The West Lake Landfill: A Radioactive Legacy of the Nuclear Arms Race

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West Lake Landfill image courtesy of stltoday.com

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Summary

The West Lake municipal landfill in Bridgeton, Missouri is not your ordinary solid waste landfill. By virtue of the highly radiotoxic wastes dumped there, it is a *de facto* nuclear waste disposal site – a legacy of the U.S. nuclear weapons program (see Figures 1 and 2). Created by illegal dumping in 1973, the waste residues originated from the Mallinckrodt Chemical Works in St. Louis which was involved in U.S. nuclear weapons program from the 1942 to late 1950s.[1] The landfill:

- contains a significant amount of radiotoxic waste s that are not adequately characterized, and that have the potential for mobility of these wastes due to groundwater fluctuation and comingled solvents; [2]
- is in a densely populated area and has no engineer ed barriers,
- is experiencing the latest of at least two subsurf ace fires over the past 21 years;[3] [4]and
- is on the alluvial floodplain approximately 1.2 mi les from the Missouri River in which the water table recurringly rises and falls by several feet, often within a few feet of the surface.

Even though these concerns were repeatedly raised with the U.S. Environmental Protection Agency (EPA)[56], and despite the extraordinary risks created by subsurface fires, the agency issued a Record of Decision in 2008 which allows for "in place disposal" of these wastes subject to institutional controls with a cap over radiologically contaminated areas. Despite the conclusion reached in 1988 by the U.S. Nuclear regulatory Commission that hazards of the wastes likely warranted removal and isolation,[7] it appears that EPA was inclined toward in-place disposal at least eight years before its decision to do this was formalized.[8]

Of significance is the fact that the largest estimated amount of thorum-230, a long-lived, highly radiotoxic element is present at West Lake - more than any other U.S. nuclear weapons storage or disposal site. Soil concentrations of radium-226 and thorium-230 are substantially greater than uranium mill tailing waste. (See figures 3 and 4). The waste residues generated at the Mallinckrodt site were found to contain the largest concentration of thorium-230 from any single source in the United States and possibly the world. [9] Thorium-230 concentrations were found to be some 25,000 times greater than its natural isotopic abundance.[10] With a half-life of 77,500 years, thorium-230 makes up more than 80% of the measured radioactivity in soil at West Lake above cleanup limits set by the Department of Energy (DOE) (see Figure 5). Moreover, as the thorium-230 decays to radium-226, it will increase the radioactivity in the landfill 10 to 100 times over a 9,100 year period.[11]

Given these circumstances, the West Lake landfill would violate all federal legal requirements, established over 30 years ago, for licensing of a radioactive waste disposal site.

Recommendations

Radiation protection of workers who enter on or near areas where radioactive waste was dumped should be mandatory, as they are at Energy Department and commercially licensed radioactive waste sites.

Finally, like other U.S. nuclear weapons legacy sites in the St. Louis, Missouri area, the U.S. Congress should seek to remove these radioactive materials and assure long-term stewardship

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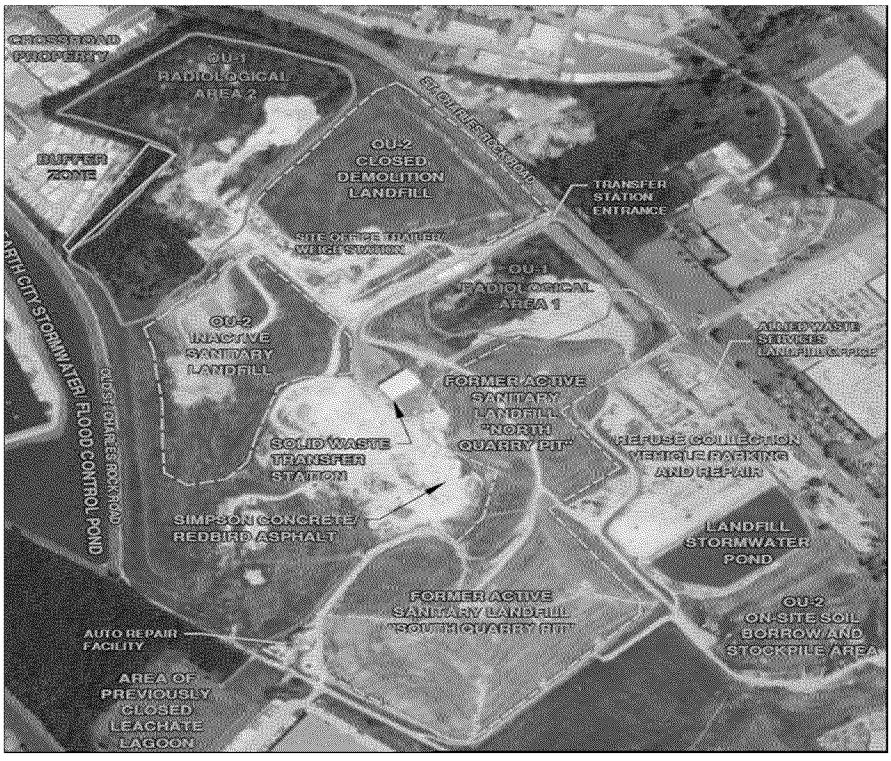
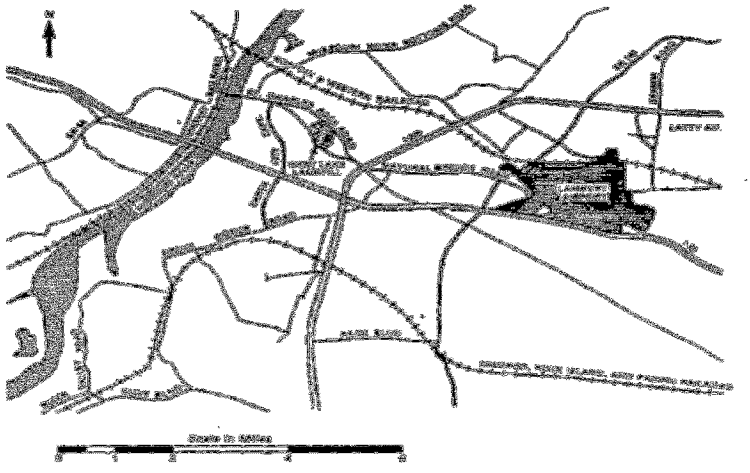
responsibilities under the Formerly Utilized Sites Remedial Action Program (FUSRAP) managed by the U.S. Army Corps of Engineers and the U.S. Department of Energy.

