Health Consultation

FORMER WOLFF-ALPORT CHEMICAL CORPORATION SITE
1125-1139 IRVING AVENUE
QUEENS, NEW YORK

FEBRUARY 29, 2012

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

A health consultation is a verbal or written response from ATSDR or ATSDR's Cooperative Agreement Partners to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a consultation may lead to specific actions, such as restricting use of or replacing water supplies; intensifying environmental sampling; restricting site access; or removing the contaminated material.

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR or ATSDR's Cooperative Agreement Partner which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

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HEALTH CONSULTATION

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1125-1139 IRVING AVENUE
QUEENS, NEW YORK

Prepared By:

Site and Radiological Assessment Branch
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry

FOREWORD

The Agency for Toxic Substances and Disease Registry, ATSDR, was established by Congress in 1980 under the Comprehensive Environmental Response, Compensation, and Liability Act, also known as the *Superfund* law. This law set up a fund to identify and clean up our country's hazardous waste sites. The Environmental Protection Agency, EPA, and the individual states regulate the investigation and clean up of the sites.

Since 1986, ATSDR has been required by law to conduct a public health assessment at each of the sites on the EPA National Priorities List. The aim of these evaluations is to find out if people are being exposed to hazardous substances and, if so, whether that exposure is harmful and should be stopped or reduced. If appropriate, ATSDR also conducts public health assessments when petitioned by concerned individuals. Public health assessments are carried out by environmental and health scientists from ATSDR and from the states with which ATSDR has cooperative agreements. The public health assessment program allows the scientists flexibility in the format or structure of their response to the public health issues at hazardous waste sites. For example, a public health assessment could be one document or it could be a compilation of several health consultations - the structure may vary from site to site. Nevertheless, the public health assessment process is not considered complete until the public health issues at the site are addressed.

Exposure: As the first step in the evaluation, ATSDR scientists review environmental data to see how much contamination is at a site, where it is, and how people might come into contact with it. Generally, ATSDR does not collect its own environmental sampling data but reviews information provided by EPA, other government agencies, businesses, and the public. When there is not enough environmental information available, the report will indicate what further sampling data is needed.

Health Effects: If the review of the environmental data shows that people have or could come into contact with hazardous substances, ATSDR scientists evaluate whether or not these contacts may result in harmful effects. ATSDR recognizes that children, because of their play activities and their growing bodies, may be more vulnerable to these effects. As a policy, unless data are available to suggest otherwise, ATSDR considers children to be more sensitive and vulnerable to hazardous substances. Thus, the health impact to the children is considered first when evaluating the health threat to a community. The health impacts to other high risk groups within the community (such as the elderly, chronically ill, and people engaging in high risk practices) also receive special attention during the evaluation.

ATSDR uses existing scientific information, which can include the results of medical, toxicologic and epidemiologic studies and the data collected in disease registries, to determine the health effects that may result from exposures. The science of environmental health is still developing, and sometimes scientific information on the health effects of certain substances is not available. When this is so, the report will suggest what further public health actions are

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Conclusions: The report presents conclusions about the public health threat, if any, posed by a site. When health threats have been determined for high risk groups (such as children, elderly, chronically ill, and people engaging in high risk practices), they will be summarized in the conclusion section of the report. Ways to stop or reduce exposure will then be recommended in the public health action plan.

ATSDR is primarily an advisory agency, so usually these reports identify what actions are appropriate to be undertaken by EPA, other responsible parties, or the research or education divisions of ATSDR. However, if there is an urgent health threat, ATSDR can issue a public health advisory warning people of the danger. ATSDR can also authorize health education or pilot studies of health effects, full-scale epidemiology studies, disease registries, surveillance studies or research on specific hazardous substances.

Interactive Process: The health assessment is an interactive process. ATSDR solicits and evaluates information from numerous city, state and federal agencies, the companies responsible for cleaning up the site, and the community. It then shares its conclusions with them. Agencies are asked to respond to an early version of the report to make sure that the data they have provided is accurate and current. When informed of ATSDR's conclusions and recommendations, sometimes the agencies will begin to act on them before the final release of the report.

Community: ATSDR also needs to learn what people in the area know about the site and what concerns they may have about its impact on their health. Consequently, throughout the evaluation process, ATSDR actively gathers information and comments from the people who live or work near a site, including residents of the area, civic leaders, health professionals and community groups. To ensure that the report responds to the community's health concerns, an early version is also distributed to the public for their comments. All the comments received from the public are responded to in the final version of the report.

Comments: If, after reading this report, you have questions or comments, we encourage you to send them to us.

Letters should be addressed as follows:

Attention: Division of Health Assessment and Consultation, Agency for Toxic Substances and Disease Registry, 1600 Clifton Road (F-09), Atlanta, GA 30333.

Summary and Statement of Issues

The United States Environmental Protection Agency (USEPA) Region II office requested that the Agency for Toxic Substances and Disease Registry (ATSDR) review radiologic data collected at the location of the former Wolff-Alport Chemical Company site (FWACC). The request is part of an ongoing removal assessment being conducted by the USEPA Region II Removal Action Branch through a referral received from the USEPA Region II Radiation and Indoor Air Branch. The USEPA requested that ATSDR evaluate current potential health threats through all potential exposure pathways to near-by residents, on-site workers, and persons that visit the buildings at the former site and/or pass through the block where the current businesses are located.

The Wolff-Alport Chemical Company has been identified as a company that supplied radioactive materials to the US Government. The company began chemical operations in the 1920s; however, ATSDR was not able to determine what type of operations occurred. The company processed imported monazite sand to extract rare earth elements from the 1940s until 1954. Waste by-products of this process included thorium and to a lesser degree uranium, both naturally-occurring radioactive elements, and liquid radioactive wastes. Until ordered to stop in 1947, the company disposed of this radioactive liquid waste directly and without treatment into the city sewer, and possibly buried the other wastes on site. The former operations caused surface and subsurface soil contamination to at least a depth of 20 feet, along with contamination underneath public sidewalks, city sewers, and nearby streets.

After the ban, the company reportedly then concentrated thorium onsite from 1947 and sold the sludge to the federal government. At the time of these operations, no license for radioactive material was required and the former Atomic Energy Commission (AEC) had determined the site did not qualify as an AEC operation [1]. Currently, several businesses operate at the FWACC including an ice company, iron works, a construction company, and auto body shop providing repair and related services activities. Radiological surveys performed by the City of New York Department of Health and Mental Hygiene (NYDHMH) and its contractors have identified thorium at these businesses, in the soils and sewers along Irving Avenue, and in exterior properties associated with former operations.

[1] Atomic Energy Commission (1987). Letter to L.R. Solon, Director of the Bureau of Radiation Control, New York City Department of Health. Dated September 29, 1987.

Background

Site Description and History

The FWACC was located at 1127 Irving Avenue, in the Ridgewood section of Queens and near the border of Brooklyn, New York (Figure 1). The original building was subdivided and currently, the site contains several buildings that have been divided into several businesses. The total land area covers 0.75 acres bound by Irving Avenue on the southwest, and Cooper Avenue on the northwest. At one time, a railroad spur extended to the rear of the buildings; now there is an active rail line adjacent to the site within 125 feet. The spur area is presently unpaved and vegetated. According to the USEPA, the rear of these buildings is partially fenced, mostly overgrown with vegetation, and is used for storage of construction equipment and a couple of small boats. The surrounding neighborhood contains light industry, commercial businesses and residences [2].

The businesses at the site include a 2-story masonry and frame building that houses a delicatessen and grocery store (1125 Irving Avenue), office space and unoccupied residential apartments with an attached 1-story masonry building housing a tire shop (1125 Irving Avenue) and mini-ATV shop; a 1-story masonry building with an auto body shop (15-14 Cooper Avenue) and office space; two (2) 1-story masonry buildings used for warehouse purposes (1133-1139 Irving Avenue and 1129 Irving Avenue); and a commercial building with an auto repair shop (1127 Irving Avenue)[2].

[2] Final Phase I Environmental Site Assessment Report for Former Wolff-Alport Chemical Corporation Site 1125-1139 Irving Avenue Queens, New York 11385. Prepared for the New York City Department of Design and Construction by Louis Berger and Associates, PC. May 26, 2010.

Figure 1. Aerial view of the Former Wolf-Alport Chemical Site.

According to federal records, Wolff-Alport operated from approximately 1920 to about 1954 [3] at these locations. About 1940, the company began importing rare earth containing monazite sands, rich in thorium, from the Belgian Congo [3]. The monazite sand was brought to the facility via the railroad spur. The company extracted these rare earth elements and sold them to various commercial entities. Initially, the thorium (with presumably other radioactive materials) was considered a waste product and was disposed of into the sewer. In 1947, the Atomic Energy Commission, a forerunner of the US Department of Energy, ordered Wolff-Alport to halt sewer disposal. Then, to minimize the waste, Wolff-Alport began concentrating the thorium as a precipitate and sold the sludge to the federal government [3]. However, some residuals,

[3] New York Department of Health and Mental Hygiene. Final Joint Field Summary Report Former Wolff Alport Chemical Corporation Site. August, 2007.

containing high concentrations of thorium, remain on-site. The waste tailings tend to appear as black or gray ashy material [4].

At various times, the building that housed the FWACC operations was subdivided by sealing access ways between the portions. The most active businesses in the block are the deli and the Primo Auto Body Shop. Most of the areas investigated during the NYDHMH field effort are used for storage of materials used by the current occupants with limited/short term entry by individuals. The one exception is in the main working areas of Primo Auto Body, (1127 and 1127A Irving Avenue, sidewalks and curbs) where individuals spend their entire working day in the building while completing various auto repairs and bodywork [3].

During the 1970s and 1980s, the New York City Health Department, the New York State Department of Environmental Conservation (DEC), and the USEPA conducted informal surveys finding radioactive contamination within portions of the buildings and in the adjacent soils and sewers. The detected levels did not exceed regulatory exposure limits in place at that time [500 millirem per year or mrem/y to the public], but federal exposure limits have since been lowered. In 2007, a joint survey by DEC and the NYDHMH confirmed that radiation at the site exceeded normal background levels. Recently, they concluded that a formal site assessment was needed and obtained EPA Brownfields funding [5].

NYDHMH, with the USEPA observing, monitored and sampled for radioactive materials in the businesses at these locations. Samples from soils, sewers, and surface wipe samples were collected and analyzed for the presence of thorium (as thorium-232, Th232), radium-226 (Ra-226), and radon, typically radon-222 (Rn-222, a decay product of Ra-226). These results were compiled and reported [4]; electronic versions of the reports were supplied to ATSDR for evaluation.

