APPENDIX I

DEPLETED URANIUM & RADON, CMI REPORTS

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NRC- Uranium Dose Estimating- Fires, Smelting, Respirable Lab Spills

Starmet CMI Plant Closing

Utah DPH DU Radon Link

NRC DU Radon Link

SC Administrative Law Court Decision re. Starmet (NMI) 2001-2002

Dumping on History – a radioactive nightmare in Concord, MA,
The Environmental Magazine / Jan-Feb 2004

M. Ragheb, Health Physics, Chapter 13 – DU and Its Health Physics

Massachusetts Dept. of Public Health Web Site Search Results
"Uranium Movement at the NMI/Starmet Site", Radioactive Waste Management Associates, September 2000 (hardcopy excerpts and full copy pdf file on CD)
Numerous referenced documents and reports by DEP, GZA, CFR, EPA and others

WISE Uranium Project – Fact Sheet
Hazards from depleted uranium produced from reprocessed uranium
First published – January 16, 2001 last revised – June 17, 2005

WISE Uranium Project
Composition of the US DoE Depleted Uranium Inventory
Revised June 17, 2005

excerpts from 162 Page Doc on CD-ROM

A.1 GENERIC ACCIDENT METHODOLOGY

A.1.1 Introduction

A generic methodology was developed to estimate radiation doses from accidents involving Nuclear Regulatory Commission (NRC)-exempted products and materials. The methodology includes the following accident exposure scenarios: (1) fires involving the release of radioactive materials from all types of products, (2) mechanical resuspension of radioactive material during cleanup after a fire, (3) spills of radioactive materials in liquid or powder form, and (4) crushing of glass tubes containing radioactive gases.

For these selected accident exposure scenarios, radionuclide-specific dose-to-source ratios (DSRs) are calculated. The DSRs give the radiation dose associated with a unit quantity of the radioactive material at risk in an accident. In the derivation of the DSRs, the methods and parameter values used in prior assessments addressing similar issues were used when applicable. The methods and parameters used in the development of this generic methodology are discussed and used in the derivation of the DSRs for a variety of radionuclides in many exempted products. Because of the broad range of exemptions, it has been necessary to estimate radiation doses for some exempted products or materials on a case-by-case basis when the DSR methodology is not applicable. In some instances, radiation doses have also been estimated on a case-by-case basis using better data when available for a specific accident exposure scenario and product of interest.

A.1.2 Airborne Concentrations

Airborne concentrations of radioactive materials during an accident and cleanup following an accident are estimated using two equations. For the instantaneous release of radioactive materials during an accident, the average airborne concentration (microcurie (μCi)/m^3) is given by

$$C = \frac{Q}{Vkt}(1 - e^{-kt}) , \qquad (1)$$

where Q = amount of radioactive material (μCi) released at $t = 0$,
k = ventilation rate (h^{-1}),
t = time over which C is averaged (h), and
V = volume of air into which material is dispersed (m^3).

For cleanup following an accident involving fire, the average airborne concentration (μCi/m^3) is given by

$$C = K \times S , \qquad (2)$$

where S = level of contamination on a surface (μCi/m^2), and
K = empirically determined factor for mechanical resuspension of respirable size particles (m^{-1}).

A.1.7.1 Radiation Dose From Inhalation During an Accident Involving Fire

For completeness, three types of fires are considered: (1) warehouses belonging to manufacturers or distributors that may contain large numbers of exempted products, (2) transportation accidents in which a few cartons or pallets of exempted products are involved, and (3) residences in which only a few exempted products are involved (see Tables A.1.4 through A.1.6). In many of the previous assessments, residential and warehouse fires have been considered, but not transportation fires. Transportation fires were included here because many exempted products may be shipped to vendors or consumers without being stored in large numbers.

For transportation accidents occurring indoors (i.e., storeroom or cargo-handling bay) or outdoors (i.e., transportation vehicles) and involving fire, the IAEA (SS No. 7) estimates that the inhalation intake during a 30-minute period following the start of the fire ranges from about 0.01 to 0.1%. The IAEA recommends the use of an intake factor, I, of 1.0×10^{-3} Q for a firefighter or bystander in the plume of smoke from the fire. It is assumed that a bystander would not stand in the plume of smoke from a fire and that a firefighter who is in the plume from the fire would wear a supplied-air respirator. Hence, an inhalation intake factor, I, of 8.6×10^{-7} Q is used, based on the average concentration in the air of a storeroom or cargo-handling bay for 30 minutes following the start of a fire and the use of a supplied-air respirator with a protection factor of 1000 (see Table A.1.3).

The first column of Table A.1.4 presents the DSRs used in this report for a firefighter at a transportation accident involving a fire. The equation for calculating the DSRs (rem/μCi or rem/mg) is obtained using Equations (3) and (4) and is given by

$$DSR = 8.6\times10^{-7} \sum_i DCF_i \times RF_i \times A_i \,, \qquad (7)$$

where DCF_i = dose conversion factor for inhalation of a radionuclide i (rem/μCi),
RF_i = release factor for a radionuclide i (unfitness), and
A_i = activity of each radionuclide i (μCi) per 1 μCi of a parent byproduct material or 1 mg of a parent source material.

The DSRs developed here are based on a release factor, RF, of 100% for gases (e.g., tritium (^{3}H) and ^{85}Kr) and 0.1% for solids, powders, or liquids (see Table A.1.1). If a solid is contained in a protective device (e.g., ^{241}Am in a smoke detector), the DSRs for inhalation of solids in the first column of Table A.1.4 should be reduced by a factor of 10.

For warehouse and residential fires, the same equation as above is used, except for the numerical constant. The numerical constant used for a residential fire was 1.0×10^{-6} and that used for a warehouse fire was 1.6×10^{-7}. These constants are based on the inhalation intakes, I, given in Table A.1.3 for a ventilation rate of 1 volume change per hour in both a residence and a warehouse. It should be noted from the data in Table A.1.3 that a ventilation rate of 1 air change per hour will predict the inhalation intake, I, to within a factor of 2 over the wide range of ventilation rates expected for residences (EPA Contract No. 68–D9–0166) and warehouses (ASHRAE, 1991). Warehouses are usually not air conditioned, but they are often heated and ventilated sufficiently to provide a tolerable working situation. The DSRs developed here for

In this assessment, recovery and recycling of items containing exempted amounts of radioactive materials are assumed to occur only for the purpose of recovering ferrous metals and alloys (e.g., steel). This assessment is not concerned with recycling of exempted items when the intent is to recover and reuse the radioactive material itself, because (1) this activity is not a form of disposal, (2) it normally would not result in the introduction of radioactive material into some other product as incidental contamination, and (3) it would be carried out by licensees of the Nuclear Regulatory Commission (NRC) or an Agreement State.