Figure 1 the West Lake Landfill



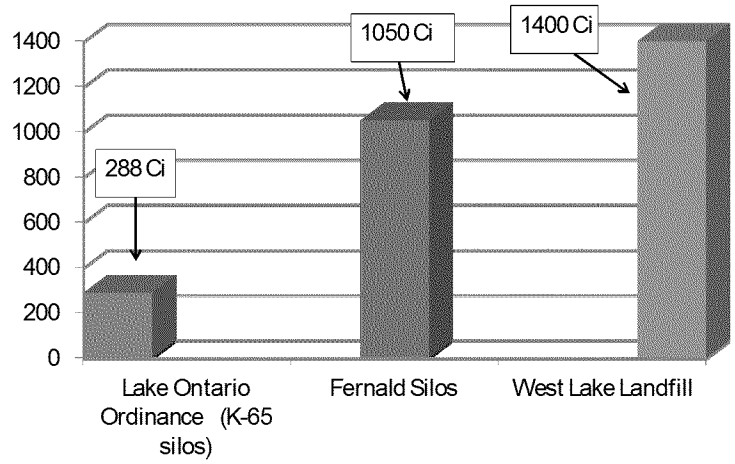
Source: EPA

Figure 2 Location of the West Lake Landfill



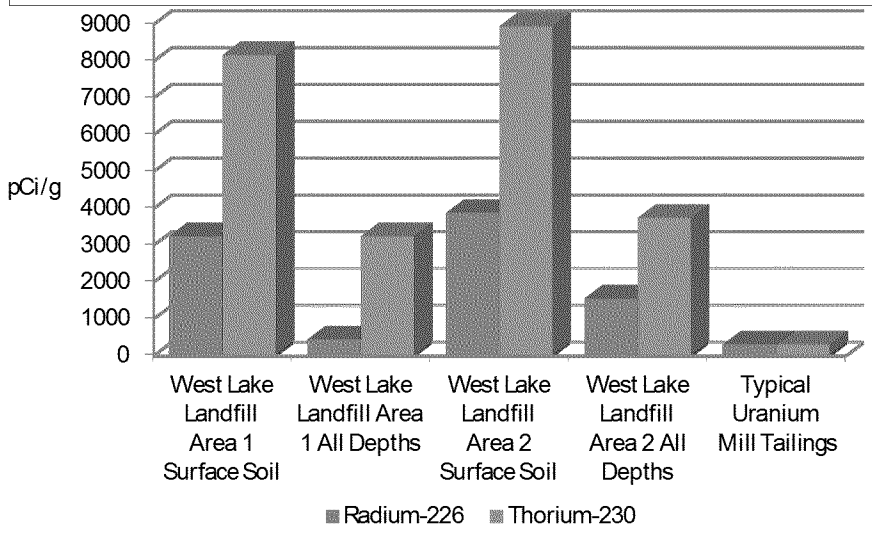
Source: NRC (1988)

Figure 3 Concentration of thorium-230 handled at US nuclear weapons sites.



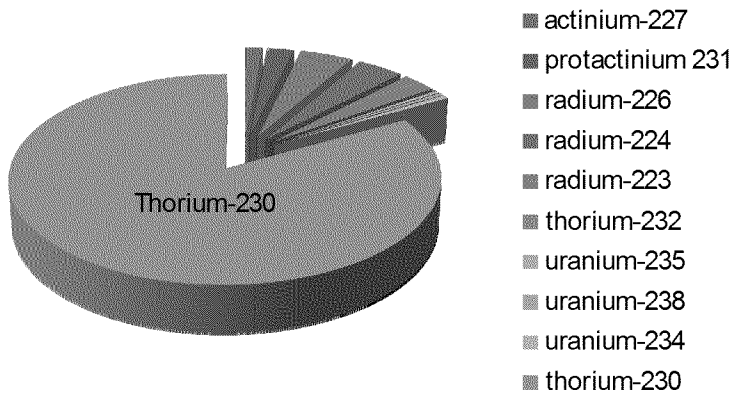
Sources: NAS (1995), (IEER 2006), NRC (1988)

Figure 4 Comparison of the concentrations of Ra-226and Th-230 at the West Lake Landfill with a typical uranium mill tailing pile.



