Health Consultation

FORMER WOLFF-ALPORT CHEMICAL CORPORATION SITE

1125-1139 IRVING AVENUE

QUEENS, NEW YORK

JANUARY 23, 2014

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Division of Community Health Investigations
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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Prepared By:

U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry (ATSDR)
Division of Community Health Investigations
Eastern Branch

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 needed.

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.

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:

Agency for Toxic Substances and Disease Registry
ATTN: Records Center
1600 Clifton Road, NE (Mail Stop F-09)
Atlanta, GA 30333

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Summary and Statement of Issues

In 2012, 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 initial request was a part of an ongoing removal assessment being conducted by the USEPA Region II Emergency and Remedial Response Division. The USEPA requested that ATSDR evaluate potential health threats from the exposures to ionizing radiation and determine if proposed shielding designs would be protective for the workers where current businesses are located.

The Wolff-Alport Chemical Company began chemical operations in the 1920s and has been identified as a company that supplied radioactive materials to the US Government. The company processed imported monazite sands extracting rare earth elements from the 1940s until 1954. The extraction process produced both solid and liquid wastes containing thorium, uranium, and radium which are naturally-occurring radioactive elements. The company disposed of the radioactive liquid waste directly, and without treatment, into the city sewer until ordered to stop in 1947. The other wastes are buried on site. The former operations caused surface and subsurface soil contamination to at least a depth of 20 feet, along with contamination below public sidewalks, city sewers, and nearby streets [2].

After the liquid dumping ban, the company reportedly concentrated the thorium residues onsite from 1947 and sold the sludge to the US 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, an iron works, a construction company, and an auto body shop providing repair and related services. Radiological surveys performed by the New York City Department of Health and Mental Hygiene (NYCDOHMH) and its contractors have identified thorium and its related decay products at these businesses, in the soils and sewers along Irving Avenue, and in exterior properties associated with former operations. A day care facility and public school operate within a 2-block area of these businesses.

In the previous ATSDR Public Health Consultation for the Former Wolff-Alport Chemical Corporation site, ATSDR determined that the greatest potential for impact on public health, including workers, was from exposure to gamma radiation. ATSDR recommended several actions be taken at the site including additional soil characterizations, reduction in radiation dose via reducing the time spent in the area, and/or increasing distance from the contamination, or other appropriate means [2].

Since the initial health consultation was released, the USEPA, in consultation with ATSDR, and the city and state of New York have discussed and performed several activities to address ATSDR recommendations. These actions have included a time study of workers in the contaminated building, better characterization of the exposure data in the contaminated areas,

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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.

2 Agency for Toxic Substances and Disease Registry (2012). Public Health Consultation, Former Wolff-Alport Chemical Company. February 2012. Atlanta: US Department of Health and Human Services.

improved radon and thoron analyses [3], and a study of materials that can be used as adequate shielding from the radiation. As a result of these actions, USEPA requested that ATSDR prepare another public health consultation to evaluate the new data.

This public health consultation analyzed the new data for radon, including thoron, and gamma radiation, and determined whether or not the proposed shielding materials would reduce the radiation exposure to a level protective of public health.

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 consists of 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 was used for storage of construction equipment and a few small boats, all of which have been removed. The area is unpaved and contaminated. According to the USEPA, the area has been fenced and vegetation removed. The area has been covered with a high density aggregate to reduce the spread of contamination and one small area was covered with 12 inches of concrete for shielding. The surrounding neighborhood contains light industry, commercial businesses, including public and private schools/day-care facilities, and residences [4].

The businesses at the site include a two-story masonry and frame building that houses a delicatessen and grocery store (1125 Irving Avenue), office space and residential apartments with an attached one-story masonry building housing a tire shop (1125 Irving Avenue) and mini-ATV shop; a one-story masonry building with an auto body shop (15-14 Cooper Avenue) and office space; two (2) one-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) [4].

According to federal records, Wolff-Alport operated from approximately 1920 to about 1954 [5] at these locations. Around 1940, the company began importing and processing rare earth containing monazite sands to extract rare earth metals, the byproduct of which was a concentrated thorium residue [5]. The monazite sand was brought to the facility via the railroad spur. 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 this sewer disposal.

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3 Radon and thoron are the same element, Radon (Rn). However they are different isotopes: radon is Rn 222 and thoron is Rn 220

4 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.

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

Then, to minimize the waste, Wolff-Alport began concentrating the thorium as a precipitate and sold the material to the federal government [5]. However, some residual waste tailings, containing high concentrations of thorium, remain on-site. The waste tailings appear as black or gray ashy material [6].