For exempted items that could be assumed to be recycled for the purpose of recovering ferrous metals, the items are assumed to be sent to a metal (i.e., steel) smelter. The following three groups of individuals are assumed to be exposed: (1) workers at smelters, (2) off-site members of the public residing near smelters, and (3) members of the public who use recycled products containing radioactive material. Assumed exposure pathways for these groups are described in the following paragraphs.

A.2.2.3.1 Smelter Workers

Based on a previous assessment (Hill et al., 1995), the individuals at metal smelters who are assumed to receive the highest doses are slag workers. These workers are assumed to receive exposures from the following three pathways: (1) external exposure to radionuclides in slag, (2) inhalation of radionuclides emitted from slag into the air, and (3) ingestion of radionuclides in slag.

A.2.2.3.2 Off-Site Members of the Public

Off-site members of the public who reside near smelters are assumed to receive exposures from stack releases of radionuclides into the air following smelting and subsequent atmospheric transport to off-site locations. The assumed exposure scenario and exposure pathways for airborne releases from a smelter are the same as those described in Appendix A.2.2.1.3 for airborne releases during landfill operations. Therefore, off-site residents are assumed to receive exposures from the following four pathways: (1) inhalation of airborne radionuclides, (2) external exposure to airborne radionuclides, (3) external exposure to radionuclides deposited on the ground surface, and (4) ingestion of food products contaminated by deposition onto the ground surface.

A.2.2.3.3 Users of Recycled Products

Members of the public are assumed to receive exposures during use of products containing recycled metal. During use of contaminated products, members of the public are assumed to receive exposures from the pathway that involves external exposure to radionuclides in the product. Inhalation and ingestion of radionuclides in recycled metal products would not normally occur (Hill et al., 1995) and, thus, is not considered in this assessment.

A.2.3 Dose Assessment for Disposal in Landfills

This section presents the models and parameter values for estimating individual and collective doses from disposal of radioactive material in municipal landfills, and the results of the dose assessment in the form of doses per unit activity of radionuclides disposed in all landfills

For uranium, only the short-lived decay products that would be in activity equilibrium with the parent uranium isotopes at times shortly after chemical separation are considered in this assessment. Therefore, the dose from inhalation of ^{222}Rn is not considered, because the parent radionuclide ^{226}Ra builds up in the waste only at times long after chemical separation.

A.2.3.5.3 Ingestion Exposure to Individuals

The annual EDE to an individual on-site resident from ingestion exposure is estimated using a model of the form given by Equation (3) in Appendix A.2.3.1.3. Therefore, taking into account the buildup and decay of radionuclides disposed over the operating lifetime of the landfill, T_L, as in Equation (6), and the time between landfill closure and the onset of permanent residency, T_C, as in Equation (12), the annual individual dose, H_i, from an annual disposal of a unit activity, A_i, of 1 μCi (37 kBq) of each radionuclide i in all landfills is given by

$$H_i/A_i\ (rem/\mu Ci) = (1/N_L) \times (1/\lambda_{R,i})\,[1 - exp(-\lambda_{R,i} T_L)] \times (1/M_w T_L) \times U_{ing} \times T \times D_{ing,i} \times exp(-\lambda_{R,i} T_C)\,, \qquad (14)$$

where the various parameters are defined with Equations (2) to (6) and (12).

The assumed number of operating landfills, N_L, and the values of the mass of waste disposed in a landfill annually, M_w, and the ingestion dose coefficient, D_{ing}, for each radionuclide are described with Equations (2) to (4). The operating lifetime of the landfill, T_L, and the time delay before onset of permanent residence, T_C, each are again assumed to be 30 years. Assumed values of the other parameters in Equation (14) are described as follows:

- The ingestion rate of waste, U_{ing}, was 4×10^{-3} g/h, which is a value appropriate for residential ingestion of soil and dust (EPA, OSWER Directive 9285.6–03).

- The exposure time was 440 h/yr, based on an assumption that ingestion exposure occurs mainly during outdoor residence on the site and that the fraction of the year during which exposure occurs outdoors is 0.05 (EPA/600/P–95/002Fa).

A.2.3.5.4 Collective Dose for Future On-Site Residents

As discussed at the beginning of Appendix A.2.3.5, the collective dose for future on-site residents at a landfill is calculated for 1 year's disposals of a unit activity of each radionuclide, rather than the annual disposals over the operating lifetime of the landfill. In this assessment, the disposals are assumed to occur in the last year of operations. Therefore, the annual individual dose from 1 year's disposals used in the calculation of collective dose is obtained from Equations (12) to (14) by omitting the term describing the buildup and decay of activity during the operating lifetime of the landfill, T_L. This approach essentially distributes the year's disposals over the entire landfill.

The calculation of collective dose for future on-site residents at landfills is based on the individual dose calculated as described above and the following assumptions. First, the number of residents at each landfill site, based on the average density of suburban populations in the

Chapter 13

DEPLETED URANIUM AND ITS HEALTH PHYSICS

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13.1 INTRODUCTION

Depleted Uranium, DU is what is left as tailings from the fuel enrichment process used in different types of reactor designs for land-based applications and nuclear propulsion, as well as nuclear weapons. In the enrichment process, the uranium fuel has its isotopic content in the isotope U^{235} increased from its natural atomic abundance of 0.72 percent to higher levels suitable to the particular application. The increase is to 3-5 percent for light water reactors applications, to 10-20 percent for fast reactors applications, to 93.5 percent for nuclear warheads applications and from 40 to 97.3 percent for naval reactors and space reactors applications. The tailings of depleted uranium range from 0.2 to 0.3 percent in the U^{235} isotope.

Because of its high density it has been used in recent conflicts in both anti armor projectiles and as protective armor against conventional as well as depleted uranium rounds. Figure 1 shows the Abrams M1 tank which uses depleted uranium armor plates and depleted uranium munitions.

Figure 1. The USA Abrams M1 tank uses depleted uranium armor plates and fires depleted uranium munitions.

Combatants are exposed to its effects during conflict, and noncombatants should be educated about its potential radiological and chemical toxicity after the end of the conflict. Combat vehicles exposed to, or destroyed by depleted uranium munitions should be decontaminated or decommissioned and properly disposed-of at the end of a conflict. Areas exposed to depleted uranium munitions in combat, training purposes, or accidental fires or explosions, need to be identified and either isolated or decontaminated. Individuals exposed to

dose if the depleted uranium rounds are handled. Thus direct contact with depleted uranium should be avoided for extensive periods of time. This includes trophy taking by combatants or inadvertent collection by unsuspecting civilian population and usage for other purposes in areas of past conflicts.