Sources: EPA West Lake ROD (2008), EPA 520/1-83-0081 (1983)

Figure 4 Radioactivity in Soil Samples in the West Lake Landfill*



*Concentrations above 5 pCi/g

Thorium-230

With a half-life of 77,500 years, thorium-230 is about 60,000 times more radioactive than uranium. [12] It is categorized by the International Atomic Energy Agency (IAEA) as having "very high radiotoxicity."[13] *The International Commission on Radiation Protection recommends internal exposure limits for thorium-230 that are comparable to plutonium-239* (see Figure 6).[14] Thorium-230 emits highly energetic alpha particles, which are considered by the U.S. National Academy of Sciences to be 20 times more carcinogenic than x-rays. [15] As they lodge in the body, alpha particles from thorium-230 emit energetic ionizing radiation that can damage cells of sensitive internal tissues.

According to the National Institutes of Health, "the most likely pathway by which the general public is exposed to thorium is by ingestion of food items. Data also indicates that the general population may be exposed to thorium compounds via ingestion of drinking water and inhalation of ambient air."[16] This is of concern if thorium-230 in the landfill comes in contact with a fire and releases breathable particles into the air. Once it is absorbed in the body, thorium has a biological half-life of 700 days. Most of the thorium (70%) has been found to lodge on the bone surface (4% to the liver and 16% to other organs) where it effectively remains throughout a person's life. An assessment of the soils at the St. Louis Airport Site found that most respirable soil particles contained the highest levels of thorium-230. [17]

The mobility of thorium in soil is low. However, its mobility in the environment is enhanced when mixed with reagents and solvents. [18] There are 19 organic solvents identified by a 2000 risk assessment of the West Lake Landfill that are comingled with the disposed radionuclides.[19]

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Thorium-230 is also considered to have a relatively high bioaccumulation in aquatic organisms.[20]

The potential hazards to human health from internal exposure to thorium-230 have been a long-recognized concern by health and safety experts in the U.S. nuclear weapons program. During the 1950's, Mallinckrodt separated small quantities of thorium-230 on a laboratory scale. However, according to the National Institutes for Occupational Safety and Health (NIOSH) when asked by the U.S. Atomic Energy Commission (AEC) to establish a thorium-230 pilot plant, "Mallinckrodt refused, on the basis that the health hazards of thorium were not well understood." [21] Finally the "AEC agreed that the pilot plant would be built and operated as if it were to process plutonium and the pilot plant began operation at [Mallinckrodt] on 25 February 1956." By 1957, the Health Department at the plant "recommended that they do no further processing [of Th-230] under their existing conditions."[22] In 1959, experts at the Energy Department's Hanford site noted that thorium-230 is "in a class as hazardous as plutonium."[23]

In 1993 it was reported that, " a case study of 112 New Jersey households in the vicinity of a thorium waste disposal site found a higher prevalence of birth defects (relative risk 2.1) and liver disease (relative risk 2.3) among the exposed population than the unexposed group."[24]

Because of the removal of uranium at Mallinckrodt from the residues disposed at the West Lake site, radioactive decay products of uranium were highly concentrated. In particular, the high ratio of Thorium-230 to Radium-226 indicates that as thorium-230 decays, there will be a substantial "in-growth" of alpha radioactivity – meaning that the radioactivity in the West Lake landfill will increase by 10 to 100 times over a 9,100- year period. [25]EPA has selected only a 1,000 year time period to bound the risks associated with radium-in-growth from thorium-230 decay, when the maximum radium ingrowth occurs nearly 9,000 years later (See figure 7.)