Radiological Survey Results

Exterior and Sewer Survey Summaries

NYDHMH and the DEC surveyed the area in 2007 and again during 2009-2010. The surveys included a vehicle-based mobile radiological survey as well as indoor gridded surveys using sodium iodide detectors. These types of instruments are not generally used for radionuclide identification but are very good for general surveying for the presence of gamma radiation, if properly calibrated. The vehicle-based survey found gamma radiation levels that peaked at about 1.5 milliroentgens per hour (mR/h) in front of 1129 Irving Avenue. This value is at least 75 times higher than the ambient background gamma radiation level that ranges between 0.01 to 0.02 mR/h[3]. ATSDR believes that this elevated radiation reading is from the presence of various decay products of thorium and uranium, as neither of these are significant gamma emitters. These decay products include, but are not limited to, the isotopes of radium, lead, polonium, and thallium.

The city and state agencies also performed exterior surveys along the rear of the facilities. These results were expressed as counts per minute (cpm) and ranged from a low of about 15,000 cpm along the former rail spur to approximately 400,000 cpm in the vicinity of the rear of 1129 Irving Avenue. A similar survey was performed along Irving Avenue and a portion of Cooper Avenue, which crosses Irving Avenue. These

[4] Final Radiological Scoping Survey for Former Wolff Alport Chemical Corporation Site 1125-1139 Irving Avenue Queens, New York 11385. Prepared for the New York City Department of Design and Construction by Louis Berger and Associates, PC. August 23, 2010

[5] New York Department of Health and Mental Hygiene. Information on Radiation Survey at the Former Wolff-Alport Chemical Corporation 1127-1129 Irving Avenue, Queens, New York. August 26, 2009.

results ranged from approximately 36,000 cpm to over 440,000 cpm. Based on the types of instruments used in these surveys, ATSDR estimated the background count rate was about 12,500 cpm although no calibration information was found in any of the documents reviewed by ATSDR.

Measurements in the sewers using a radiation exposure meter indicated the sewers in the vicinity were heavily contaminated with exposure rates as high as 4 mR/h. These readings were collected when the radiological survey workers had relatively unlimited access to manholes near the site after special permits were obtained.

Indoor Radiological Survey Summary

Indoor radiological surveys were performed either by walk-through surveys or by a systematic grid process. The flooring material in all surveyed areas was concrete. Some floors had drains and/or sewer cleanout plugs; there were no discussions on the presence of drain traps. Either of these features penetrating the concrete would allow for easier infiltration of radon gases.

The Primo Auto Body has two distinct work areas at 1127 Irving Avenue and 1129 Irving Avenue. The highest radiation exposure readings were in the storage area with a maximum reported value of 1 mR/h on contact with a wall surface. ATSDR did not find any discussion as to the background radiation in the building materials. In addition, over 90% of the surveyed area exceeded the average external background radiation readings. Within the auto body repair portion of the building, the maximum exposure reading was 0.3 mR/h with a reading of 0.2 mR/h in the center of the work area. About 90% of this facility exceeded the external background radiation levels [3].

At 1129 Irving Avenue, the business is a welding and manufacturing operation with some warehouse operations. An estimated 85% of the facility was measured at levels above background radiation with a maximum exposure reading of 0.2 mR/h. A portion of 1129 Irving Avenue, designated 1129A was occupied by the S&M Construction Company that, at the time of the investigation, was storing equipment, bags, and chemicals. The maximum radiation exposure in this portion of 1129 Irving Avenue was 0.3 mR/h in only a few locations along the rear wall. In the vicinity of the sewer cleanout, the exposure reading was 0.2 mR/h. The remainder of the building was about 0.03 mR/h [3]. The Terra Nova Company currently leases the building.

The other operations (1129B and 1139 Irving Avenue) were also surveyed. In these locations the reported radiation exposures did not exceed 0.04 mR/h, except at the sewer cleanout vault area in 1129B Irving Avenue [3].

In the scoping report, subsurface samples collected inside the businesses were analyzed for their isotopic composition. The highest concentration of Th-232 (1133 picocuries per gram or pCi/g) was reported in 1127 Irving Avenue. The other addresses surveyed (1129 and 1133 Irving Avenue) also showed elevated levels of Th-232, up to 200 times typical background values, assumed to be 1 pCi/g as stated in site reports. In most cases, the concentrations of the uranium-238 (U-238) decay product Radium-226 (Ra-226) were also elevated, ranging from about background to greater than 150 times the typical Ra-226 background concentrations [4].

Outdoor Soil Sampling Summary

A screening analysis of two soil samples was performed to identify specific radionuclides in the soil. One sample was collected behind 1129 Irving Avenue; whereas, the second sample was collected from Moffat Street—a contaminated area—which intersects Irving Avenue to the southeast of the businesses [3]. The results show that the sample from behind 1129 Irving Avenue contained Th-232 and its decay products at concentrations of about 290 pCi/g. Ra-226 was also inferred from the gamma spectroscopy as its decay products were detected at 40 pCi/g [3].

Additional surface soil samples were collected along the rail spur during the scoping survey. Th-232 was reported as high as 472 pCi/g. Ra-226 was also reported elevated with a maximum reported value of 25 pCi/g [4]. Typical environmental levels of Th-232 and Ra-226 are near 1 pCi/g.

Soil samples were also collected at various depths down to 15 to 20 feet, and showed elevated thorium concentrations ranging from several 100 to over 1,000 pCi/g. The soil borings indicated that the soils in the top four feet were very similar to the tailings material found throughout the site; however, the deeper contamination found under 1125 – 1127 Irving Avenue was in a localized area [4].

Other exterior isotopic analyses show contamination along the sidewalks ranging from about twice background to 144 times above background (2.1 – 143.7 pCi/g). A composite sewer sample was also collected from walls and bottom gravel with Th-232 measured at 81.3 pCi/g. Sampling outside the sewer line was recommended by the city's contractor [4]. This sampling could assist in determining if the high radiation levels were from contamination inside the pipe or residual contamination and rock outside the sewer line.

Indoor Surface Sampling Summary

Swipe samples were collected to determine if the elevated radiation readings were due to surface contamination. These samples would determine if the contamination was physically fixed to the surface or was removable. These results are expressed as disintegrations per minute (dpm); 2.22 dpm is equivalent to 1 pCi. Contamination that is removable is available for internalization leading to a radiological body burden. As reported in the scoping survey, of approximately 70 swipe locations, only one location registered elevated removable levels of both alpha particle radiation (160 dpm) and beta particle radiation (88 dpm) [4]. The location of that sample was in the body shop near the floor drain.

Indoor Radon Monitoring Summary

Radon detectors were placed in 3 contaminated locations. These were the 1127 Irving Avenue work area, the 1129 Irving Avenue body shop, and the basement of the deli at 1125 Irving Avenue. Of these locations only the deli basement which is used to transfer produce showed total radon (Rn-222 + Rn-220) concentrations above 14 pCi/L. The other locations were within the recommended maximum level of 4 pCi/L, perhaps because they are better ventilated [4].

Discussion

ATSDR is evaluating the site conditions to determine whether people are being or could be exposed to site-related contaminants. When evaluating exposure pathways, ATSDR identifies whether, through ingestion, dermal (skin) contact, or inhalation, exposure to contaminated media (e.g., soil, water, food, air, waste, or biota) has occurred, is occurring, or could occur. With regard to radioactive contamination, a person can be exposed to both external radiation and internal radiation. Internal exposures result from radioactive sources taken into the body through the inhalation of radioactive particles or through the ingestion of contaminated food or water. External exposure results from radiation sources originating outside the body, such as radiation emitted from contaminated sediment. Radiation from these external sources can sometimes penetrate human skin. ATSDR also identifies an exposure pathway as completed or potentially complete if either internal or external exposures occur. If there are no exposure possibilities, the pathway is eliminated from further evaluation. Exposure pathways are complete if all human exposure pathway elements are present. A potential pathway is one that ATSDR cannot rule out because one or more of the pathway

The five elements of an exposure pathway are:
1) a source of contamination,
2) an environmental medium,
3) a point of exposure,
4) a route of human exposure, and
5) a receptor population.

The source of contamination is where the chemical or radioactive material was released. The environmental medium (e.g., groundwater, soil, surface water, air) transports the contaminants. The point of exposure is where people come in contact with contaminated media. The route of exposure (e.g., ingestion, inhalation, dermal contact) is how the contaminant enters the body. The people actually exposed comprise the receptor population.

elements cannot be definitely proved or disproved. If one or more of the elements is definitely absent, a pathway is eliminated.

Assessing Health Effects

As stated, exposure to radiation does not always result in harmful health effects. The type and severity of health effects that a person might experience depends on the dose, which is based on the person's age at exposure, the exposure rate (how much), the frequency (how often) or duration (how long), the route or pathway of exposure (breathing, eating, drinking, or skin contact), and the multiplicity of exposure (combination of contaminants). Once a person is exposed, characteristics such as age, sex, nutritional status, genetic factors, lifestyle, and health status influence how the contaminant is absorbed, distributed, metabolized, and excreted. An environmental concentration alone will not cause an adverse health outcome—the likelihood that adverse health outcomes will actually occur depends on site-specific conditions, individual lifestyle, and genetic factors that affect the route, magnitude, and duration of actual exposure.

ATSDR uses comparison values (CVs) to identify those site-related hazardous substances that are not considered health threats.

As a first step in evaluating exposures, ATSDR health assessors screen the radiation levels and doses found in a particular media (i.e., soil, air, or drinking water) against health-based comparison values known as Minimal Risk Levels (MRLs). ATSDR develops comparison values (CVs) from available scientific literature concerning exposure, dose, and health effects. CVs represent radiation doses or chemical concentrations that are lower than levels at which, in experimental animals or in human epidemiological studies, no effects were observed. CVs are not thresholds for harmful health effects; rather, they reflect an estimated radiation dose or chemical media concentration that is not expected to cause harmful health effects. Radiation doses and chemical media concentrations at or below the CVs can reasonably be considered safe. When a CV is exceeded, exposures will not necessarily produce undesirable health effects. This screening process enables ATSDR to eliminate safely from further consideration contaminants not of health concern and to further evaluate potentially harmful contaminants.

If the estimated radiation doses or chemical media concentrations at a site are above selected health-based comparison values, ATSDR proceeds with a more in-depth health effects evaluation. ATSDR scientists then determine whether the doses are large enough to trigger public health action to limit, eliminate, or study further any potentially harmful exposures. ATSDR scientists conduct a health effects evaluation by 1) examining site-specific exposure conditions for actual or likely exposures, 2) conducting a critical review of radiological, toxicological, medical, and epidemiological information in the scientific literature to ascertain the levels of significant human exposure, and 3) comparing an estimate of possible radiation doses or chemical doses to situations that have been associated with disease and injury. This health effects evaluation involves a balanced review and integration of site-related environmental data, site-specific exposure factors, and toxicological, radiological, epidemiological, medical, and health outcome data to help determine whether exposure to contaminant levels might result in harmful, observable health effects.