Table 5: Average effective doses from exposure to radiation in cSv, rem.

Source	Effective dose cSv, rem
Annual maximum allowable occupational effective dose	5
Annual maximum allowable dose, member of the public	0.5
Annual maximum allowable dose, member of the public at large	0.170
Global average exposure to natural sources	0.240
Range of global exposure depending on location	0.1-1.0
Average USA exposure from natural and medical sources	0.360
Average exposure from nuclear power plants operation	0.00002
Exposure from a typical chest X-ray	0.010
Surface dose from depleted uranium, 20 hours contact time	5.0
Tank crews, non surface dose, 20 hours mission time	0.005

AGED DEPLETED URANIUM

As depleted uranium is stored for years, other members of the decay chain should be expected to start appearing. Figure 14 shows a storage yard for cylinders containing depleted UF6 at the Portsmouth enrichment plant in Ohio.

Figure 14. Concrete-floor storage yard for depleted uranium UF_6 cylinders at the Portsmouth, Ohio enrichment plant.

Depleted uranium health physics aspects would then become similar to those applied to uranium in general.

Thorium^{230}, a daughter of U^{238} decays into Radium^{226}, the common isotope of radium. It decays in turn into Radon^{222}, which can escape to the atmosphere since it is gaseous at room temperature. Radon^{222} has a half-life of 92 hours and it decays into Polonium^{218}, which is now a solid product with a half-life of 3 minutes. In turn, polonium^{218} decays into Lead^{214}, then Bismuth^{214}, and Polonium^{214}. All of the latter are solid elements with short half-lives, and consequently high activity levels, as shown in Table 6. Polonium^{214} decays into Lead^{210}, which has a comparatively long half-life of 20 years. This group of radionuclides is referred to as the short-lived daughters of Radon. Since radon has a short half-life itself, these daughters are present whenever radon is present.

The solid daughters of radon tend to deposit themselves on small dust particles and droplets of moisture present in the air. If air containing radon gas and its decay products is breathed, the solid daughter nuclides are retained by the interior lining of the lungs. Here the emission of short-range alpha particles from Polonium^{218} and Polonium^{214} can cause damage to the alveolar tissue that can lead to the development of lung cancer.

The effect of the beta particles emission from Lead^{214} and Bismuth^{214} is minimal compared with the effect of the alpha particles. Lead^{210}, the daughter of Polonium^{214}, decays slowly with low activity and emits beta particles. Radon as a gas does not remain for long in the lung. Thus the main hazard results from the short-lived solid daughters that are deposited in the lungs.

Since the half-life of Uranium^{238} is 4.5 billion years, it is very long compared to that of its daughters. Consequently, a state of secular equilibrium is attained in the course of time. In this equilibrium state, equal numbers of nuclei of the radioactive members of the chain disintegrate per unit time. This means that they decay with the same activity level. Consequently equal numbers of curies or Becquerels of each daughter exist at any given time under equilibrium. Equilibrium here occurs if the radon gas does not escape, such as in uranium ores or solid parts of depleted uranium munitions.

Table 6. Radon and its daughters in aged depleted uranium.

Isotope	Radiation	Half life
Radon^{222}	α	92.00 h
Polonium^{218}	α	3.05 m
Lead^{214}	β, γ	26.80 m
Bismuth^{214}	β, γ	19.70 m
Polonium^{214}	α	2.70×10^{-6} m
Lead^{210}	β	20.00 a

MIXED SOURCE DEPLETED URANIUM

Mixed source depleted uranium is a mixture of natural depleted uranium from the enrichment process, and recycled uranium from reprocessing: the latter possibly containing fission products and transuranic elements; both potential health hazards.

FindArticles / Reference / E: The Environmental Magazine / Jan-Feb, 2004

Dumping on history: a radioactive nightmare in Concord, Massachusetts

by Ed Ericson, Jr.

Comments

The waitress at the ice cream shop in Concord: Massachusetts was surprised. "A Superfund site?" she asked, incredulous, "on Main Street?" Not just a Superfund site--a Superfund site that a cleanup contractor has dubbed "near the tip of the peak in terms of [cleanup] difficulty." A radioactive Superfund site.

Concord, the crucible of the American Revolution, where the "shot heard 'round the world" rang out on April 19, 1775, is a Boston suburb filled with professionals and stately homes. Tourists still come to see the war sites, and to visit the bucolic Walden Pond that Thoreau celebrated.

Few know about the nuclear waste dump at 2229 Main Street. But this shady burg of 15,000 residents quietly struggles with its legacy as the maker of depleted uranium slugs for the U.S. military's latest wars. The soil more than a mile from the nuclear dump is radioactive. A 1993 epidemiological study found the town's residents suffered higher rates of cancer than the state average.

Today, atop and buried beneath a low hill above a cranberry bog, more than 3,800 barrels of radioactive and toxic waste lie, subject to a governmentpaid cleanup estimated to take 10 years and cost at least $50 million.

The company responsible for most of the waste, Starmet, declared bankruptcy in 2002. Massachusetts has sued Starmet and several related companies to enforce state laws against radioactive dumping, but so tar has had little success on the legal front. The Environmental Protection Agency (EPA) hastily concluded that Starmet was broke and has made no move to charge it for the pending cleanup.

"All of the people who benefited and made millions from the process are not being tagged at all with the cleanup process" says Mark Roberts, an environmental lawyer and member of Citizens Research and Environmental Watch (CREW), a citizens group that has fought to get the site cleaned up for more than 20 years.

Since 1958, Starmet (formerly known as Nuclear Metals) processed depleted uranium into tank shells and armor for the U.S. Army, using caustic acids, beryllium and other dangerous substances. From the early 1970s until 1985, the company dumped depleted uranium into an unlined lagoon on the property, sending a toxic plume of radiation, heavy metals and solvents migrating into the groundwater, fouling at least two wells. The company resisted pressure to clean up the lagoon until 1997, when the pond was finally dug Lip and the soils shipped to a low level nuclear waste dump in Utah. That project was costly, though, and the remediation company sued Starmet for unpaid bills. lust about this time, military orders for depleted uranium munitions stopped too. Starmet began to lose money.

In May 2001, Starmet officials illegally shipped 1,700 barrels of depleted uranium "greensalt" from a company facility in Barnwell, South Carolina to Concord. The cash-strapped company was cleaning the South Carolina facility in preparation for sale, EPA documents say.

When Massachusetts' health and environmental officials protested, Starmet's president, Robert Quinn, threatened to abandon the Concord site and stick the state with the cost of cleanup. In 2002, alter the state forced bankrupt Starmet into receivership, according to EPA records, the company did abandon the site for several weeks.