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Figure 6

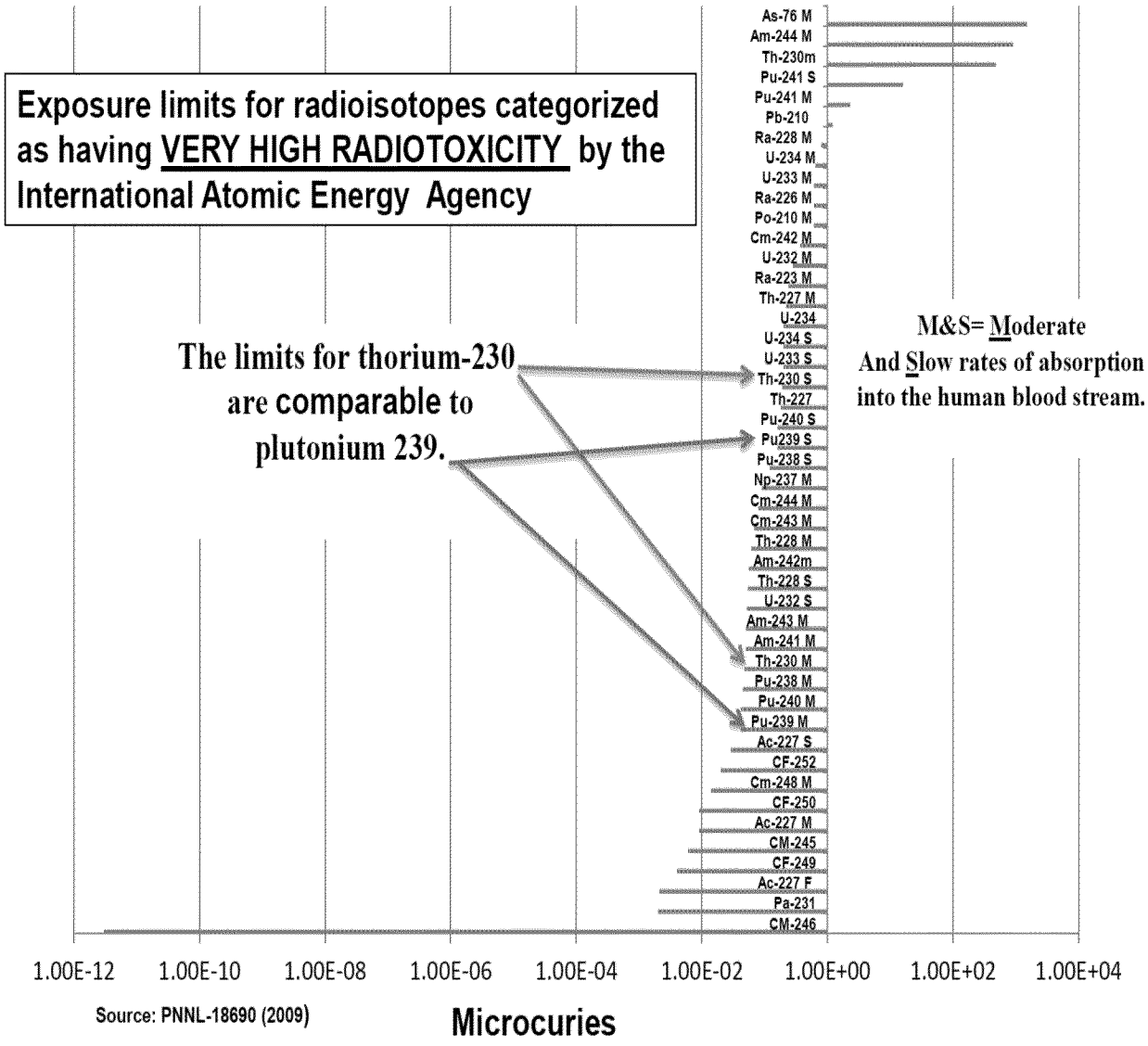
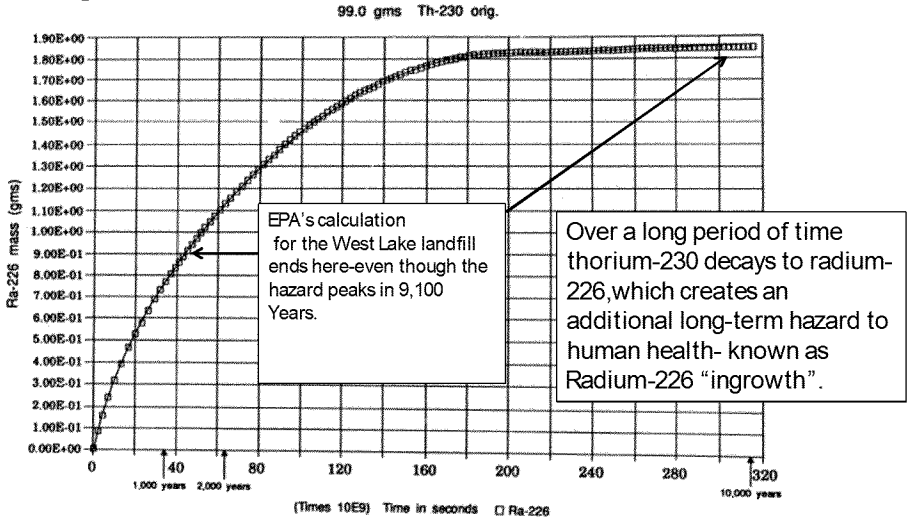

Exposure limits for radioisotopes categorized as having VERY HIGH RADIOTOXICITY by the International Atomic Energy Agency
The limits for thorium-230 are comparable to plutonium 239.
M&S= Moderate And Slow rates of absorption into the human blood stream.
As-76 M
Am-244 M
Th-230m
Pu-241 S
Pu-241 M
Pb-210
Ra-228 M
U-234 M
U-233 M
Ra-226 M
Po-210 M
Cm-242 M
U-232 M
Ra-223 M
Th-227 M
U-234
U-234 S
U-233 S
Th-230 S
Th-227
Pu-240 S
Pu239 S
Pu-238 S
Np-237 M
Cm-244 M
Cm-243 M
Th-228 M
Am-242m
Th-228 S
U-232 S
Am-243 M
Am-241 M
Th-230 M
Pu-238 M
Pu-240 M
Pu-239 M
Ac-227 S
CF-252
Cm-248 M
CF-250
Ac-227 M
CM-245
CF-249
Ac-227 F
Pa-231
CM-246
1.00E-12
1.00E-10
1.00E-08
1.00E-06
1.00E-04
1.00E-02
1.00E+00
1.00E+02
1.00E+04
Source: PNNL-18690 (2009)
Microcuries

Figure 7 RA-226 INGROWTH (GMS)



Source:DOE/NV/10630-58 Ingrowth of Ra-226 from 99 grams of Th-230 at time t=0 years.