ATSDR has established a MRL to members of the public who might be exposed to elevated levels of radioactivity. Because the MRL is an estimate of daily human exposure to a hazardous substance that is unlikely to have an appreciable risk of adverse cancer and non-cancer health effects over a specified route and duration of exposure, a dose exceeding the MRL does not mean that an adverse health effect will occur. The ATSDR MRL for ionizing radiation regardless of the source is 100 mrem/y above ambient background levels [6].

The ATSDR MRL is not a regulatory level but for ionizing radiation, the MRL is the same value used by both the US Department of Energy (DOE) and the US Nuclear Regulatory Commission (NRC) to protect members of the public from general exposures produced by their licensees. The MRL could be 25 mrem/y, which is the regulatory dose limit if a licensed site is to be available for unrestricted use (10 CFR 20.1402) because regulatory agencies regularly inspect facilities holding licenses for the use of radioactive materials. The USEPA also has radiation dose limits based on pathway analyses such as air, water, soil, and ingestion. Furthermore, the USEPA also has limits based on a calculated risk when the USEPA is involved with cleanup of radiologically contaminated sites, especially those sites in which the contamination is in an uncontrolled environment such as the FWACC. The USEPA risk value for cleanup is set at the upper bound of their CERCLA cancer risk range, not to exceed 1×10^{-4} which equates to approximately 15 millirem per year as discussed in USEPA OSWER Directive 9200.4-18 [7].

For the FWACC assessment, ATSDR reviewed the site conditions, the types of work performed in the facilities, estimated the times that various work functions may take and an estimate of uncertainty in these times. For the probability distribution of each of these parameters, ATSDR used a Monte Carlo software package [8] which evaluated the data points and selected the best fit distribution to run the assessment simulations. In some cases, a triangular distribution was used since it can be used with limited data [9].

The gamma radiation readings selected for the assessment only included those in which the gamma exposure rate was at least 0.03 mR/h. This value was selected because the estimated ambient background was reported as low as 0.01 mR/h. Knoll states that for a single measurement, 1.96 times the standard deviation results in a 95% probability of the true mean [10]. Therefore, the 0.03 mR/h value exceeds background by 1.96 standard deviations, the estimated 95% statistical variance in the background. The areas selected for this assessment included the sewers, along the sidewalks, and two business interior survey areas (A-1 and A-6). Survey areas that were omitted, including the unoccupied residential areas, are considered safe by ATSDR. Moreover, in the grid surveys, only those readings that were not directly against a wall were used. Survey readings in which the grid coordinates included a zero were considered a wall surface. ATSDR did not include inhalation of radon in this evaluation because the basement is not considered an occupied portion of the structure and time spent in the basement area is limited to a few minutes per day; however, ingestion of contaminated soils was included in this evaluation. In previous

[6] Agency for Toxic Substances and Disease Registry (1999). Toxicological Profile for Ionizing Radiation. Atlanta: US Department of Health and Human Services.

[7] USEPA (1997). Establishment of Cleanup levels for CERCLA sites with radioactive contamination. OSWER Directive No. 9200.4-18 dated August 22, 1997.

[8] Palisade Corporation. @RISK. http://www.palisade.com/risk/ (accessed 01/011/2011). Mention of this software is not an endorsement by ATSDR, the Centers for Disease Control and Prevention, or the US Government.

[9] Kirchner, TB (2008). Estimating and applying uncertainty in assessment models *in* Radiological Risk Assessment and Environmental Analysis. John Till and Helen Grogan, eds. New York: Oxford University Press.

[10] Knoll, GF (2000). Radiation detection and measurement 3rd edition. New York: John Wiley & Sons, Inc. 802 pp.

public health evaluations, ATSDR has determined that the greatest potential for impact on public health is from the exposures to gamma radiation.

Estimated times of activities leading to exposures in the survey areas were based on information contained in the USEPA Exposure Factors Handbook [11] or through discussions with USEPA personnel who had observed activities at the site. The annual exposures were based on 8 hour days, 5.5 days per week for 50 weeks. In the case of underbody auto service, the times vary based on type of service performed. ATSDR estimated the amount of time for various types of service such as oil changes, brake service, and muffler replacement ranging from 1 to 3 hours. Times spent in warehouses, basements or storage areas were estimated from 10 to 30 minutes. Workers at the deli were also evaluated and their estimated annual doses are included in the table. Because of the soil contamination at the rear of the buildings, a trespasser scenario also was evaluated with respect to external exposures and inadvertent ingestion of contaminated soils. These factors are listed in Table 1.

To calculate the annual exposures an individual might receive from the contamination present at the various locations covered in the public health consultation, ATSDR uses a standard radiological exposure calculation as shown below:

$$(exposure\ rate \times exposure\ hours\ per\ year) = annual\ exposure$$

In the case of any work performed outdoors, ATSDR selected 50 weeks that would be suitable for outdoor work. This time frame was selected based on comments received from the USEPA which stated that outdoor work could occur for as long as 12 months based on direct observations, outdoor temperatures, and weather conditions. The results of these modeled calculations are shown in Table 2**Error! Reference source not found.**. These results show that there are three areas where the estimated annual radiation exposure exceeds the ATSDR MRL. These are in the storage area located at 1127 Irving Avenue, any automobile repair work performed in front of 1127 Irving Avenue, and to an individual who regularly walks on the sidewalks of both Cooper Avenue and Irving Avenue.

The soils in the rear of the Irving Avenue businesses are also contaminated with both thorium and radium as indicated by soil sampling. Although this property is abandoned according to the USEPA, equipment storage and trespassing occurs. Furthermore, many of the Irving Avenue businesses have rear doors allowing access to the area for various uses. ATSDR, in response to USEPA concerns, also modeled incidental soil ingestion using the parameters given in Table 3 and using the Monte Carlo input distributions and the resulting outputs as shown Tables 9 and Table 10, respectively, in Appendix A. The dose coefficients used were derived from ICRP and USEPA dose coefficients. The estimated doses are given Table 4.

Additional information on the uncertainty analyses including the input assumptions and outputs of the simulations is included in Appendix A of this report. This information includes graphic representation of the assumptions and simulations, statistics as the result of 10,000 approximations, the probability distributions and the 95% confidence intervals of these simulations. Appendix B includes a brief discussion of the risks of adverse health effects that may result from these exposures.

[11] US Environmental Protection Agency Exposure Factors Handbook available on line at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=12464 (last accessed on August 5, 2011).

Table 1. General Assumptions used in the Radiologic Assessment

Activity	*Location*	*Work Activity Level†*	*Exposure Range mR/h§*	*Estimated Time per day*
Work in Sewer	Cooper Avenue and Irving Avenue	High	0 – 4	120 minutes per month
Deli Employee	1125 Irving Avenue (basement)	Low	ND‡	Less than 10 minutes
Access storage room	1127 Irving Avenue	Low	0.04 – 0.5 (contact) 0.04 – 0.180 (1 meter)	10 to 30 minutes
Perform Auto body repair, painting, and maintenance	1127 Irving Avenue	Medium	0.13 – 0.18 (contact) 0.03 – 0.12 (1 meter)	60 to 300 minutes
Walk down Irving Avenue and Cooper Avenues (estimated distance of 500 ft)	Irving and Cooper Avenues	Low	0.01 – 1.5	2 minutes to 30 minutes
Work outdoors at body shop	1127 Irving Avenue	Medium	0.01 – 1.5	225 minutes
Work Inside warehouses	1129 Irving Avenue	Low	0.03 – 0.26 (contact) 0.03 – 0.16 (1 meter)	240 minutes
Warehouse (unspecified areas)	1133-1139 Irving Avenue	Low	ND	ND
Trespassing (or various uses by employees)	Rear of buildings	Low	1 – 2	60 minutes
Trespassing	Rear of buildings	Low	400 pCi/g§ Th-232 25 pCi/g Ra-226	250 mg/d (ingestion of soils)

†The work activity level was determined by USEPA Region II
‡Not determined or not measured
§pCi/g – picocuries of radioactivity per gram material; mg/d – milligrams per day ingested; mR/h – exposure rate in Roentgens per hour

Table 2. Modeling results for external gamma radiation exposures.*

Location	*5% lower confidence limit (mrem/y)*	*Estimated average (mean) dose (mrem/y)*	*95% upper confidence limit (mrem/y)*	*Estimated maximum dose† (mrem/y)*
Deli workers in basement	10	22	38	163
1127 Irving Avenue Access Storage Room Low Activity	13	122	271	925
Working outdoors at body shop Medium Activity	56	315	886	5400
Walking outdoors Low Activity	7	39	109	656
1129 Irving Avenue Work inside warehouse Low Activity	22	50	84	215
1127 Irving Avenue Body shop Medium Activity	41	105	196	453
1129 Irving Avenue Work inside warehouses Low Activity	46	117	210	403
Warehouse 1129 Irving Avenue Medium Activity	17	40	72	112
Warehouse 1133-1139 Irving Avenue Low Activity	32	98	197	446

*The confidence intervals were determined by the Monte Carlo software package used to estimate the dose distributions. The confidence intervals indicate that there is a 90% certainty that the estimated average radiation dose will lie between the upper and lower limits.

†The estimated maximum dose is the dose calculated using the maximum exposure rates, maximum stay times, and maximum frequencies of exposure. The abbreviation mrem/y is the dose in millirem per year.

Table 3. Modeling Results of incidental soil ingestion*

Parameter	*5% Confidence Level*	*Mean value*	*95% Confidence Level*	*Maximum Value*
Th-232 pCi/g	407.2	440.0	511.2	1,277.3
Ra-226 pCi/g	25.5	27.5	32.0	69.5
Soil g/d	0.2	0.3	0.3	0.4

*The confidence intervals were determined by the Monte Carlo software package used to estimate the dose distributions. The confidence intervals indicate that there is a 90% certainty that the estimated average radiation dose will lie between the upper and lower limits.

pCi/g is picocuries per gram material.

Table 4. Modeled radiologic doses from ingestion.

Parameter	*5% Confidence Level*	*Mean dose (mrem/y)*	*95% Confidence Level*	*Maximum dose (mrem/y)*
Bone Surface dose from Ra 226	87	107	131	281
Bone Surface dose from Th 232	1390	1710	2100	5080
Bone Surface Total dose via ingestion	1480	1820	2220	5190
Red Marrow dose from Ra 226	7	8	10	20
Red Marrow dose from Th 232	54	67	82	199
Red Marrow Total dose via ingestion	61	75	91	207
Effective dose from Ra 226	2	3	3	7
Effective dose from Th 232	22	33	45	85
Effective dose total	23	35	48	89

mrem/y is the modeled radiation dose to the organ expressed as millirem per year of exposure. REM is an acronym for Roentgen Equivalent Man

Conclusions and Public Health Implications

Data collected by the NYDHMH, the State of New York, their contractors, and the USEPA show that the Cooper Avenue and Irving Avenue intersection and surrounding buildings are contaminated with radioactive material arising from chemical separations and waste disposal practices performed during the 1940s until 1954 by the former Wolff-Alport Chemical Corporation. The contamination consists of the naturally occurring radioactive isotope Th-232 and its decay products, as well as some contamination resulting from the presence of radium. These radioactive elements decay, forming radon and thoron which has accumulated in at least one basement in the area. The data also indicate soil contamination in and around the sewer system and in the former rail spur.