Nowadays Quinn--who angrily blames the U.S. Army for Starmet's bankruptcy--sits at a lonely desk in a low building on the site while a few security guards watch over the mess. And what a fine mess it is. Conservatively speaking, there is at least 20 times more depleted uranium on and under Starmet's 46 acres on Main Street, Concord than the 340 tons that were fired in "all of Iraq during the first Gulf War. There are tons of beryllium--a probable carcinogen--in the soil and leaking from buried drums. And in a recently discovered area known as the "old dump" there are unknown substances, possibly including high -level radioactive waste and exotic explosives.

Much of the work during the next four to five years will consist of determining what's in the barrels buried in the old dump, according to Bruce Thompson of De Maximis, Inc., the engineering group chosen by EPA to head the cleanup process. He says some preliminary research indicates that exotic radioactive and heavy metals may have been buried there by MIT scientists during the Manhattan Project. He is also concerned about the potential presence of an explosive, zirconium azide. "That's something I don't want to hit with a backhoe," Thompson told a town subcommittee meeting in September.

That Thompson and the EPA arrived in Concord at all is credit to the efforts of a small group of committed activists. CREW is led by Rick Oleson, a Princeton and Harvard-educated radiation biologist and toxicologist whose late father was a nuclear physicist. Oleson spent part of his childhood in a house near the factory. State records show the most contaminated area on the site is adjacent to "Camp Thoreau," a summer camp for children ages three and up.

"It's one industrial setting in a very residential area," says Oleson. "People later could put a house or well nere, or grow vegetables." Oleson and CREW are focusing their efforts to make sure the EPA demands that the dump is cleaned up to a "residential level," rather than the looser standards allowable for an "industrial" site.

Jeffrey McNabola was a member of Concerned Citizens of Concord, CREW's predecessor, in the 1970s and early 1980s. He notes that the group was warning people about the dangers of depleted uranium and other activities at Nuclear Metals for decades before anyone in officialdom gave them any credence. "There was a cavalier attitude about depleted uranium," he says. "They said that it's safe as chocolate milk."

Even Oleson took years to conclude that Nuclear Metals' activities were unacceptable. "I used to cross-country ski and run back there," he says of the woods bordering the dumpsite. "It was a very pretty place...and there was this big pond. It was frill of psychedelic colors."

Oleson and CREW are hunkering down for a long battle, keeping a wary eye on the EPA and its contractors. Loath to rink deaths from cancer or rare diseases to the factory, Oleson (who works for Monsanto) and others in CREW strive to hue a strict scientific line--lest they appear as "radicals."

The strategy seems to be working. "The real story behind the story I tell people," Oleson says, "is that a few people volunteered their time to do something that needed doing. And for years they were dismissed and made fun of. And they totally turned the town around." CONTACT: Citizens Research and Environmental Watch, (978)3690296, www.crewconcord.org; Nuclear Information and Research Service, (202)328-0002, www.nirs.org.

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Massachusetts DPH Web Site Search Results

http://yosemite.epa.gov/r1/npl_pad.nsf/f52fa5e31fa8f5c885256adc0050b631/7B6349F1A22FFDF3852569E5006CA840?OpenDocument
US EPA site
NPL Site History, referenced reports and agency contact information

http://www.mass.gov/portal/search?btnG=Search&pageID=mg2searchlanding&sid=massgov2&output=xml_no_dtd&q=nuclear+metals&client=mgov&proxystylesheet=mgov&site=EOEAxDEPx&numgm=0&ie=UTF-8&access=p&sort=date%3AD%3AL%3Ad1&entqr=3&entsp=a&oe=UTF-8&ud=1&start=10
NMI document search results

http://www.nmisite.org/assets/pdf/20664.pdf
report by Radioactive Waste Management Consultants, September 2000

1980 drinking well contamination. 350 employees exposed p 18
grounds contamination employee exposure eating lunch

pp 23 worker exposure levels

p 14 800 lb U235

p18 march 1980 350 employees drank VOC contaminated ground water from well SW-2A
"the NMI employees represent a Level II Contamination Population and they number up to 350"
40CFR300 Para 3.3.5

p 19 contaminated soil on and beyond the property references 1996 DPH report on NMI soil sampling

p 20 contamination where workers eat lunch and parking
liklihood of exposure factor is 550 where 100 is acceptable.

p 27 ask the question, "how could uranium contamination beyond the site occurred at NMI if there weren't releases to the air from the plant?

http://www.nmisite.org/
Historical reports from 1991 - 2002 by EPA AND OTHERS ON NMI SUPERFUND SITE STATUS

RADIOACTIVE WASTE MANAGEMENT ASSOCIATES

Uranium Movement at the NMI/Starmet Site Concord, Massachusetts

2229 MAIN ST

3-0295

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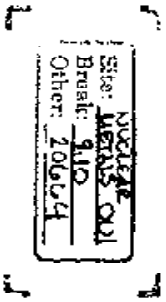
September 2000



Executive Summary

Since 1958, Nuclear Metals, Inc. (NMI, now known as Starmet) has operated a uranium processing facility in Concord, Massachusetts, producing depleted uranium products, primarily anti-tank uranium penetrators. Between 1958 and 1985, NMI dumped process wastewaters and sludges that contained depleted uranium, copper, nitrates and toxic chemicals into the Holding Basin, an unlined depression resembling a swimming pool. As a result, very serious contamination of soil and groundwater in and below the Holding Basin has occurred. Under the watchful eyes of the Massachusetts Department of Environmental Protection (DEP), Starmet is engaged in the early stages of work to remediate the Holding Basin, surrounding soils and groundwater. Yet to be determined by the DEP and perhaps by the Environmental Protection Agency (EPA) are the soil cleanup criteria, the Remedial Action Levels (RAL's).

After removing 8,000 cubic yards of contaminated sludge from the Holding Basin, Starmet has essentially halted the cleanup while it conducts further studies. Post "cleanup" testing of groundwater near the Holding Basin shows uranium concentrations up to 3,000 times the safe drinking water standards. A monitoring well into the bedrock aquifer 750 feet from the Holding Basin has had uranium concentrations over 15 times the drinking water standards, and is still above drinking water standards. Starmet is now arguing that the high concentrations of uranium in the bedrock aquifer are natural and that residual uranium in and around the Holding Basin is below the new RAL's Starmet is proposing and does not have to be removed.

Rainfalls in June and July 1998 led to extremely high uranium groundwater concentrations in the overburden within 30 feet of the Holding Basin; the high uranium concentrations, occurring within two months of rainfalls, were entirely unanticipated by DEP and Starmet groundwater models. In an argument later rescinded, Starmet reasoned that ice channel deposits, long fingers of gravelly soil, were responsible for this rapid movement of uranium. This rapid movement of uranium remains unexplained.