Federal Requirements for a Licensed Radioactive Waste Landfill

Under current federal requirements for landfill disposal of radioactive wastes, which were adopted after the dumping occurred in the West Lake landfill, EPA's Record of Decision (ROD) would significantly violate federal standards for the selection of such disposal sites (10 Code of Federal Regulations Part 61). They include:

- The disposal site shall be capable of being characterized, modeled, analyzed, and monitored.
- The disposal site shall not be in the 100-year floodplain.
- The disposal site should provide a stable foundation for engineered containment structures.
- The disposal site should be selected so that projected population growth will not affect the disposal facility's ability to meet the performance objectives.
- Areas having known natural resources should be avoided.
- The disposal site must be well drained.
- The disposal site must provide sufficient depth to the water table.
- The disposal site must not be located where nearby facilities or activities could adversely impact the site's ability to meet the performance objectives or the ability to be monitored.

Although the West Lake Landfill contains significant amounts of long-lived radiotoxic wastes as comparable to federally licensed commercial radioactive waste landfills, it meets none of the above legal requirements for protection of the human environment.

Origin and Fate of the Wastes

The residue wastes disposed in the West Lake landfill were mostly generated from ore of the Shinkolobwe mine in the Belgian Congo. Described as a "freak occurrence of nature" by a top official of the early U.S. nuclear weapons program, [26] the Congo mine yielded the highest concentrations of uranium (30-70%)[27] of any mine found in the world since that time. [28] By comparison the Congo ore contained as much as much as 7,000 times the concentration of uranium mined in the United States (~1%).

Between 1942 and 1958, the Mallinckrodt plant in St. Louis processed approximately 50,000 tons of uranium of which roughly 40 percent (20,000 tons) were from the Shinkolobwe mine. [29] [30] [31] After the ore was processed to remove uranium and radium, about 133,007 tons of process waste residues and scrap resulted and were stored at the St. Louis Airport Site. Approximately 70 percent of the wastes stored at the Airport Site were from the Congo ore. Included in the waste residues were 32,500 tons of raffinate resulting from the processing of ore from the Colorado Plateau (see Table 1). Of greatest concern to human health are the radiotoxic decay products that were concentrated above their natural abundance. Among the most significant were thorium-230, radium-226, uranium-234, actinium-227 and protactinium-231.

In addition to uranium, hundreds of grams of radium were extracted. [32] Other highly radioactive Congo uranium wastes weighing 1,757 tons containing unrecovered radium generated at the Mallinckrodt plant were sent to the Ontario Ordnance Works in Niagara NY, and to the Fernald uranium foundry in Ohio, where they were neglected for decades.

In March 1962, the U.S. Atomic Energy Commission (AEC) offered up approximately 116,700 tons of waste residues stored at the St. Louis Airport Site for sale. They were purchased by the Continental Mining and Milling Company of Chicago, IL in April of that year for a price of $126,500.[33]

The wastes were subsequently moved to the Latty Avenue property in Hazelwood, MO. All of the wastes were deposited directly on the ground in 1966 and 1967. [34] After a turn-over in ownership, some of the residues were dried and shipped to Canon City, Colorado, by the Commercial Discount Corporation and the Cotter Corporation. In 1973, the remaining residues were removed from Latty Ave, and 12 to 18 in. of topsoil was transported to the West Lake Landfill in Bridgeton, Missouri.

The records documenting the disposition of the wastes sitting at the Latty Avenue site are fragmentary and incomplete. The waste piles were poorly characterized, and their uranium decay product concentrations are mostly based on limited samples taken at the Mallinckrodt plant, in the 1940's and early 1950s. [35]

What was Dumped in the West Lake Landfill?

An investigation by the St. Louis Post-Dispatch and the NRC indicate that records documenting how much volume, weight and types of radionuclides were sent to the West Lake Landfill were partial and based on anecdotal information. Other than relying on incomplete information, the EPA or the NRC did not perform an accurate mass balance of the source terms and fate of the Mallinckrodt waste residues.

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The top soil at the Latty Avenue site contained high levels of long-lived uranium decay products, *after*, the removal of a reported 39,000 tons of top soil over a wide area were mixed with the remaining wastes disposed at West Lake. Despite this evidence, how much of the other wastes were sent to the West Lake landfill remains unaddressed.