The radiologic exposure to employees of the Primo Autobody Shop located at 1127 Irving Avenue are those most likely to receive a radiation exposure above the ATSDR screening value of MRL of 100 mrem per year above background levels as determined by Monte Carlo modeling and incorporating a 90% confidence interval. However, these levels of exposure are not expected to result in adverse health conditions. As discussed in the ATSDR Toxicological Profile on Ionizing Radiation [12], no adverse health effects from chronic exposure to ionizing radiation at these levels have ever been observed, even in those areas of the world where background radiation levels are 2 to 5 times higher than the typical background of the United States. Individuals who do not work in the area but use the sidewalks may also receive exposures that exceed the ATSDR MRL; however, these exposures contain sufficient uncertainties that there is little public health hazard because any variation in typical activities such as using the other side of the street would reduce the potential exposures to perhaps below the MRL.

If one applies the Linear Non-threshold model of radiation exposure which is used in setting standards, then these doses, although below the level for any observable adverse health effects, do represent some level of risk, albeit, a risk that cannot be observed.

Radiation-induced cancer resulting from external exposures has not been observed at these estimated levels of radiation exposure (See Appendix B for more information). Furthermore, the United States has areas of the country, particularly in the western states, where the typical background levels of natural radiation exceed these calculated doses with no indication of increased adverse health impacts. Even when the data from atomic bomb survivors is taken into account, health impacts were not observed until the estimated doses exceeded 10 rad [13]. In this case, there was at least a 2 to 8 year latency period prior to the appearance of leukemia; however, the exposures were instantaneous exposures resulting from the bomb blasts [14]. In terms of dose, there is a difference between a rad and a rem. Whereas the rad or radiation absorbed dose is a measure of the amount of energy deposited per unit mass, the rem is an estimated dose, taking into account the rad as well as weighting factors used to estimate various radiologic effects.

Thorium and radium, because of their chemical properties, will concentrate in bone and irradiate both the bone itself as well as the red bone marrow where blood cells are produced. The radiological dose from these radioactive materials to the entire body, described by the effective dose is lower than the dose delivered to the individual bone and red bone marrow. The total dose to the bone surface from the ingestion of these isotopes could be as high as 5.2 rem per year and the dose to the blood forming cells could be as high as 0.2 rem per year. Studies of the radium dial painters of the early 20th century indicated that doses in

[12] ATSDR (1999). Toxicological Profile for Ionizing Radiation. US Department of Health and Human Services. Public Health Services. Agency for Toxic Substances and Disease Registry. Atlanta, Ga.

[13] DT Goodhead (2009). Understanding and characterization of the risks to human health from exposure to low levels of radiation. Radiation Protection Dosimetry 137:109-117.

[14] Schull (1998). The somatic effects of exposure to atomic radiation: The Japanese experience, 1947-1997. Proc. Natl. Acad. Sci. 95:5437..

excess of 20,000 rem to the bone were associated with adverse health effects [15]. There have been no studies involving the ingestion of environmental thorium compounds and adverse health effects. However, the man-made thorium compound Thorotrast, a colloid containing thorium dioxide was used in medical facilities as an X-ray contrast medium and was administered by injection. Adverse health effects associated with this route of administration included reticulo-endothelial system-related diseases and liver cancers. The dose from the Thorotrast associated with liver cancer ranged from about 25 to 36 rad per year to the liver as measured at autopsy [16]. The corresponding doses to the red bone marrow and bone surfaces would be between one third to one half of the dose to the liver [17].

ATSDR believes that based on these studies, the potential for observable adverse health impacts following the ingestion of contaminated soils from this site is low, especially at these levels of exposure.

Evaluation of risks from estimated doses

The USEPA uses risk analysis to determine the need for removal of hazardous substances in the environment. Under its Superfund Program, the cancer risk is expressed as a range from one in one million to one in ten thousand (10^{-6} to 10^{-4}) [18]. That is, of one million exposed individuals, between 1 and 100 individuals may develop cancer over their lifetime. Using a risk coefficient and estimated doses, the risk is calculated to determine if the contamination exceeds these guidelines. ATSDR does not typically perform risk analyses; however, following a request from the USEPA Region II, ATSDR did calculate the cancer mortality risks which are discussed in Appendix B of this public health consultation.

The risk evaluation for the ingestion of contaminated soils did not exceed the upper range of the USEPA limit of 1 in 10,000. The theoretical cancer risk, as calculated by ATSDR, was 4 in one million (4×10^{-6}). As a comparison, the annual risk of cancer resulting from unavoidable exposure to background radiation is 2 in 10,000. These calculations are shown in Table 11.

The calculated theoretical risks from external exposures; however, were much higher than the risks from internal exposures. As shown in Table 12, many of the activities that take place along Irving Avenue do exceed the USEPA upper lifetime range of 1 in 10,000 after only 1 year of exposure at the maximum estimated dose. ATSDR calculated a maximum lifetime theoretical cancer risk of 31 in 10,000 for exposure for one year while performing work activities outdoors at the body shop.

To summarize the conclusions of this public health consultation, ATSDR evaluated the radiological surveys of the facilities in the Irving Avenue of Queens, New York. Our analysis is as follows:

1. There is radiological contamination of building structures, including walls and floors as well as city sewers;

[15] Rowland, R. (1994). Radium in Humans. A review of US studies. Argonne, Illinois, Argonne National Laboratory: 246.

[16] National_Research_Council (1988). Health Risks of Radon and other internally deposited alpha emitters. Washington, DC, National Academy Press.

[17] Kaul and Muth (1978). Thortrast kinetics and radiation dose. Results from studies in thorotrast patients and from animal studies. Radiation and Environmental Biophysics 15: 241.

[18] USEPA (2010). Memorandum – Establishment of cleanup levels for CERCLA sites with radioactive contamination. OSWER 9200.4-18.

2. It is unlikely that utility workers who access the sewer system will exceed the ATSDR MRL of 100 mrem/y; however, there are sufficient uncertainties in the sewer line measurements that there may be instances where the MRL could be exceeded;
3. Sidewalks along Irving Avenue are contaminated with radiological materials;
4. Workers for the auto body shop may have an elevated risk of cancer from exposure to ionizing radiation and their exposures may exceed the ATSDR Minimal Risk Level for Ionizing Radiation; and
5. Pedestrians who frequently use the sidewalks of Irving Avenue may have an elevated cancer risk from the exposure to ionizing radiation and their exposures may exceed the ATSDR Minimal Risk Level for Ionizing Radiation.

Recommendations

ATSDR makes recommendations to other agencies and organizations. These recommendations are based on the data and information received by ATSDR. For the FWACC, ATSDR recommends:

1. More thorough characterization of the underlying soils to determine the extent of the contamination spread. This includes the sewer system and former rail spur areas;
2. Eliminate the need to access materials in the storage area of 1127 Irving Avenue should be performed as rapidly, but safely as possible. To reduce radiation exposure, consider moving the materials to another location in this storage area where the exposure rates are lower;
3. Reduce the amount of outside work on the sidewalk in front of 1127 Irving Avenue or relocate this work to portions of the sidewalk where the radiation levels are lower; or physically remove the contamination. The USEPA should consider discussing this issue with the US Occupational Safety and Health Administration (OSHA).
4. Place controls on the amount of time any worker can be in the area sewer system to minimize radiation exposure, and ensure adequate work permits and training are available for workers;
5. In the case of any extensive sewer work including excavation or line replacement, radiological surveys should be performed by a qualified radiation safety professional before any work is performed; and
6. Ventilate any basement or area with limited air exchange to reduce the concentration of radon which accumulates during the decay of both radium and thorium.

Public Health Action Plan

None at this time; however, ATSDR will continue work with all agencies involved in this project to ensure the public's health is protected.

Authors, Technical Advisors

Paul A. Charp, Ph.D.

Appendix A

Monte Carlo Analyses of Radiation Exposures and Doses from the Former Wolff-Alport Chemical Company

The estimated exposures and doses discussed in this public health consultation were determined through a statistical process known as Monte Carlo analysis. Briefly, this type of analysis is a computer-driven statistical technique in which distributions are chosen based on a goodness-of-fit routine which most likely represents the data distribution in a set of samples. Following the selection of the distributions, the values are randomly entered into a model to generate a range of possible results. From the statistics generated, one can select probability ranges of the generated distributions.

In 1997, the USEPA released a policy on the use of Monte Carlo to characterize uncertainty in estimates of exposure or risk [19]. In some instances, a Monte Carlo assessment may not be required, especially if preliminary screening calculations show the resulting exposures are not above levels of concern. This is especially true if the screening calculations are use over-estimates of the exposures.

The FACC data collected by the USEPA and state or local agencies suggested that the potential exposure to workers, intruders or individuals using the contaminated sidewalks could reach exposure levels of public health concern to ATSDR as well as the USEPA. Therefore, the Monte Carlo approach was used to estimate the radiation exposures and concomitant doses these individuals may receive.

This appendix gives both the input parameters and the output parameters of the distributions used for the simulations. These parameters include the computer-generated minimum, mean (average), and maximum value for both the inputs and outputs. Also included in these tables is the 90% confidence interval around the mean where the 5% percentile is the lower range of the distribution and the 95% percentile is the upper range of the distribution. In all cases, these values will be between the minimum and maximum values of the input parameters.

The software used to generate the Monte Carlo distributions was a commercial software package.

[19] USEPA (1997). Guiding principles for Monte Carlo Analysis. EPA/603/R-97/001.