Since our last report[1] for CREW in 1999, GZA, Starmet's contractor, has drilled additional monitoring wells and conducted extensive sampling around and in the Holding Basin. We have reviewed all the supporting reports prepared by GZA and correspondence between Starmet and DEP since our last report, a list of which is contained in Appendix A. Our comments reflect information from these supporting references and independent calculations.

Also since our last report, the Commonwealth of Massachusetts has requested the EPA to place the NMI/Starmet site on the Superfund list. A Federal Register notice details the EPA's basis for recommending placement on the Superfund list and numerically ranks the hazard. Starmet is resisting this listing and for obvious reasons. A Superfund listing

[1] M Resnikoff, "Review of Risk-Based Remedial Action Levels and Holding Basin Feasibility Study, Starmet Corp." prepared for CREW, April 1999.

likely means the value of the NMI/Starmet site would decline and all potentially responsible parties (PRP) would be drawn into the dialogue about cleanup levels and courses of action. Once on the Superfund list, remediation of the NMI/Starmet site would be overseen by the EPA, under a court order; the PRP's would draw up a feasibility study and proposed plan. The PRP's would include NMI/Starmet, the U.S. Army and all corporations and entities that were present when the NMI plant was constructed and uranium waste was dumped into the Holding Basin. These may include MIT, Arthur D. Little, Textron Incorporated, Whittaker Corporation, Mutual Life Insurance Company of New York and Allegheny Ludlum Steel Co. We expect therefore that the EPA ranking of the NMI/Starmet site will be vigorously resisted by Starmet and its former owners and operators.

The extent of further cleanup and potential placement on EPA's Superfund list centers on the relationship between uranium in soil and the associated uranium in groundwater. Starmet has argued that the residual uranium concentrations would lead to no significant risk, that is, the residual concentrations are below Starmet's proposed RAL's. According to Starmet, little or no further removal of uranium soil contamination is necessary.

In support of the new proposed RAL's, GZA has conducted extensive site and laboratory measurements and analysis to show that the RAL's, the allowable soil concentrations, are far below the presently measured concentrations and therefore, no additional contaminated soil need be exhumed. The Remedial Action Levels are intimately related to the groundwater model employed and the partition coefficients, K_d, the ratio of uranium concentrations in soil to that in water. Not surprisingly, Starmet has produced site-specific measurements to show that the site K_d's are much greater than what appear in the literature and therefore less uranium will be present in groundwater. We further anticipate that Starmet will use these site-specific K_d's to oppose EPA's initiative to place the Starmet/NMI site on the Superfund list.

This report addresses two issues, the groundwater model and partition coefficients, and the Superfund ranking by the EPA. Section 2 discusses in some detail GZA's measurement protocol, partition coefficients, the groundwater model and Starmet's revised estimate for allowable uranium concentrations. Section 3 evaluates the EPA's numerical ranking of the Starmet/NMI site and presents our independent calculations for soil contamination.

Our general conclusions are the following. GZA's measurement protocol effectively reduces the uranium seen in groundwater. Essentially, GZA is measuring the dissolved uranium by filtering out fine particulates, even though these particulates could be drawn into public water intakes. This measurement protocol effectively raises the K_d and increases the RAL. Based on these measurements, GZA erroneously concludes that no additional uranium-contaminated soil need be removed from the Holding Basin. The arguments by GZA are in error for several reasons.

- In focusing on measurements to support a high value for K_d, GZA has avoided the primary issue, the risk posed by residual uranium. GZA's hydrological model does not represent the physical reality of the Holding Basin. It appears likely that

remaining uranium is both soluble and insoluble and GZA is measuring just the soluble portion. This is our hypothesis that has some support in GZA's measurements.

- The faulty sampling protocol also leads GZA to the conclusion that uranium contamination in the bedrock aquifer is natural. But uranium concentrations in bedrock aquifer monitoring wells have declined since the Holding Basin has been covered, strongly implying an intimate connection.
- As we show, the GZA model is physically incorrect and leads to nonsensical conclusions. Both the sampling protocol and model must be changed.

The EPA has done commendable work in ranking the NMI/Starmet site. We support the inclusion of the NMI/Starmet site on the Superfund list. EPA's high scoring of the Starmet site based on aquifer contamination is justified since the bedrock aquifer is shared with and serves public water supplies. Soil contamination and air releases were not factored into EPA's ranking determination. However, we feel these two pathways should have been considered given that the Starmet site itself is contaminated, resulting in an exposure to the workers. Furthermore, the site is in a residential neighborhood and uranium contamination has been detected off-site. We recalculated the hazard score for the Starmet property by including the contribution of the soil exposure pathway, which resulted in a small increase in the EPA ranking. An EPA ranking for the air migration pathway could not be calculated without additional information from the company.

With the Starmet site's proposed inclusion on the Superfund list, we are hopeful that the EPA can move the process along quickly; it has been 15 years and counting since problems with the Holding Basin were first broached by the Nuclear Regulatory Commission and later followed up more aggressively by the Massachusetts DEP.

Section 1. Introduction

Since 1958, Nuclear Metals, Inc. (NMI, now called Starmet Corporation) has operated a uranium processing facility in Concord, Massachusetts. It produced depleted uranium products, particularly anti-tank uranium penetrators for the Army, although it has recently stopped doing so. It has continued though to manufacture metal powders and other specialty metal products for industrial, medical, and military purposes. Between 1958 and 1985, NMI dumped process wastewaters and sludges containing depleted uranium, copper, nitrates and other toxic chemicals into the Holding Basin, an unlined natural depression resembling a swimming pool. This resulted in very serious contamination of the soil and groundwater in and below the Holding Basin. Under the watchful eyes of the Massachusetts Department of Environmental Protection (DEP), Starmet is engaged in the early stages of remediating the Holding Basin, surrounding soils and groundwater. Yet to be determined by the DEP, and perhaps by the Environmental Protection Agency (EPA), are the actual, final standards for this cleanup, the Remedial Action Levels (RAL's).

After removing 8,000 cubic yards of contaminated sludge from the Holding Basin, Starmet has essentially halted the cleanup while it conducts further studies. Post "cleanup" testing of groundwater near the Holding Basin shows uranium concentrations up to 3,000 times the safe drinking water standards. A monitoring well into the bedrock aquifer 750 feet from the Holding Basin had uranium concentrations over 15 times the drinking water standards. Starmet is now arguing that the high concentrations of uranium in the bedrock aquifer are natural and that residual uranium in and around the Holding Basin are below the new RAL's Starmet is proposing and does not have to be removed.

