Pool Cooling and Purification System (4)
-Low Pressure Heater Drains and Vents System (1)
-Pumping Station Environmental Control System (1)
-Radwaste Building Environmental Control System (1)
-Sampling and Water Quality System (6)
-Solid Waste Management System (2)
-Tech. Support Center Environmental Control System (2)
-Turbine Building Environment Control System (3)
-Ultimate Heat Sink System (12)
-Containment Spray (3)
-Primary Water Storage and Transfer (5)
-Miscellaneous Oil Systems (1)
-Circulating Water System (9)

Appendix C

Congressman Edward Markey Requests Government Accountability Office (GAO) Investigation of NRC Oversight of Radioactive Leaks from Buried Pipes at Nuclear Power Plants[180]

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