Table 5. Monte Carlo Exposure Rate Input Parameters - I

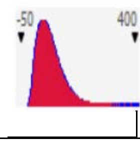
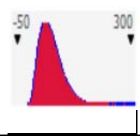
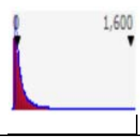
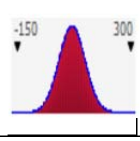
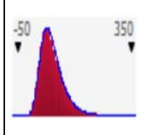
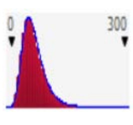
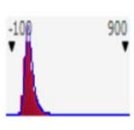
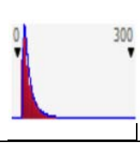
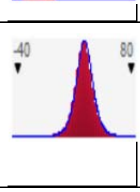
Variable	Monte Carlo Worksheet	Graph	Minimum exposure rate	Monte Carlo calculated 5% Confidence Level	Mean exposure rate	Monte Carlo calculated 95% Confidence Level	Maximum exposure rate
µR/h at contact	Warehouse		0.00	20.00	75.85	161.00	373.00
µR/h at one meter	Warehouse		0.00	20.00	61.87	122.00	269.00
µR/h at contact	Storage 1127 Irving Avenue		22.89	34.38	120.07	334.93	1519.11
µR/h at one meter	Storage 1127 Irving Avenue		-113.14	-9.31	69.86	148.98	271.16
µR/h at contact	1127 Irving Avenue body shop		-4.88	29.65	78.61	148.55	348.64
µR/h at one meter	1127 Irving Avenue body shop		4.77	31.32	67.01	117.99	280.99
µR/h at contact; low physical activity area	1129 Irving Avenue		-0.77	38.53	90.98	166.45	835.26
µR/h at contact; high physical activity area	1129 Irving Avenue		23.27	26.51	42.19	76.25	285.80
µR/h at contact; medium physical activity area	1129 Irving Avenue		-23.34	15.58	30.49	45.39	79.02

Table 6. Monte Carlo Exposure Rate Input Parameters - II

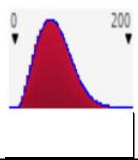
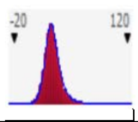
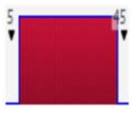
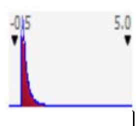
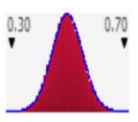
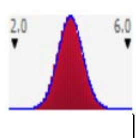
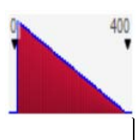
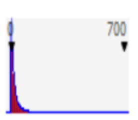
Variable	Monte Carlo Worksheet	Graph	Minimum exposure rate	Monte Carlo calculated 5% Confidence Level	Mean exposure rate	Monte Carlo calculated 95% Confidence Level	Maximum exposure rate
µR/h at one meter; low physical activity area	1129 Irving Avenue		15.12	33.30	73.43	120.83	189.17
µR/h at one meter; high physical activity area	1129 Irving Avenue		-2.95	16.78	30.12	46.57	112.60
µR/h at one meter; medium physical activity area	1129 Irving Avenue		9.39	11.00	25.50	40.00	41.61
maximum outdoor exposure rate estimate	Outdoor and Deli		0.01	0.04	0.25	0.70	4.71
maximum time for walking down block	Outdoor and Deli		0.31	0.42	0.50	0.58	0.69
working outdoors	Outdoor and Deli		2.45	3.34	4.00	4.66	5.80
µR/h at contact; deli basement	Outdoor and Deli		25.00	34.00	143.50	300.96	377.09
µR/h at one meter; deli basement	Outdoor and Deli		21.62	24.42	44.76	93.00	603.56

Table 7. Monte Carlo Input Parameters for exposure times

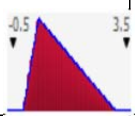
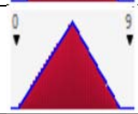
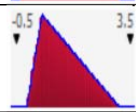
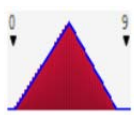
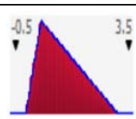
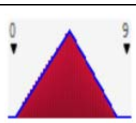
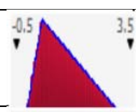
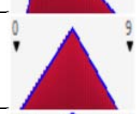
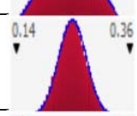
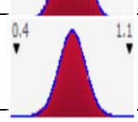
Category: exposure time (h/day)							
Variable	Monte Carlo Worksheet	Graph	Minimum	Monte Carlo Calculated 5% Confidence Level	Mean	Monte Carlo Calculated 5% Confidence Level	Maximum
exposure time (h/day) at contact	Warehouse		0.00	0.27	1.17	2.39	2.98
exposure time (h/day) at 1 meter	Warehouse		0.55	1.72	4.33	6.85	7.96
exposure time (h/day) at contact	Storage 1127		0.01	0.27	1.17	2.39	2.98
exposure time (h/day) at 1 meter	Storage 1127		0.50	1.72	4.33	6.85	7.96
exposure time (h/day) at/ contact	1127 body shop		0.00	0.27	1.17	2.39	2.98
exposure time (h/day) at 1 meter	1127 body shop		0.54	1.72	4.33	6.85	7.96
Category: hours/day							
h/d / µR/h contact	1129		0.01	0.27	1.17	2.39	2.98
h/d / µR/h meter	1129		0.51	1.72	4.33	6.85	7.96
h/d / µR/h contact	Outdoor and Deli		0.16	0.21	0.25	0.29	0.35
h/d / µR/h meter	Outdoor and Deli		0.46	0.63	0.75	0.87	1.06

Table 8. Monte Carlo Output-- Estimated Dose Distributions

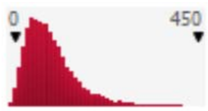
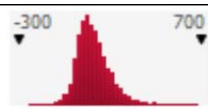
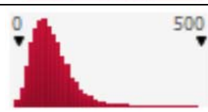
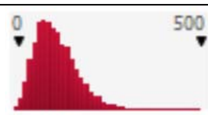
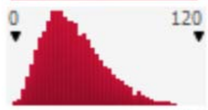
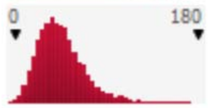
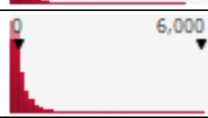
Location	Monte Carlo Worksheet	Graph	Min	5%	Mean	95%	Max
1129-1133 Irving Warehouse Areas (mrem/y)	Warehouse		3.63	31.82	97.82	196.89	403.70
1127 Irving Storage (mrem/y)	Storage 1127		-201.26	13.37	121.68	270.25	660.50
1127 Irving Indoors Body shop (mrem/y)	1127 body shop		12.28	41.02	105.14	196.61	479.95
1129 Irving Low Activity (mrem/y)	1129		9.36	46.16	116.55	209.45	485.19
1129 Irving Medium Activity (mrem/y)	1129		3.98	15.97	40.15	71.79	103.98
1129 Irving High Activity (mrem/y)	1129		1.70	21.59	49.45	86.28	169.11
deli workers in basement (mrem/y)	Outdoor and Deli		6.80	10.09	21.88	38.21	163.29
walking on sidewalks (mrem/y)	Outdoor and Deli		1.20	6.92	39.33	109.97	808.17
working outdoors (mrem/y)	Outdoor and Deli		9.16	55.46	315.48	877.64	5946.81

Table 9. Input Parameters for ingestion of contaminated soils.

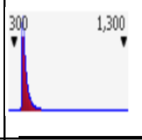
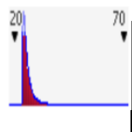
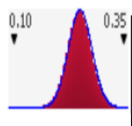
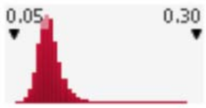
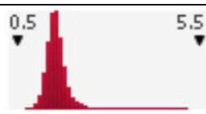
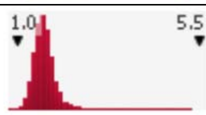
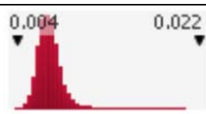
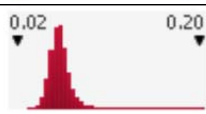
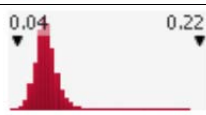
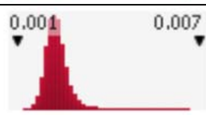
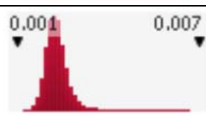
Name	Graph	Minimum	Monte Carlo calculated 5% Confidence Level	Mean	Monte Carlo calculated 95% Confidence Level	Maximum
Th-232 pCi/g		401.24	407.19	440.01	511.16	1277.25
Ra-226 pCi/g		25.07	25.45	27.50	31.95	69.45
grams per day		0.14	0.21	0.25	0.29	0.35

Table 10. Output parameters for soil ingestion based on total soil ingestion from Table 9.

Name	Graph	Minimum Dose (rem)	Mean Dose (rem)	Maximum Dose (rem)	Monte Carlo calculated 5% Confidence Level	Monte Carlo calculated 95% Confidence Level
Ra / Bone Surface		0.063	0.11	0.28	0.087	0.13
Th / Bone Surface		0.94	1.71	5.08	1.39	2.10
Ing / Bone Surface Total		1.01	1.82	5.19	1.48	2.22
Ra / Red Marrow		0.005	0.008	0.02	0.006	0.01
Th / Red Marrow		0.04	0.07	0.2	0.05	0.08
Ing / Red Marrow Total		0.04	0.07	0.21	0.06	0.09
ra / Effective		0.001	0.003	0.007	0.002	0.003
Ing / Effective Total		0.001	0.003	0.007	0.002	0.003

Appendix B

The Use of Radiation Dose versus Radiation Risk in Public Health Documents
and
Evaluation of Risks Associated with Exposures at the Former Wolff-Alport Chemical Company

The Use of Radiation Dose versus Radiation Risk in Public Health Documents

Introduction

The Agency for Toxic Substances and Disease Registry (ATSDR), Division of Health Assessment and Consultation, Site and Radiologic Assessment Branch (SRAB) has evaluated the scientific basis for the use of radiation dose and the expression of this dose in terms of risk in the preparation of public health documents. This document reviews the concepts of dose vs. risk and establishes the rationale for the use of dose in documents pertaining to radiation, radiation exposure and radiation dose.

To properly evaluate the dose and risk issues associated with radiation exposure, the terms dose and risk should be clearly defined. The international Society for Risk Analysis (www.sra.org) defines **risk** as "*The potential for realization of unwanted, adverse consequences to human life, health, property, or the environment; estimation of risk is usually based on the expected value of the conditional probability of the event occurring times the consequence of the event given that it has occurred*."

The society defines **dose** in terms of a "**Dose-response assessment**: *The process of characterizing the relation between the dose of an agent administered or received and the incidence of an adverse health effect in exposed populations and estimating the incidence of the effect as a function of human exposure to the agent.*"

Risk assessments compared to public health assessments

The US Environmental Protection Agency (USEPA) develops regulations based on risk. They also develop health risk assessments. The EPA conducts these assessments for both specific sites (such as Superfund sites) and specific chemicals. In site assessments, the USEPA uses a four-part process to estimate the *chance* that contact with chemicals from that site will harm people now or in the future. These steps include data collection and evaluation, exposure assessment, followed by toxicity assessment and then risk characterization to reveal which chemicals are posing risks and what the health risks are.

In contrast to the USEPA, ATSDR develops its public health documents on a scientific review of toxicological, radiological health, peer-reviewed science, and other reliable sources of information to evaluate the impact of hazardous chemicals and radiation on the public health. The ATSDR public health assessment differs from the USEPA risk assessment in many ways. Perhaps the most important difference between ATSDR public health assessments and USEPA risk assessments is that ATSDR bases its findings on *site-specific factors* including demographics, realistic land use, realistic pathway analysis, and other pertinent data related to the site. As defined, the ATSDR health assessment is the *evaluation of data and information on the release of hazardous substances into the environment in order to assess any current or future impact on public health, develop health advisories or other recommendations, and identify studies or actions needed to evaluate and mitigate or prevent human health effects* (55 Federal Register 5136, February 13, 1990, as codified at Title 42 Code of Federal Regulations Part 90).