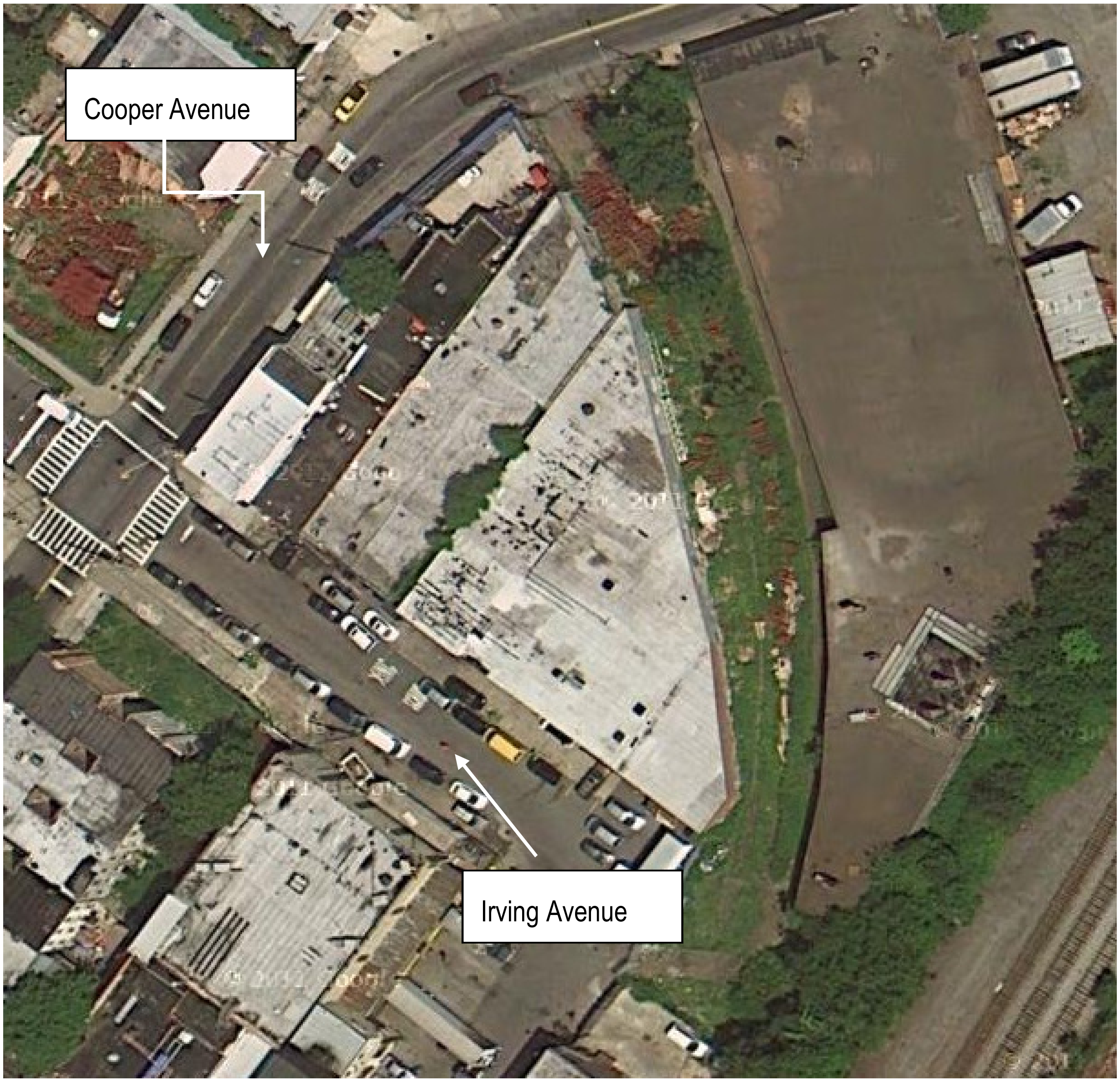

Figure 1. Aerial view of the Former Wolf-Alport Chemical Site.

6 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

Current Conditions

At various times, the building that housed the FWACC operations was subdivided by sealing access ways between the walls. The most active businesses in the block are the Jaracoba Deli and the Primo Auto Body Shop. Most of the areas investigated during the NYCDOHMH field effort are 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 [5].

The previous radiation measurements used equipment that was not necessarily calibrated to respond adequately to the contamination present at FWACC; thus the reported exposure measurements could have been either over- or under-reported [7]. In the latter half of 2012, the USEPA and NYCDOHMH conducted a study to compare the radiation exposure meter response of the potentially inaccurate meters with radiation meters specifically designed to measure radiation exposures. The initial radiation exposure readings used a sodium iodide (NaI(Tl)) detector. The efficiency of these types of detectors varies with energy of the radiation, decreasing as the energy increases. Typically calibration is performed with radioactive cesium 137 which has a different energy spectrum than thorium, uranium, or radium radionuclides. The meter used for comparison was a pressurized ionization chamber with uniform efficiency over the energy range of concern foregoing the need for specific calibration. Therefore, its use is better suited for determining radiation exposure rates. For a discussion of the instruments used by the USEPA in this study, please see Appendix A at the end of this document.