This problem was identified in a detailed review in March of this year by Robert Criss at Washington University in St. Louis. According to Criss:

> "No available reports mention any accurate analysis of the chemical, physical or radiological character of the radioactive materials dumped at West Lake." He finds that official judgments regarding the chemical composition of the wastes to be "simplistic and untrue" and concludes that a large amount, if not most, of the radionuclides at West Lake are not contained in barium sulfate, but instead are incorporated in other types of processing waste that could be more reactive, soluble and leachable than barium sulfate." [36]

According to the Nuclear Regulatory Commission, in July and August 1973, the B & K Company, under contract to the Cotter Corporation illegally dumped 8,700 tons of leached barium sulfate mixed with 39,000 tons of top soil from the Latty Avenue site at the West Lake Landfill. [37] The National Institute for Occupational Safety and Health described the wastes dumped in the West Lake Landfill as "the worst source" among the residues at the Latty Avenue site. "The gamma dose rates were highest from the 'aged' barium cake material.. Thus the assumption is made that the calculated doses can be based on barium sulfate as the maximal residue." [38]

In May 1974, AEC inspectors concluded that the Latty Avenue wastes were too radioactive to be dumped in the West Lake Landfill because they violated federal disposal standards. Inspectors noted that workers were instructed so that "the barium sulfate cake material was spread over a considerable portion of the site and then removed along with the top soil."[39] The AEC inspectors did not question the claim that the wastes dumped in West Lake were mixed with "clean" soil. [40] However, a considerable amount of evidence since the dumping indicates that highly contaminated materials –containing a composite mix of the wastes residues stored at the site were also sent to West Lake.

Top soil analysis taken during an Atomic Energy Commission –AEC (Now Nuclear Regulatory Commission) investigation of the Latty Avenue site indicated the significant presence of uranium and thorium-bearing residues. Several surveys subsequently found that the wastes disposed in the West Lake Landfill were not only leached barium sulfate materials, but also appear to be a composite of the other wastes at the Latty Avenue Site. After a significant amount of "topsoil" was removed, the remaining surface soil was hardly "clean" and was subsequently found to be highly contaminated. For instance:

- In 1976, the NRC found soil radioactive soil conce ntrations" exceeding NRC criteria for decontamination of land areas 'prior to return to unrestricted use."[41]

- Top soil measurements taken at the Latty avenue si te for the U.S. Nuclear Regulatory Commission in 1981, reported that, " thorium-230 levels in these soils were particularly high, ranging from ranging from110 pCi/g [picocuries per gram] to 84,000 pCi/g for

random samples. Biased samples ranged from 96,500 to180,000 pCi/g. The ratio of thorium-230 to radium-226 was as high as 290 to 1." T[42]

- In 1993, a risk assessment by the U.S. Energy Depa rtment reported a thorium-230 to radium-226 ratio in 9,713 cubic meters of top soil scraped into two piles at the Latty Avenue site of 157 to 1. The estimated dose to humans exposed at the point of concentration from Latty Avenue top soil was 28,000 millirem (more than 5 times the annual legal limit for radiation workers), with a fatal cancer risk of nearly 1 in 50.[43] Thorium-230 is responsible for 64 percent of the dose from the Latty Avenue topsoil (See tables 2 and 3).

These data are consistent with the NRC's estimate of a high ratio of th-230 to ra-226, which creates significant radium-226 ingrowth, rather than EPA's much lower estimate.[44]

The Roles of U.S. Atomic Energy Commission and Nuclear Regulatory Commission

The wastes dumped into the West Lake Landfill were subject to direct control and nuclear regulation by the U.S. government under the Atomic Energy Act for 53 years. Generated and owned by the U.S. nuclear weapons program beginning in 1942, the wastes were sold for commercial use in 1962. After that they were subject to federal licensing and nuclear safety regulation as "source materials" under the Atomic Energy Act.

Ownership of the wastes changed hands three times requiring three separate licenses to be issued by the Nuclear Regulatory Commission (NRC) and its predecessor, the U.S. Atomic Energy Commission (AEC). *When the license was relinquished in 1974, the NRC assumed responsibility for decommissioning of the West Lake Landfill and considered it to be among its top ten sites requiring a higher-level of attention and resources than several other defunct sites.* In 1995, the NRC ended its control over the wastes in the West Lake Landfill by transferring responsibility for their disposition to the U.S. Environmental Protection Agency's Superfund Program.

During this period (1974-1994), the AEC and then NRC, which regulated the "source materials" dumped there, conducted four publically available inspections and investigations of West Lake Landfill and the Latty Avenue site, several radiological surveys, and developed plans for remediation.

- The first in 1970 found that exposure monitoring s amples to protect workers "were totally inadequate to detect concentrations of radioactive materials to which persons are exposed."[45]

- In November 1974, an AEC inspection reported that 8,700 tons of barium sulfate wastes containing 7 tons of uranium and unmeasured quantities of uranium decay products, were mixed with 38,000 to 39,000 tons of top soil from the Latty Avenue site and disposed by trucks in the "St. Louis Sanitary Landfill Area No. 1on Old Bridge Road over the period July 31 through October 1973." The inspection found that disposal of these

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materials was in violation of federal standards in a "manner not authorized" by the AEC.[46]