General Accounting Office Review of the Basis for Radiation Standards

The General Accounting Office (GAO) released a1994 report reviewing the US radiation standards and radiation protection issues [20]. The GAO further refined their results in 2000 [21]. The 1994 findings indicated a general lack of federal agency consensus on acceptable radiation risk to the public. Among the reasons for this lack of consensus is that agencies have different missions and Congressional mandates. For example, the USEPA implements a risk-based radiation protection approach; whereas, the US Nuclear Regulatory Commission (NRC) approaches the radiation protection issue with a dose based framework. The USEPA attempts to address individual contamination sources, whether chemical and/or radioactive materials thus protecting both human health and environmental resources [22]. Historically, the USEPA generally set a risk of 1 in a million that an individual will develop cancer in a lifetime as a goal for remediation and has considered a risk of greater than 1 in 10,000 to be potentially excessive. The GAO described the approach used by the USEPA approach as a "bottom up approach" setting a relatively restrictive risk goal to be pursued through the best available technology. This also permits a less restrictive limit in site-specific situations. In contrast, USNRC bases its methodology on a human health protection approach [23]. The GAO described this methodology as a "top down approach." Compared with USEPA, USNRC sets a relatively less restrictive dose limit but reduces doses (and risks) well below the limit in site-specific situations where the reductions are "reasonably achievable." This is the basis of the USNRC ALARA methodology (As Low As Reasonably Achievable).

The 2000 GAO report reported that "conclusive evidence of radiation effects is lacking below a total of about 5,000 to 10,000 millirem, according to the scientific literature" and this was also the consensus of experts they interviewed. At these levels of radiation doses, expert organizations estimate radiation risks using complex models of existing data [24] although the outcomes are perhaps not statistically significant [21]. Nonetheless, regulatory agencies, using the linear no-threshold hypothesis assume there is a risk at any radiation exposure.

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20 United States General Accounting Office (1994). Report to the Chairman, Committee on Governmental Affairs, U.S. Senate. Nuclear Health and Safety: Consensus on Acceptable Radiation Risk to the Public Is Lacking. GAO/WED-94-190.

21 United States General Accounting Office (2000). GAO Report to the Honorable Pete Domenici, U.S. Senate. June 2000 Radiation Standards: Scientific Basis Inconclusive, and EPA and NRC Disagreement Continues. GAO/RCED-00-152.

22 EPA based its protection approach on the regulation chemicals, many of which have a mode of action generally less understood that the mode of action of radiation exposure and dose.

23 The approach used by the NRC is derived from years of experience in estimating radiation-specific risks from the former Atomic Energy Commission, international organizations and internationally recommended radiation dose limitations associated with a risk assessment framework that factors in the naturally occurring radiation exists naturally in the worldwide environment.

24 For example, a 1990 study by a National Academy of Sciences committee, called BEIR V, estimated that, at the 90-percent statistical confidence interval, out of 100,000 adults exposed to 100 millirem a year of radiation over a lifetime, anywhere from 410 to 980 men and 500 to 930 women might die of cancer caused by the exposure. This confidence interval assumes the validity of the linear model and reflects the uncertainty of inputs to the model.

Table 1 from the GAO reports shows that federal radiation doses and risks are widely distributed even among the same agency, dependent on mission.

Table 1. Federal standards or guidelines, radiation limits, and assumed risk values.

Standard or guideline	Agency	Limit	Lifetime Risk
General public limit	USNRC	100 mrem/y	1 in 300
Indoor radon	USEPA	4 pCi/L	1 in 40
Radium in soil	USEPA	5 pCi/g	1 in 50
Groundwater MCL	USEPA	4 mrem/y	1 in 7000
Air pollution	USEPA	10 mrem/y	1 in 3000
CERCLA	USEPA		1 in 15,000 to 1 in 1.5 million (lifetime)
Annual risk per rem		0.0005	3.5E-2 per rem
Background of 311 millirem per year, 70 years			~ 1 in 92 (1.1E-2)

Data derived from Table 1, GAO 1994

Discussion of the Linear No Threshold Model

The health effects induced by radiation exposures has been studied for over 100 years, but the risk based standards are derived from hypothetical models utilized for low level radiation doses and dose effects [25]. The models used by agencies such as the USEPA, USNRC, Department of Energy, and others are based on atomic bomb survivors, radium dial painters of the early 20th century, medical treatments, uranium miners, accidental radiation exposure individuals, and other studies of large populations who have received various doses of ionization radiation of several types for various reasons. Unfortunately, scientists have had much difficulty extrapolating the known effects from the high radiation doses to lower, less well-verified dose related health effects, especially those associated with radiation exposures marginally exceeding backgrounds.

Accepted as a mathematically simple working hypothesis that may not underestimate risks yet may be conservative, the linear no-threshold model (LNT) drives regulations. The LNT states that even the smallest radiation exposure carries a quantifiable cancer risk. The National

25 For the purpose of this document, ATSDR is defining low dose and low dose rate as any dose that is associated with radiation doses of less than 20 rads (0.2 Gray; Gy) or 50 milliGy per year (5 rad/y)

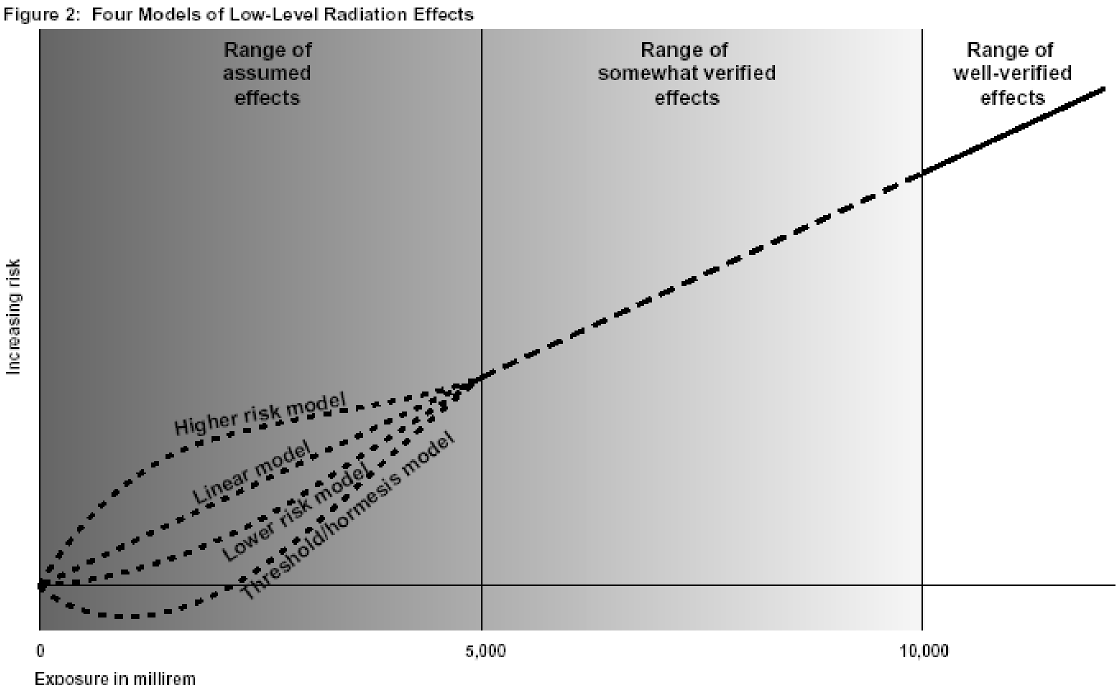
Academy of Science also stated that the LNT concept was not universally accepted and its use "clearly introduces another uncertainty factor into the calculation of risk." The committee reviewing the iodine-131 (I-131) issues also stated that "uncertainty also applies both to the assumption of constancy of ERR and to the assumption of additivity of multiple exposures. [26]" The regulatory agencies use LNT for risk assessments, regulatory impact analyses, cost-benefit analyses, and other studies to support decision-making. In using the model, they are able to estimate risk reductions and hypothetical lives saved from regulating at a given exposure level. At issue with LNT and with its use to establish risk is the evidence that the response relationship may vary in individuals, and with the type of radiation, rate of radiation exposure, type of cancer, body organs exposed, sex, and/or age at exposure. These unknowns add to the issue of uncertainty in the risk numbers. The GAO, during their investigation "found considerable agreement among regulators and scientists that the linear model may be a conservative "fit" to the data, unlikely to underestimate risks. However, some said the data support the existence of a safety threshold below which there are no risks, and others said low levels of radiation can be beneficial to health."

As the preferred model, LNT has been used for many years for regulating low-level radiation although its scientific basis has come under scrutiny in recent years by national and international organizations such as the International Commission of Radiological Protection (ICRP), the National Council on Radiation Protection and Measurements (NCRP), American Nuclear Society and the Health Physics Society and by individual scientists and private organizations. Therefore, many scientists want conclusive evidence of radiation effects at the lower levels of exposure where the impact of LNT-driven regulations is greatest. The GAO stated "The consensus view we encountered is that the research data on low-level radiation effects are inadequate either to establish a safety threshold or to exclude the possibility of no effects. Scientists we contacted and scientific literature we examined generally did not indicate that any one model clearly best fit the overall data."

The GAO then developed the following figure (Figure 1) from their analysis. The figure shows the representative knowledge base of radiation effects in relation to radiation dose. Besides the four possible dose response curves indicated on the figure, it also shows that at a dose of 10,000 mrem (10 rem, 0.1 Sv) or more, the data are conclusive with respect to the identification of health effects resulting from radiation exposure. Between 10 rem and five rem, the data are not clear as to the health effects. Below five rem the effects are not observed, only assumed to occur. Therefore, the risk associated with a dose that approaches background, 0.311 rem/year (311 mrem or 3.11 mSv) is essentially impossible to measure.

26 National Academy of Sciences (1999). Exposure of the American People to Iodine-131 from Nevada Nuclear-Bomb Tests: Review of the National Cancer Institute Report and Public Health Implications.

Figure 1. Four models of low-level radiation effects from GAO 2000 report.



Nonetheless, there is general acceptance of the risk coefficient (referred to as detriment by the ICRP) used to calculate these risk numbers. That coefficient is 0.05% per rem per year of exposure to low dose, low dose rate radiation [27 28 29]. The coefficient is for cancer mortality.

Do the data fit a LNT approach: Implications of linear risk

As seen in Figure 1, a major factor in dealing with risk at low dose is the shape of the dose response curve below five rem. For various types of radiation-induced cancers, the data may not fit the linear model but fit other models such as the linear-quadratic or quadratic models of dose versus effect. The error (uncertainty) associated with these models is not an additive error but a geometric error where the observed value is either multiplied or divided by the associated error. If the associated error is large, then the confidence intervals can vary by an order of magnitude.