During October through December, 2012, the USEPA and NYCDOHMH also performed a shielding study to determine what types of materials and thickness of materials would effectively reduce the radiological exposures to workers at these sites. The shielding options included multiple layers of steel plates, each ½ inch in thickness and a 4 inch slab of concrete. The shielding study used these materials in different configurations.

In December 2012, the NYCDOHMH, USEPA, and their contractor conducted an occupational survey of workers at the site similar to a time and motion study. Workers were observed during a typical work day to determine where their activities occurred and compared those locations to the radiological exposure readings. In some cases the radiological readings were estimates as automobiles interfered with the radiation readings.

During this same period, USEPA or its contractors placed charcoal canisters in area schools, day care, and impacted businesses to determine the levels of radon and/or to determine those areas where radon may enter the building. Thoron detection requires specialized equipment which the USEPA also used to detect and monitor for this radioactive gas. Any points of entry of these gases were permanently sealed and points of entry retested.

7 Knoll, G (2000). Radiation Detection and Measurement. 3rd Ed. John Wiley and Sons, Inc. New Jersey. 802 pp.

Results

Radiation detector and exposure meter inter-comparison study (Appendix A)

The results of the radiological studies around the Wolff-Alport site prepared by the USEPA, the State of New York and City of New York will be discussed in this subsection as a general discussion for members of the public. A more detailed, technical discussion is presented in Appendix A. Where necessary, a reference to a specific table will refer to that appendix.

For the inter-comparison, two meters were used, a hand-held pressurized ion chamber which measures exposures, and a NaI(Tl) crystal-based photomultiplier which is a gamma radiation detector but can be used to measure exposures once its limitations are recognized. Measurements were collected over soil and concrete at the surface and at a height of one meter. The results are shown in Table 1. In general the NaI(Tl) meter over-responded as compared to the ion chamber. Other than at soil contact, the average over-response was 1.54 times higher than the ion chamber. Therefore, the exposure readings previously collected in the occupational areas were over-estimated and should be reduced to about 65% (1/1.54) of the initial amount. The soil contact measurements indicated that the NaI(Tl) meter reading was an average of 2.27 times higher than the ion chamber.

Comparison of shielding materials

A radiation shield is made of material that because of its composition can reduce the amount of radiation to which an individual is exposed. Radiation shielding simply means having something that will absorb radiation between you and the source of the radiation. The amount of shielding required to protect against different kinds of radiation depends on the energy of the radioactive material. Materials that can be used for radiation shielding are usually dense. For example, lead sheets, steel, concrete, and even soil can be used as shielding material albeit, different amounts of these materials would be necessary to achieve an equal amount of shielding.

Radiation shielding is a complex problem as radiation interactions within the shield can produce additional radiation hazards. Computer models are used to take into account shield construction, material composition, thickness, size, and position with respect to the radiation field. Besides shield design, the amount of contamination as well as its distribution must be factored into the design. Field testing the model either confirms or indicates additional shielding efforts necessary to reduce the radiation exposure by the necessary safety factor dependent on the shield type. The shielding study not only modeled the type of shielding but the USEPA and city also field-tested the shielding designs to determine the shielding adequacy.

Table 1. Inter-comparison of radiation meters*

Location	*NaI(Tl)†*	*Ion‡*	*Ratio*	*Average*
Soil (contact)	210 490 875	110 190 340	1.91 2.58 2.31	2.27
Soil (1 meter)	100 160	80 90	1.25 1.78	1.52
Concrete (contact)	405 640 590 1205	240 420 390 770	1.69 1.52 1.51 1.56	1.57
Concrete (1 meter)	205 555 555 575	130 390 330 420	1.57 1.42 1.68 1.36	1.51

*Given values other than the ratio or average are in microroentgens per hour (μR/h).
† Sodium iodide scintillation detector
‡ Pressurized ionization chamber
Data copied from Appendix A

Radiation measurements were made using various thicknesses of the steel plate without or with concrete at various locations and various exposure rates at the site. The results given in shows that using shielding materials can reduce the radiation exposure, depending on the amount of material, 40% to 95% from the original exposure.