- In July and August 1976, the NRC conducted a follo w-up investigation after the St. Louis Post Dispatch reported that, "a St. Louis-area construction firm has dumped several thousand tons of low-level radioactive waste in a St. Louis County Landfill under circumstances that confused federal authorities about the strength and location of the waste...."[47] The article also noted that no one in a position of authority "actually saw or tested the material B&K moved to the landfill." The NRC investigation found that the location and depth of the disposal were in error. The West Lake Landfill was the actual disposal site and that the radioactive residues were not covered by 100 feet of refuse. The report concluded that 8,700 tons of barium sulfate residues and 39,000 tons of top soil scraped at the Latty Avenue Site were mixed in. "The Latty Avenue surveys showed radiation levels exceeding NRC criteria for decontamination of land areas 'prior to return to unrestricted use.' "[48]

- From 1979 to 1993, the NRC and the U.S. Energy Dep artment conducted several radiological surveys, which indicated that: (a) two areas in the landfill contained high-levels of uranium decay products – with particular concerns over the long-term hazards associated with thorium-230 and radium-226; and (b) [49] top soil transported to the West Lake Landfill contained high concentrations of radiotoxic uranium decay products, principally thorium-230.

- *In 1988, the NRC staff issued a report on West Lake Landfill which, concluded that the wastes represented a significant long-term hazard and "will likely require moving the material to a carefully designed and constructed 'disposal cell.' "* in support of this conclusion the NRC reported, among other things:

> "(1) There is a large quantity (on the order of 150,000 tons) of soil contaminated with long-lived radioactive material in the West Lake Landfill. Almost all the radioactivity consists of natural uranium and its radioactive decay products.
>
> (2) Based on the radiological surveys, the radioactive wastes as presently stored at the West Lake Landfill do not satisfy the conditions for Options 1-4 of the NRC's Branch Technical Position (BTP) regarding the disposal of radioactive wastes containing uranium or thorium residues.
>
> (3) A dominant factor for the future is that the average activity concentration of Th-230 is much larger than that of its decay product Ra-226, indicating a significant increase in the radiological hazards in the years and centuries to come.
>
> (4) Some of the radioactive material on the northwestern face of the berm has no protective cover of soil to prevent the spread of contamination and attenuate radiation.
>
> (5) Slightly more than 8 acres of the site exceed 20 urn [microreontgens] per hour; the highest reading of 1600 uR per hour occurs near the Butler-type building.

(6) Radon and daughters were measured at 0.031 WL [working level]s in and around the Butler-type building. This exceeds the BTP [Branch Technical Position- NRC's public exposure limit]…"

(7) Based on monitoring-well sample analyses, some low-level contamination of the groundwater is occurring, indicating that the groundwater in the vicinity is not adequately protected by the present disposition of the wastes.

(8) Although these radiological conditions indicate that remedial action is needed, it is unlikely that anyone has received significant radiation exposures from the existing situation.

(9) Sampling results show that chemically hazardous materials have been disposed of adjacent to or possibly mixed with the radioactive material. It is possible that part of the radioactive material has become "mixed" [both radioactively and chemically hazardous] waste."[50]

- *By 1990, after a Congressional investigation, the NRC listed the West Lake Landfill as one of 7 out of 30 sites as "Level A" requiring "priority attention in use of NRC resources for completion of decommissioning."*[51]

- In 1994 an inspection report by the Nuclear Regula tory Commission concluded that the West Lake landfill "contains significant quantities of residual contamination which was the result of disposal of licensed material."[52]

- By 1995, the NRC transferred responsibility for th e illegally disposed radioactive wastes to the U.S. EPA stating, "the program being administered by EPA is adequate to protect the public and the environment from the risks associated with radioactive contamination. NRC therefore believes that its oversight of remediation at the site, in addition to that of EPA, would be burdensome and duplicative."[53]

Meanwhile, after Congressional action in 1997, the Army Corps of Engineers took over responsibility for the cleanup of all of the designated sites contaminated by uranium residues processed at the Mallinckrodt plant in St. Louis, except for the West Lake Landfill.

EPAs Record of Decision Regarding the West Lake Landfill

The United States Environmental Protection Agency (EPA) issued a Record of Decision (ROD) in 2008 under its Superfund authority to allow for "in-place" disposal, augmented by institutional controls and the placement of a cap made from clay, rocks and rubble from construction materials over the radiation contaminated areas. EPA has indicated that its National Remedy Review Board overseeing Superfund projects has requested further data be collected regarding the potential removal of some of the radioactive wastes. [54]

In 2000, the Nuclear Regulatory Commission noted that the EPA "will utilize cap or cover rather than soil cleanup criteria" at the West Lake Landfill - eight years before EPAs ROD was made public. "If remediation were required, the EPA would rely on standards set for cleanup of uranium mill tailings (40 CFR192)".[55]

tailings (40 CFR192).[56]

Unlike the NRC, which operates under the principal of hazard characterization, EPA uses exposure scenarios. Based on EPA's risk assessment done in 2000,[57] EPA's ROD assumes that the primary risks over a 1,000 year period will be to landfill groundskeepers, adjacent building occupants, and storage yard workers over the age of 19 years. By contrast, the Energy Department requires waste performance assessments involving substances such as Th-230 to include the public and scenarios involving intruders.[58] A much smaller inventory of thorium-230 (2 curies) was sent to the DOE's Nevada National Nuclear Security Site in Nevada from the Fernald Ohio site in 1992, which required analysis extending out 10,000 years. [59]