The issue in using risk for public health documents is the applicability of the existing data. Radiation risks derived from epidemiological studies are not necessarily precise because of the small sample size for a given endpoint. Issues in applying the risks derived from these types of studies include population differences such as demographics, base line health of the populations (controls and experimental), lifestyles, and how these compare to American lifestyles. Another issue important to the risk assessment not adequately addressed is the evaluation method used to adjust high dose and high dose rates to low dose and low dose rates. The term dose and dose rate

27 Environmental Protection Agency (1994). Estimating Radiogenic Cancer Risks. EPA 402-R-93-076

28 International Commission on Radiological Protection (1991).1990 Recommendations of the International Commission on Radiological Protection. ICRP Publication 60.

29 National Council on Radiation Protection and Measurements (1993). Risk Estimates for Radiation Protection. NCRP Report No. 115.

effectiveness factor (DDREF) has been used to account for this difference but no clear determination of the true DDREF has been accepted. Typically a value of 2 is used, meaning the risk associated with exposure to low dose, low dose-rate radiation is ½ the risk from exposure to high dose, dose rate radiation. The DDREF is a factor applied to the risk from the radiation exposure estimated in the high-dose atomic bomb studies to predict the risk from radiation exposure in low-dose and low-dose-rate studies.

Issues related to proper determination of risk

The evaluation of data in the development of risk numbers is important. For example, was the information on death certificates correct and verified by the appropriate agency? Important issues for this include cause of death, site of cancer, primary or secondary malignancy and related disease states that may have played a role in the onset of death. In fact cancer is listed as the secondary cause of death on the death certificate.

There are some indications that sex and age are important in the induction of radiation-induced effects on humans. This is especially true for cancer estimates in the different sexes. The National Academy of Science BEIR V report [30], which has received much criticism for its methods of data analysis and disease groupings, assesses an uncertainty of 10% for sex-related cancers. In the case of age-related cancers, there may be different sensitivities based on age. Younger children may be more susceptible than older children based on the type of cancer. However, this sensitivity may change as the child ages especially if the time of disease onset is unknown. This is important if the evaluation is occurs on less than a lifetime exposure. The evaluation over a lifetime is difficult in its own right. Also important is at what age the radiation exposure was received.

As an example, in the atomic bomb survivors, the type of radiation associated with the bombing of Nagasaki was essentially gamma rays. A linear model fits best or at least as well as a linear-quadratic model for many cancers other than leukemia, specifically, cancer of the breast, lung, stomach, and thyroid, where the fit of the quadratic model is not good. This is in contrast to leukemia where the quadratic model fits better than either the linear or the linear-quadratic model. Statistically, however, one cannot actually distinguish one model from another.

The NCRP, in their Report No. 136 on the LNT issues [31] reevaluated the existing data as it pertains to the dose-response of ionizing radiation and the health effects associated with exposures to ionizing radiation. Their evaluation focused on “the mutagenic, clastogenic (chromosome-damaging), and carcinogenic effects of radiation ...” As with other reviews by the NCRP, the council found no conclusive evidence to reject the LNT model for radiation dose response. One result of these reviews, however, is that the NCRP stated that for cell systems receiving “low-LET radiations the lowest dose at which a statistically significant increase of transformation over background has been demonstrated is 10 mGy.” This is equivalent to a radiation dose of 1 rad. In the case of animal studies, there is a variation however, in the dose response curves and “the available information does not suffice to define the dose-response

30 National Research Council (1990). Health Effects of Exposure to low levels of Ionizing Radiation. Washington, DC, National Academy Press.

31 National Council on Radiation Protection and Measurement (2001). Evaluation of the linear-nonthreshold dose-response model for ionizing radiation. NCRP Report 136. NCRP: Bethesda, Maryland.

curve unambiguously for any neoplasm in the dose range below 0.5 Sv...” as stated on page 210 of the NCRP report. To caveat this however, the NCRP also stated that other data on mice with regard to induction of neoplasms and life-shortening was not inconsistent with a linear response. Thus, there is uncertainty in the response to the types of radiation, the endpoint under investigation, and the animal system being studied.

According to the NCRP, similar dose responses occur in humans as evidenced by many studies. However, many of these studies were the atomic bomb survivor studies where the doses and dose rates are much different to those parameters typically observed at hazardous waste sites. The NCRP states that in the bomb survivors, induction of leukemia appears to be linear-quadratic; however, studies may have missed the initial wave of leukemia as these studies began at least 5 years following the bombing. Overall, the induction of solid cancers has a LNT component as low as 50 mSv (5 rem). Other radiation studies show a possible increase in fetal cancer following an exposure of 10 mGy and increased thyroid cancer following irradiation during childhood following a dose of 100 mGy (10 rad) [31].

What are the problems of using risk in public health documents?

Currently, the only unequivocally known health effect resulting from the exposure to radiation is the induction of cancer. However, data are beginning to appear in the literature associating exposures to cardiovascular diseases [32]. The NCRP in 1993 reviewed the risks associated with radiation exposure and radiation-induced cancers [29]. The NCRP identified 4 non-trivial concerns with the use of risks in the evaluation of radiation exposure. ATSDR has paraphrased these concerns as follows.

1. The risk varies with the selection of the appropriate risk-projection model.
2. The duration of exposure may vary from small periods of time to 50 years (workers) to 70 years (life time).
3. Are doses calculated for a short period of time or over the lifetime of the exposed individual. How the extrapolation from high dose, high dose rate to low dose, low dose rate becomes important over these various time frames.
4. Concomitant with the problems associated with the dose/dose rate issues, is the adjustment for ethnicity, population dynamics, and other significant differences among the populations irradiated. For example, the Japanese population of the 1940s and the United States population of the latter half of the 20th century.

The NCRP also recommends that other factors contributing to this detriment should be considered. These factors include genetic effects, teratogenic effects, length of loss of life.

What is an acceptable risk?

The issue then becomes how does one establish the acceptable risk and how do you correct for population dynamics, dose vs. risk assessment, and other issues discussed in the previous section.

32 Yoichiro Kusunoki, Seishi Kyoizumi, Mika Yamaoka, Fumiyoshi Kasagi, Kazunori Kodama and Toshio Seyama (1999). Decreased Proportion of CD4 T Cells in the Blood of Atomic Bomb Survivors with Myocardial Infarction. Radiation Research 152:539-543.

Researchers have attempted to define risks in terms of what is acceptable to the general population. In industry, the risk of accidental death is approximately 1 in 10,000 per year. Industries with this risk, or less, are referred to as "safe" industries. The following activities would have the same risk assumed for a 1 mSv (100 mrem) radiation exposure [33]:

- Smoking 70 cigarettes (cancer, heart disease)
- Drinking 25 liters of wine (cirrhosis of the liver)
- Spending 50 hours in a coal mine (black lung disease)
- Traveling 300 minutes by canoe (accident)
- Traveling 500 miles by bicycle (accident)
- Traveling 7,500 miles by car (accident)
- Eating 2,000 tablespoons of peanut butter (liver cancer caused by aflatoxin B)

The Swedish Radiation Protection Authority stated that 1 mSv is not a boundary between dangerous and harmless levels. The authority compared this reasoning to automobile speed. For example, a speed just under 60 miles per hour is not "safe" and a speed just over is not "dangerous," because naturally the risk increases with the increase in speed.

The Authority also stated that in response to Chernobyl, the European communities established action levels for radiation in food. The reasoning for keeping the radiation dose for foodstuffs below 1 mSv per year (100 mrem) was based on the Authorities' weighing up of the risks and costs involved. Based on a 1986 risk assessment, this dose would mean that if 50,000 people all received a radiation dose of 1 mSv, one person would statistically get a fatal cancer. Follow-ups since then have shown that the vast majority of the Swedish population was exposed to significantly lower doses, on average only a few hundredths of a mSv per year.

Nonetheless, the Swedish Radiation Protection Authority stated that it was "difficult to compare the radiation risks of the Chernobyl disaster with other risks. Regardless of the comparisons used – cigarette smoking, driving a car, being struck by lightning, drowning, x-ray examinations or living in a house with high radon levels – they can all be challenged. Comparisons never hold water. Some risks are taken voluntarily and others are not. Some risks mean health effects later in life, whilst others can cause death instantaneously. What is more, we as individuals interpret these risks in different ways. A large number of studies also indicate considerable differences in how laymen and experts interpret the risks associated with radiation." [34]

The use of dose in public health documents

The ATSDR uses radiation doses in its public health documents for various reasons. Among these are the facts that dose coefficients are based on a more exact science; that is, the doses are based on physical constants and primary principles of physics such as energy absorption, and health effects resulting from radiation doses are based on a "weight-of-evidence" approach. Furthermore, the foundation of radiation health studies use these facts as well as a long history of

33 Allman, WF (1985). Staying Alive in the 20th century: The Experts Can Tell Us What's Risky. But Most of Us Take Our Own Chances. Science, October 1985, p.30

34 Swedish Radiation Protection Authority as published in Dagens Nyheter, the major Stockholm morning paper on April 24, 2002. http://www.ssi.se/english/DN_Article_Eng.pdf

research in which health outcomes were evaluated on the radiation dose and not on the perceived risk. That is, the basis for health outcomes is direct observations using known parameters. ATSDR also recognizes there is uncertainty in these dose coefficients; however, the agency believes the magnitude of this uncertainty is less than the uncertainty associated with risk assessment methodologies.

ATSDR, in preparing its public health documents, also rely on site-specific parameters such as demographics, realistic land use, and other pertinent data related to the site. Using dose coefficients and modifying the coefficients for chemical forms and particle sizes that are not typically done for risk assessments allows for ATSDR to develop more realistic values for the agency dose assessments as they pertain to public health documents.

In 2002, the Chairman of the ICRP proposed a new method of harmonization of radiation protection based on a series of radiation doses [35]. Based on this new harmonization, if the risk of harm to the health of the most exposed individual is trivial, then the total risk is trivial – irrespective of how many people are exposed. The levels of concern, based on dose and health concern and not risk, are in Table 2.

Table 2. Harmonization of radiation doses to levels of health concern based on comparison to background radiation.

Level of Concern	Effective Dose
High	Greater 100 times background
Raised	Greater than 10 times background
Normal	Average Natural Background (nominal USA of 3.11 mSv)
Low	Less than one tenth of background
None	Less than one hundredth of background

<u>Health effects associated with exposure to ionizing radiation</u>

Exposure to radiation is expressed as two generic types, acute and chronic exposures. By definition, ATSDR considers acute exposures as exposures having a duration of less than two weeks; whereas, chronic exposures occur over a year or more.