Rainfalls in June and July 1998 led to extremely high uranium groundwater concentrations in the overburden within 30 feet of the Holding Basin; the high uranium concentrations, occurring within two months of rainfalls, were entirely unanticipated by the DEP and Starmet groundwater models. DEP requested an explanation from NMI/Starmet for these new developments. In an argument later rescinded, Starmet reasoned that ice channel deposits, long fingers of gravelly soil, were responsible for this rapid movement of uranium. DEP then required NMI/Starmet to substantiate this theory by locating these ice channels. But GZA could not, leaving the rapid movement of uranium still unexplained.

Since we issued our last report[2] for CREW in 1999, GZA, Starmet's contractor, has drilled additional monitoring wells and conducted extensive sampling around and in the Holding Basin. These data have been factored into a groundwater model to estimate a new RAL for uranium. We have reviewed the supporting reports prepared by GZA and correspondence between Starmet and DEP, a list of which is contained in Appendix A, and our comments reflect information gathered from these supporting references and independent calculations.

[2] *Ibid.*

In support of the new proposed Remedial Action Levels, GZA has conducted extensive site and laboratory measurements and analysis to show that the RAL's, the allowable soil concentrations, are far below the presently measured concentrations and therefore no additional contaminated soil need be exhumed. The RAL's are intimately related to the model of the Holding Basin and the partition coefficients, K_d, the ratio of uranium concentrations in soil to that in water. Not surprisingly, Starmet has produced site-specific measurements to show that the site K_d's are much greater than what appear in the literature and therefore less uranium will be present in groundwater. We further anticipate that Starmet will use these site-specific K_d's to oppose EPA's initiative to place the Starmet/NMI site on the Superfund list. Thus, much of this report deals with the issue of partition coefficients. Section 2 discusses GZA's measurement protocol, the partition coefficients, the SESOIL/AT123D groundwater model and Starmet's revised estimate for allowable uranium concentrations.

Also since our last report, the Commonwealth of Massachusetts has requested the Environmental Protection Agency (EPA) to place the NMI/Starmet site on the Superfund list. The Superfund list is a list of the country's most seriously contaminated waste sites identified for long-term cleanup. We expect the ranking of the NMI/Starmet site by the EPA to be vigorously resisted by NMI/Starmet and its former owners and operators for obvious reasons. Once on EPA's Superfund list, the value of the NMI/Starmet site could be reduced and all potentially responsible parties (PRP) would be drawn into the dialogue about cleanup levels and courses of action. Under Superfund law, remediation would be overseen by the EPA under a court order. The PRP's would draft a feasibility study and proposed plan. The PRP's would likely include NMI/Starmet, the U.S. Army, and all past owners and operators, including MIT, Arthur D. Little, Textron Incorporated, Whittaker Corporation, Mutual Life Insurance Company of New York and Allegheny Ludlum Steel Co.

A Federal Register[3] notice details the EPA's basis for recommending placement on the Superfund list. We evaluated the EPA's numerical ranking of the Starmet/NMI site and discovered that soil contamination and air releases were not factored into EPA's scoring of the NMI/Starmet site. They were rightly considered of lesser importance in ranking the site. However, we feel these two pathways should still have been considered given that the Starmet site itself is contaminated, resulting in an exposure to the workers. Parts of the NMI/Starmet site, such as the "sweepings fill" area and the cranberry bog, are contaminated with uranium. Although the first priority under DEP's Contingency Management Plan (CMP) is the remediation of groundwater contamination near the Holding Basin, other parts of the site, including surface soil, will also have to be dealt with. In addition, the site is in a residential neighborhood and uranium contamination has been detected offsite. We therefore recalculated the hazard score for the Starmet property by including the contribution of the soil exposure pathway, and this resulted in an increase in the EPA ranking. Unfortunately, a hazard score for the air migration pathway could not be calculated without additional information from the company. Section 3 of this report discusses the proposed ranking and additional calculations we have made. Section 4 contains our conclusions and recommendations.

[3] 65 FR 46131-46137, July 27, 2000.

Section 2. Partition Coefficients and Remedial Action Levels

Previous Hydrological Model Disproved

Under the Contingency Management Plan (CMP), the Massachusetts DEP is attempting to require NMI/Starmet to reduce the hazard caused by the presence of uranium and toxic chemicals on the site. The risk comes from the uranium that has leaked from the Holding Basin and is contaminating groundwater. The hazard is also due to soil and air contamination, but remediation has been divided into two stages: the Holding Basin and everything else, with the former being the first priority. With the recent series of reports by NMI/Starmet's contractor, the focus has turned to groundwater contamination due to the remaining soil and groundwater contamination within and below the Holding Basin. Still remaining is remediation of site soils, including the sweepings fill area and the cranberry bog.

Since uranium will leach from soil to groundwater, DEP is attempting to determine the allowable residual uranium concentrations in soil that would lead to no significant risk from contaminated groundwater. The uranium concentration in soil that leads to no-significant risk is called the Remedial Action Level or RAL. The RAL's depend on the groundwater model and several input parameters, including the relationship between uranium in soil and uranium in water represented by the partition coefficient, K_d. DEP has set the maximum concentration limit (MCL) in water as less than or equal to 10 pCi/L (28 µg/L) depleted uranium.[4,5] [However, EPA's proposed National Drinking Water Standards sets the MCL to 20 µg/L uranium[6], making no distinction between natural or depleted uranium since the MCL is based on heavy metal toxicity to liver, not on radiation effects.] Under DEP's model shown in Fig. 1, the residual soil concentrations (or RAL's) that resulted in uranium concentrations in groundwater less than or equal to 28 µg/L, were calculated to be 12.8 ppm in soil.[7] On the other hand, GZA previously proposed its own RAL of 20 ppm uranium, which they arrived at using a risk-based approach.[8] Now, under a new NMI/Starmet model shown in Fig. 2, their proposed RAL increases to 541 ppm uranium[9], 42 times greater than the DEP's RAL and 27 times larger than GZA's previous RAL. Under this new RAL, NMI/Starmet would not have to exhume additional contaminated soil since GZA has calculated the average

[4] N Mohanty (DEP) memo to C Weidner (DEP), Re: Leaching-Based Cleanup Criteria for the Holding Basin Removal Project, October 25, 1996, p. 1.
[5] At present, the Massachusetts drinking water guideline for uranium is 20 µg/L. Refer to "Drinking Water Standards and Guidelines for Chemicals in Massachusetts Drinking Waters" published by the Office of Research and Standards (ORS) of the Massachusetts Department of Environmental Protection, Spring 2000.
[6] 65 FR 21576, April 21, 2000.
[7] Mohanty, pp. 6, 8.
[8] GZA, "Development of Risk-Based Remedial Action Levels (RALs", February 1997, Table 6.
[9] GZA, "Supplemental Report to Uranium Partitioning Coefficient Evaluation and Holding Basin Soil Characterization Studies", July 2000, pp. 11, 13.

hypothesis with measurements. GZA sampled monitoring wells near the Holding Basin[24], such as HBPZ-2 and HBPZ-4, and compared the ratios of U-238 to U-234. These ratios ranged around 7 to 8, indicating depleted uranium. These samples were compared to the U-238 to U-234 ratios in bedrock aquifer wells GZW-7-2 and GZW-6-3, which ranged from 0.463 to 1.12. From this, GZA concluded that the high uranium concentrations in the bedrock aquifer were natural. We disagree. Had the filtered particles also been sampled for radioactivity, and found to have isotopic ratios similar to natural uranium, we would agree with GZA. Filtration biases the results towards radioactivity in solution.