In response to concerns raised about the long-term stewardship challenges associated with the radioactive wastes at the West Lake site, EPA states it "has had success locating land records in Missouri dating back to the early 1800s. Modern record keeping has greatly improved, and electronic record keeping has revolutionized the availability of data once difficult to locate and read. Many historic records have been transferred to electronic media." [60]

With respect to the EPA's decision to require a cap over the radiologically contaminated areas, EPA states: "the challenge is no greater at the Site than it is at various Superfund sites or other waste sites where long-lived radionuclides, heavy metals, or other nondegradable waste materials will be permanently disposed or managed in place…. Most of the engineering measures used at the Site will continue to be effective even in the event that institutional control becomes ineffective. The conceptual design of the landfill cover identified in the Selected Remedy relies on natural materials rather than synthetics."[61]

By contrast, the National Academy of Sciences (NAS), which was tasked to assess long-term stewardship at nuclear weapons sites, informed the Energy Department in 2000 that,*"… the likelihood that institutional management measures will fail at some point is relatively high.... reliance on engineered barriers and institutional controls—are inherently failure prone…Other things being equal, contaminant reduction is preferred to contaminant isolation and the imposition of stewardship measures whose risk of failure is high...much of our current knowledge of the long-term behavior of wastes in environmental media may eventually be proven wrong."* [62]

In 1986 the NAS also reported that: "the 80,000-year half-life of 230Th, the principal long-term precursor of radon in the uranium mill tailings, is very long, not only in comparison with recorded human history but also in comparison with the times in which substantial changes in the landscape occur owing to natural processes of erosion." [63]

The radioactive wastes at West Lake are considered by the NRC and EPA to be "technologically enhanced naturally occurring radioactive materials" (TENORM), which are not subject to formal federal regulations issued by the EPA or NRC. Instead EPA is "developing and providing education and guidance for safely and economically controlling exposures to TENORM wastes."[64]

On the contrary, because of their unique origin and hazardous properties, the Department of Energy and the Corps of Engineers do have specific regulatory requirements governing the wastes dumped in the West Lake Landfill,[65] which the EPA has chosen to not apply.

Table 1 Residues Stored at the St. Louis Airport Site

Material Name	Code	Max. Inventory (tons)	Uranium Inventory (tons)	Materials Received (years)	Materials Removed (years)
Pitchblende Raffinate	AM-7	74,000	113.2	1946-1955	1966-67 (a)
Colorado Raffinate	AM-10	32,000	47.6	1946-1955	1966-1967 (a)
Barium Sulfate Cake	AJ-4	1500	20	1946-1955	1966-67(a)
Barium Sulfate Cake (leached of radium)	AJ-4	8,700	7	1946-1955	1966-67(a)
Radium Bearing Residues	K-65	1,157	4.6	1946-1948	1948-1949 (b)
Vitro Residues	C-6	290	1.9	1954	1966-1967 (a)
Interim Residue Plant Tailings	C-701	4,000	239	Late 1950s	1959 (c)
Captured Japanese Uranium-containing sand	V-10	60	0.2	1954	1966-67 (a)
C-Liner Slag	None	7,800	122.3	1946-1953	1956 (d),1966-1967 (a)
Scrap Metal	None	3,500	Unknown	1946-1959	1962 (e)

Source: NIOSH (2009)

(a) Sent to Latty Avenue site in Hazelwood, MO.
(b) Sent to Fernald, OH uranium plant and Ontario O rdinance Plant in NY.
(c) Sent to the Fernald, OH plant for processing.
(d) Sent to Fernald, OH uranium plant for processin g.
(e) Sold and removed from the site.

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Table 2. Radionuclide Concentrations in the Composite Samples from the Hazelwood Storage Piles (pCi/g)

Radionuclide	Composite 1	Composite 2	Composite Average
Actinium-227	205	Not analyzed	205
Protactinium-231	114	117	116
Radium-226	64	117	116
Radium-228	2.3	1.5	1.9
Thorium-228	2.1	117	2.1
Thorium-230	8770	8950	8860
Thorium-232	2.3	1.5	2.1
Uranium-235	3.6	4.4	4.0
Uranium-238	82	62	72

Source: DOE/OR-23701-41.1(1993)

Table 3. Estimated Dose and Fatal Cancer Risk from the Contaminated Hazelwood Soil Piles

Radionuclide	Exposure Point of Concentration (pCi/g)	Dose (mrem)	Fatal Cancer Risk
Actinium-227	200	6,800	4.1E-03
Protactinium-231	120	3,000	1.7E-03
Radium-226	57	79	4.7E-05
Radium-228	1.9	2.9	1.7E-06
Thorium-228	2.1	6	3.6E-06
Thorium-230	8,900	18,000	1.1E-02
Thorium-232	1.9	20	1.2E-05
Uranium-235	4	2.3	1.4E-06
Uranium-238	72	41	2.5E-02
Total		28,000	1.7E-02 (~1/50)

Source: DOE/OR-23701-41.1(1993)

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