The adverse health effects from acute exposures to radiation have been well defined as a result of the atomic bomb survivors, medical accidents and industrial accidents. The issues for this document are those health effects associated with low dose chronic exposures to ionizing radiation. These health effects are more difficult to define, characterize, and discuss. ATSDR experience in sites contaminated with radioactive materials shows that chronic exposures are incremental in comparison to background. In the United States, average annual dose from background radiation comes from exposure to naturally occurring radon and other inhaled radionuclides (73%), terrestrial (6.7%) and cosmic radiation (11%), and radionuclides in the

35 Clarke, RH (2002). New Ideas on Recommendations from ICRP for Control of Radiation Sources. Presented to CIEMAT on September 19, 2002.

body via ingestion (9.3%) [36]. The typical average background radiation in the United States is 3.11 mSv (311 mrem) per year.

Exposures associated with background radiation

ATSDR could not identify any peer-reviewed studies to show that background is harmful. In fact, there are portions of the globe where the background is higher than the typical area in the United States. According to the United Nations, the background radiation can vary from below 1 mSv (100 mrem) to above 6.4 mSv (640 mrem) per year or more. For example an area in China where elevated levels of natural background radiation are found, studies have shown a significant increase in chromosomal aberrations; however, no increases in adverse health effects have been observed in the 20 or more years this area has been studied. Other areas in the world where there are high background radiation levels include India, Brazil, and Iran. The area in Iran, Ramsar, has verified doses as high as 130 mSv per year (1,300 mrem) [37].

Furthermore, the USEPA Science Advisory Board stated that it is difficult to distinguish radiation-induced changes in risk from the baseline exposures in the range of natural background. They also recommended that the USEPA discuss potential problems associated with the use of LNT dose response model risk estimates in very low dose settings. Currently at these low doses, statistically significant differences between the cancer rates among "exposed" (defined study populations) and "non-exposed" (defined comparison populations) are not observed. These near background doses are only a fraction of those that have been found to be associated with statistically significant differences in cancer frequency between "exposed" and "non-exposed" populations [38].

Incremental exposures above background radiation

Many studies have attempted to show a cause and effect from low-level chronic radiation exposure. In these studies, low dose can be defined as doses in excess of 10 mSv (1 rem). No studies exist for exposures or doses below this limit. For many of these low dose epidemiological studies, researchers used the standard mortality ratio (SMR). The SMR is defined as the ratio of observed deaths in a population to the expected number of deaths as derived from rates in a standard population with adjustment of age and possibly other factors such as sex or race (Society for Risk Analysis).

An English study of over 95,000 radiation workers whose collective dose from external radiation is about 3,200 man Sv (3,200/95,000 = 34 mSv or 3.4 rem average cumulative dose) only took

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36 NCRP (2009). Ionizing radiation exposure of the population of the United States. MCRP Report 160. National Council on Radiation Protection and Measurements. Bethesda, MD.

37 Several data sources were used in developing this section include internet searches and the Health Physics Journal and United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) reports.

38 USEPA (2008). Advisory on agency draft white paper entitled "Modifying EPA Radiation Risk Models Based on BEIR VII." EPA-SAB-08-006 dated January 31, 2008.

into account external radiation exposure and dose. The results showed the standard mortality ratio for all cancers was less than 1 [39].

A later study by Cardis and coworkers included 95,000 nuclear industry workers in the United States, Canada, and the United Kingdom. The study participants were monitored for external radiation exposure (mostly gamma) and were employed for at least 6 months. In all, there were 15,825 deaths, of which, 3,976 were from cancer. The authors found no evidence of a dose response and mortality association from all causes or from all cancers. Of the cancer types, leukemia except for chronic lymphocytic and multiple myeloma showed a significant association with cumulative external radiation dose [40].

In a cohort study to determine if children were at risk of developing leukemia or other cancers before 25 years of age, Roman and coworkers included 39,557 children of male workers and 8,883 of female workers. The study suggested that the incidence of cancer and leukemia among children of nuclear industry employees is similar to that in the general population. The SMR for all cancers and leukemias for both sexes was less than 1 [41].

Conclusion

The science associated with risk is based on a model that, at low doses typically associated with small multiples of background, cannot be proven or disproven. ATSDR also realizes that every action, radiation dose, or activity has an associated risk. However, the mission of ATSDR is to "**Serve the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposures and disease related to toxic substances.**"

As previous defined, risk is "*[T]he potential for realization of unwanted, adverse consequences to human life, health, property, or the environment; estimation of risk is usually based on the expected value of the conditional probability of the event occurring times the consequence of the event given that it has occurred*."

The Site and Radiological Assessment Branch does not consider this a health-based process but a statistical evaluation.

The opinion of the Site and Radiologic Assessment Branch is that the best science is based on weight-of-evidence dose response to ionizing radiation. Therefore, our documents will not be based on risk but on radiation dose

39 Kendall GM, Muirhead CR, MacGibbon BH, O'Hagan JA, Conquest AJ, Goodill AA, Butland BK, Fell TP, Jackson DA, Webb MA, et al. (1992) . Mortality and occupational exposure to radiation: first analysis of the National Registry for Radiation Workers BMJ Jan 25;304(6821):220-225.

40 Cardis E, Gilbert ES, Carpenter L, Howe G, Kato I, Armstrong BK, Beral V, Cowper G, Douglas A, Fix J, et al. (1995). Effects of low doses and low dose rates of external ionizing radiation: cancer mortality among nuclear industry workers in three countries. Radiation research 142:117-132.

41 Roman E, Doyle P, Maconochie N, Davies G, Smith PG, Beral V. (1999). Cancer in children of nuclear industry employees: report on children aged under 25 years from nuclear industry family study. *BMJ*. 1999 May 29;318(7196):1443-1450.

Evaluation of Risks associated with exposures at the Former Wolff-Alport Chemical Company

ATSDR discussed site related issues with the USEPA Region II removal staff during the week of October 10, 2011. One result of these conversations is that ATSDR would include a discussion of theoretical cancer risks associated with the radiation exposures associated with this site as an appendix to the public health consultation.

In April 2011 the USEPA released new estimates of the cancer incidence and mortality to the US population resulting from exposures and doses received from low levels of ionization radiation [42]. These estimates correlate with the estimated dose coefficients developed by the USEPA with the release of Federal Guidance Report 13 entitled *Cancer Risk Coefficients for Environmental Exposure to Radionuclides.* FGR-13 includes coefficients for calculating estimates of cancer risk for over 800 radionuclides by several exposure pathways, models, and U.S. usage patterns [43].

The risk coefficients used in this document were calculated based on the United States population determined by the 2000 Census and assumes the radiation exposure is constant throughout the lifetime of an individual. The coefficients are also based on findings of the National Academy of Sciences Biological Effects of Ionizing Radiation (BEIR) VII report.

The USEPA states for uniform whole-body exposures of low-dose gamma radiation to the entire population (both sex and age adjusted), the cancer incidence risk coefficient (Gy^{-1}) is 1.16×10^{-1} (5.6×10^{-2} to 2.1×10^{-1}), where the numbers in parentheses represent an estimated 90% confidence interval. The corresponding coefficient for cancer mortality (Gy^{-1}) is about one-half that for incidence; that is, 5.8×10^{-2} (2.8×10^{-2} to 1.0×10^{-1}) [42]. The USEPA further states that the risk from exposure to background radiation over a lifetime of 75 years is about 0.87% (incidence) and 0.44% (mortality).

Converting dose calculations to risk estimates

The risk coefficient used by the USEPA is expressed in terms of risk per unit dose of absorbed radiation in which the absorbed radiation is the term Gray (Gy). In this public health consultation, the dose is expressed in terms of effective dose (mrem; 100 mrem = 1 mSv). Although the two terms are not necessarily interchangeable, for the purposes of this document 1 Gray can be substituted with 1 Sievert. With this substitution, the risk values then become 1.16×10^{-3} rem^{-1} for cancer incidence and 5.8×10^{-4} rem^{-1} for cancer mortality per year of exposure. In the case of an individual exposed to one rem per year for 50 years, their cancer incident risk would be 5.8% and their cancer mortality risk would be 2.9%. The risk coefficients are dose dependent; that is, the coefficient is the same regardless of the specific radionuclide. The conversion from dose to risk involves one additional computational step in which the estimated dose is multiplied by the risk coefficient yielding the increased risk per year of exposure.

[42] USEPA (2011). EPA radiogenic cancer risk models and projections for the U.S. population. US Environmental Protection Agency. April 2011. EPA 402-R-11-001.

[43] USEPA (1999). Cancer risk coefficients for environmental exposure to radionuclides. Federal Guidance Report 13. US Environmental Protection Agency. September 1999. EPA 402-R-99-001.

The following tables shows the parameters, annual estimated maximum radiation dose, the risk coefficient and the annual risk associated with that dose. For comparison purposes, the annual risk resulting from the typical dose received from background radiation, excluding medical procedures is included in the table as well. The value for the background radiation dose was derived from the National Council on Radiation Protection and Measurements Report 160 is estimated to be 0.311 rem per year [44].

Table 11. Estimated ingestion risk values for radiation doses at the Former Wolff-Alport Chemical Company

Soil Ingestion Parameter	Maximum Dose (rem)	USEPA Risk Coefficient* (per rem lifetime)	Lifetime Risk
Ing / Bone Surface Total	5.2	8E-07	4E-6
Ing / Red Marrow Total	0.21	5.7E-05	1E-5
Ing / Effective Total	0.007	5.8E-4	4E-6
Background	0.311	5.8E-4	2E-4

*The risk coefficients were obtained from EPA Radiogenic cancer risk models and projections for the U.S. population (EPA 402-R-11-001; Table 3-16). The risk numbers are mortality-based [42].

[44] National Research Council (1988). Health risks of radon and other internally deposited alpha emitters. Washington, DC, National Academy Press.

Table 12. Estimated risks to a worker from exposure to external ionizing radiation based on 95th percentile doses from Table 2.

Location	*Estimated 95th Percentile dose (rem/y)**	***Annual Risk based on USEPA Risk Coefficient of 5.8E-4 per rem per year†***	***Lifetime Risk based on USEPA Risk Coefficient of 5.8E-4 per rem per year for 50 years†***
Warehouse Dose (rem/y)	0.2	116	5800
1127 Irving Avenue Storage area (rem/y)	0.27	157	7830
1127 Irving Avenue Body shop (rem/y)	0.20	116	5800
1129 Irving Avenue Low Activity (rem/y)	0.21	122	6090
1129 Irving Avenue Medium Activity (rem/y)	0.07	41	2030
1129 Irving Avenue High Activity (rem/y)	0.08	46	2320
Walking outdoors (rem/y)	0.11	64	3190
Working outdoors (rem/y)	0.90	522	26100
Deli workers in basement	0.04	23	1160

*Doses were determined using a Monte Carlo approach. The doses were copied from Table 2 and adjusted to the appropriate number of significant figures.

† The risk is expressed as the number of cancers to a population of 1 million exposed individuals. These numbers cannot be used to determine one's individual risk from radiation exposure. The acceptable risk range is between 1 and 100 per million.