While the focus of GZA's investigation has been on depleted uranium, it is important to point out that uranium in the Holding Basin is comprised of a mixture of depleted uranium and highly enriched uranium. The Holding Basin contains approximately 400,000 lb of DU, consisting almost entirely of U-238, and 800 lb of highly enriched uranium, consisting almost entirely of U-235. Together, this represents uranium containing 0.5% U-235, and therefore close to natural uranium, which has a U-235 assay of 0.71%. Thus, testing has to be precise to distinguish between natural uranium and uranium from the Holding Basin. Removal of fine uranium particulates makes the distinction between uranium from the Holding Basin and natural uranium that much more difficult.

We are concerned about filtering for another reason. Experience at the Fernald uranium plant in Ohio shows that uranium movement in the environment has two components with different transit times. Dissolved uranium had a mean transit time of one month, whereas insoluble uranium had a mean transit time of 14 years.[25] The sampling protocol does not allow GZA to distinguish between these two components. It is our hypothesis that the rapid movement of uranium into monitoring wells HBPZ-2 and HBPZ-4 was due to uranium in solution. Movement of uranium particulates is far slower, but not zero.

It is important to point out that total and dissolved uranium measurements from monitoring well GZW-7S differ strikingly.[26] The total uranium concentration is 720 µg/L while the dissolved uranium concentration is only 71 µg/L. GZA does not discuss this difference. Clearly, the small particulates carry much of the radioactivity in the sample. An isotopic breakdown of the particulates would have been useful in determining whether the high uranium concentrations were due to natural or depleted uranium.

Finally, the uranium concentrations in the bedrock monitoring well GZW-6-3 have declined dramatically since the Holding Basin was covered, and more so since 8,000 yd^3 of contaminated waste was removed from the Holding Basin. There appears to be a strong correlation between covering the Holding Basin and the decline of uranium

[24] GZA, "Groundwater Monitoring Report", December 1999, p. 15.
[25] Radiological Assessments Corporation, "Task 6: Radiation Doses and Risk to Residents from FMPC Operations from 1951-1988, Volume II Appendices, Fernald Dosimetry Reconstruction Project", prepared for the Centers for Disease Control and Prevention, August 1996, p. B-2.
[26] GZA, February 2000, Table 3.

Population (target)

Although residents have been rightfully counted as potential contamination targets, it must be remembered that there were workers who were actually subject to actual contamination.

Although lacking in original analytical documentation and not scored by the EPA, there is a summary data table from the Massachusetts Department of Environmental Quality Engineering (MADEQE) indicating that in March 1980, water from well SW-2A, a process/drinking water well at the NMI site, was contaminated with 8 VOCs. At that time, 350 employees were working for NMI and drank VOC-contaminated water from well SW-2A. After that, SW-2A was reportedly no longer used as a drinking water source.[33]

If we count these workers as targets, the Targets factor would have increased by a minimum of 395 because:

- the SW-2A well would have qualified as a Nearest Well with (at the very least) Level II concentrations, equivalent to 45 points[34], and
- the NMI workers represent a Level II-contamination Population and they number up to 350[35],
- therefore, 45+350 = 395.[36]

As of now, the EPA has assigned the Targets factor a score of 844 based solely on the distance-weighted number of residents subject to a potential contamination in a community well, the existence of a wellhead protection area within the NMI site, and importance of the community wells as a resource to the Town of Concord.[37] With our above calculation of an additional 395 points due to the workers who were subject to actual contamination, the Targets factor increases from 844 to 1,239.[38]

If we multiply the Likelihood of Release score (550) by the Waste Characteristics score (32) and Targets score (1,239), and divide the product by 82,500, we get the groundwater migration pathway score, subject to a maximum of 100.[39] In NMI's case, the product divided by 82,500 is 264.32. However, the maximum allowed is only 100. Hence, the EPA's current score of 100 for the groundwater migration pathway[40] stands.

Soil Exposure Pathway

This section outlines the procedure we followed in scoring the soil exposure pathway.

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[33] *Ibid*, p. 36.
[34] 40 CFR 300, App. A, section 3.3.1.
[35] *Ibid*, section 3.3.2.
[36] *Ibid*, section 3.3.5.
[37] Tetra Tech NUS, Inc. and Dynamac Corp., July 2000, pp. 4, 46-52.
[38] 40 CFR 300, App. A, section 3.3.5.
[39] *Ibid*, section 3.4.
[40] Tetra Tech NUS, Inc. and Dynamac Corp., July 2000, p. 4.

Areas of observed contamination

In order to score the soil exposure pathway, we must first find areas of observed contamination. Generally, an observed contamination can be established for a certain area by direct observation or chemical analysis. For the soil exposure pathway, an observed contamination by a radionuclide is established by chemical analysis or gamma radiation measurements. For a radionuclide that is naturally occurring, the following criteria applies to analytical (chemical) samples that have to be met to establish observed contamination by that radionuclide:

- Measured concentration (in units of activity) has to be equal to or greater than the value 2 standard deviations above the mean site-specific background concentration OR the measured concentration has to be greater than the upper limit value of the range of regional background concentrations.
- A portion of the increase is attributable to the site.
- The radionuclide must be found at the surface or covered by 2 feet or less of cover material.[41]

On the other hand, gamma radiation measurements need to meet the following criteria:

- The gamma exposure rate (in μR/hr) measured using a survey instrument held 1 m above the ground surface equals or exceeds 2 times the site-specific background.
- A portion of the increase is attributable to the site.
- The radionuclides do not have to be within 2 feet of the surface of the source.[42]

Within the boundaries of the NMI property, there exists an Area of Contaminated Soil, a.k.a. Source 3, which qualifies as an area of observed contamination. Covering an area of approximately 395,000 ft^2, contamination has been established to be significantly above background and includes a mixture of toxic chemicals and radioactive materials, including copper, beryllium, and uranium. These hazardous substances are attributable to NMI's operational processes. Source 3 does not include the area of the holding basin, cooling water recharge pond, sphagnum (cranberry) bog, the on-property buildings, and paved areas.[43]

Beyond the boundaries of the NMI property, we have found another Area of Observed Contamination, which we will call AOC 1. AOC 1 covers about 4,773,437 ft^2. We were able to delineate the boundaries of this area by relying on soil sampling measurements taken for a joint NRC-DPH study[44]. Table 1 presents the soil sampling results we used.

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[41] 40 CFR 300, App. A, section 7.1.1.
[42] *Ibid.*
[43] *Ibid*, pp. 30-35.
[44] "Joint Report of the Commonwealth of Massachusetts Department of Public Health – Radiation Control Program and the United States Nuclear Regulatory Commission Region I to the NMI Soil Sampling Discussion Group", December 13, 1996.

The upper limit background concentration measured was 0.33 pCi/g uranium. This was taken roughly 5 miles north of the NMI site. 5 other sampling locations yielded uranium concentrations that were greater than background. Three of the samples appear to indicate depleted uranium. All the soil samples were collected within 2 inches in depth.[45]

Since these soil samples meet the criteria for observed contamination, we were able to delineate an Area of Observed Contamination bordered by these sampling locations. Figs. 3 and 4 illustrate the location of AOC 1 relative to the NMI site and Town of Concord. Given the limited amount of soil sampling performed offsite (i.e., beyond the NMI property), we will assume that the only contaminant is U-238. We also assume that AOC 1 is a purely residential neighborhood.

Having established these two areas of observed contamination, we proceeded to evaluate the threat posed by the soil exposure pathway on resident and nearby populations. The following discussion and calculations are summarized in Table 2.

Resident Population Threat

According to section 5.1.3 of the HRS, the resident population considered here includes the following:

- Resident individual. Lives or attends school/day care center on a property with an area of observed contamination AND whose residence or school/day care center is on or within 200 feet of the area of observed
- Worker. Works on a property with an area of observed contamination AND whose workplace area is on or within 200 feet of the area of observed contamination. Worker activities may include eating lunch and parking.
- Resources. This refers to commercial agriculture, commercial silviculture (forestry), livestock production or grazing areas that are located on an area of observed contamination.
- Terrestrial sensitive environments. This refers to national parks, national monuments, federal or state-designated wilderness areas, preserves, or wildlife areas that are located on an area of observed contamination.

1. Likelihood of Exposure

According to section 5.1.1 of the HRS[46], a value of 550 can be assigned to the likelihood of exposure factor if there is an area of observed contamination in one or more of the resident population locations mentioned above. In NMI's case, NMI workers are on and within 200 feet of Source 3 while some Concord residents live on and within 200 feet of AOC 1. Therefore, the likelihood of exposure factor is 550.

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[45] *Ibid*, pp. 2, 6, Table 2, Attachments 1-1, 1-2.
[46] 40 CFR Part 300, Appendix A.

to Level II concentrations is 100 * 3 = 300. Therefore, the Level II resident population factor is 300.[57]

Since there are no resident individuals subject to Level I concentration, the Level I resident population factor is 0.

- Workers

NMI employs about 200 workers. It is reasonable to assume that while working or eating lunch or parking their cars, they were on and within 200 feet of contaminated soil of Source 3. HRS scores the worker factor based on the number of workers, with a maximum worker factor of 15 corresponding to a greater than 1,000 workers.[58] In NMI's case, from Table 5-4 of the HRS, the applicable worker factor would be 10.

We have assumed that AOC 1 is purely residential and that there are no workplaces within its boundaries.

- Resources

We have assumed that there are no commercial agriculture, commercial silviculture, commercial livestock production, or commercial livestock grazing on Source 3 or AOC 1. Therefore, the resources factor is 0.[59]

- Terrestrial Sensitive Environments

We have assumed that there are no lands that are national parks, federal or state-designated wilderness areas, wildlife refuge, or game management located on Source 3 or AOC 1. Therefore, the terrestrial sensitive environments factor is 0.[60]

- Resident Population Targets

This factor is the sum of resident individual, resident population, workers, resources, and terrestrial sensitive environments factors.[61] Therefore, the resident population target factor is 355.

4. Resident Population Threat Score

The resident population threat score is the product of the likelihood of exposure, waste characteristics, and targets: 3,514,500.[62]

[57] 40 CFR 300, App. A, section 5.1.3.2.2.
[58] *Ibid*, section 5.1.3.3.
[59] *Ibid*, section 5.1.3.4.
[60] *Ibid*, section 5.1.3.5.
[61] *Ibid*, section 5.1.3.6.
[62] *Ibid*, section 5.1.4.

S_s = soil exposure pathway score

S_a = air migration pathway score

If a site's HRS score is equal to or greater than 28.5, the site qualifies for Superfund listing.

EPA's HRS Score for the NMI Site

In the case of the NMI site, the EPA calculated the following pathway scores[77]:

S_{gw} = groundwater migration pathway score = 100

S_{sw} = surface water migration pathway score = 60

S_s = soil exposure pathway score = 0

S_a = air migration pathway score = 0.

Thus, EPA calculated the HRS score for the NMI/Starmet site to be 58.31[78], which makes the site highly qualified to join the Superfund list.

$$\text{HRS Score} = \{ (S_{gw}^2 + S_{sw}^2 + S_s^2 + S_a^2) / 4 \}^{1/2}$$
$$= \{ (100^2 + 60^2 + 0 + 0) / 4 \}^{1/2}$$
$$= \{ (10{,}000 + 3{,}600) / 4 \}^{1/2}$$

NMI Score = 58.31

Our Proposed HRS Score for the NMI Site

We fully support the addition of the NMI/Starmet site to the Superfund program. We agree with the EPA that the groundwater migration pathway should receive the maximum score of 100 because it has caused actual contamination of the aquifer and poses a great risk to the public and the environment. However, the EPA did not score the air and soil contamination pathways. In contrast to the EPA position, we feel these two pathways should still have been considered given that the Starmet site is contaminated, resulting in an exposure to the workers. How could workers not have been exposed to air and soil contamination when sweepings from the NMI property give high levels of uranium concentrations and direct gamma readings in the vicinity of the NMI buildings were above background? In addition, the NMI property is located in a residential neighborhood, with uranium contamination already having been detected offsite. How could depleted uranium have been detected in offsite locations if NMI had not released uranium to the air?

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[77] Tetra Tech NUS, Inc. and Dynamac Corp., July 2000, pp. 1, 3-8.
[78] *Ibid*, p. 3.