Table 2. Results of Shielding Study

Initial Exposure Rate (μR/h)*	Shielding design	Percent reduction†
55	2 inches (5 centimeters) steel or 4 inches (10 centimeters) concrete	80 90
70	½ inch (1.3 centimeters) steel or 1 inch (2.5 centimeters) steel	40 60
129	1 ½ inch (3.8 centimeters) steel	74
223	1 inch steel with 4 inches concrete 2 ½ inches (6.4 centimeters) steel 3 inches (7.6 centimeters) steel with 4 inches of concrete	80 85 95
* Values are expressed as microroentgens per hour (μR/h) in excess of 15 μR/h background radiation at the site † The percent reduction is a function of incident radiation, the measured radiation after the shield installation and the attenuation coefficients of the shield composition). A regression curve was generated with a r^2 of 0.98 and based on this curve, the half value layer (HVL) was calculated to be 0.69 inches (1.75 centimeters) of steel.		

Occupancy – Time and Motion Study (Appendix B)

The USEPA, their contractor, and the City of New York visually monitored five workers of the Primo auto repair facility and two Terra Nova employees over a typical workday to determine typical locations and time spent in those locations. The locations were matched with radiation exposure readings. For the Primo workers, various times were spent indoors or outdoors depending on the individual. The results of this analysis are shown in Table 3 for both the Primo employees and the Terra Nova employees. Tables in Appendix B show the data supplied by USEPA. In several cases, radiation exposure readings were not taken directly because of obstacles. In those situations, the reading was estimated by the USEPA at 100 μR/h indoors or 50 μR/h (outdoor) as these were the nearest readings [8].

The data presented in Appendix B**Error! Reference source not found.** do not include any uncertainty evaluations but are based on averages of the data received by ATSDR. The monitored workers spent 8 hours per day at their respective jobs; the workers, however, did not spend the entire work day in the same location. Because the locations varied, the time spent on

8 USEPA (2012). Wolff Alport Site Occupational Survey December 18, 2012.

various automotive tasks varied with automobile type and experience of the mechanic, probability distribution functions (pdf) were determined and assigned to the data. These functions help determine the uncertainty or variation in times and location spent during automotive repairs. The pdfs were selected using Monte Carlo simulation software and allowing the software to determine the best fit for the reported data. The appropriate distribution for both occupancy times and exposure rates were applied to the exposure calculations. The resulting combined pdfs were analyzed and the 90% confidence interval was then determined. The confidence level represents the range of probable values between the 5th percentile (low end) and 95th percentile (upper end) of exposures. Additional information on the Monte Carlo technique is given in Appendix C.

Table 3. Results of the occupational study

Worker	*Work Locations and times (hours)*		*Total exposure time (hours)*	*Average radiation exposure (μR/h)*
Employee 1	Car lift	1.4	7.8	70
	Office	2		100
	Sidewalk	4.4		300
Employee 2	Unspecified southeast area	6.9	8	50
	Sidewalk	1.1		275
Employee 3	Unspecified southeast area	2.5	9.6	75
	Unspecified northwest area	0.5		50
	Office	1.7		2
	Sidewalk	3.7		300
Employee 4	Unspecified northwest area	6.3	8	78
	Sidewalk	1.7		300
Employee 5	Unspecified southeast area	0.4	8	75
	Unspecified northwest area	0.3		50
	Car lift	4.6		75
	Sidewalk	2.7		300
Terra Nova	Office	6	6	85

Radon determinations (Appendix D)

In December 2012, February 2013, and March 2013, Rn 222 and Rn 220 measurements were performed by an USEPA contractor. These measurements were made in the public school near the site, a day-care center adjacent to the public school, and the businesses along Irving Avenue. These radioactive, inert gases were present because radon is produced from the natural decay of radium 226; whereas, thoron is produced by the decay of radium 228 which is derived from thorium 232, a contaminant of concern. Radon measurements are typically determined using activated charcoal inside aluminum containers (charcoal canisters). The canisters are open to the air to be measured and after a specific time, typically two to seven days, the canisters are sealed and shipped for analysis. The analysis involves the determination of the radioactivity adsorbed to the charcoal then calculating the amount of radon present when the canisters were sealed. Thoron, however, requires a different measurement because its radioactive half-life is short, less than 1 minute. Thoron measurements are determined using equipment specially calibrated for the detection of this gas either as a grab sample or via continuous monitoring. The grab sampling mode allows for the instantaneous determination of thoron entry points into a structure. The instrument, a Durridge RAD7[9] will also detect radon simultaneously with the thoron.

During December 2010, the USEPA distributed 45 radon canisters and at that time, no canister readings exceeded the recommended 4 pCi/L limit for residential structures. More recently, the USEPA placed 61 canisters throughout the businesses. The measured radon canister levels ranged from a low of 0.1 picocurie per liter (pCi/L) to a high of 4.6 pCi/L along the Irving Avenue businesses. The highest reading of 4.6 pCi/L was in the Terra Nova facility offices. In the residential apartments, the radon levels did not exceed 1 pCi/L. Three radon canister readings made in the public school ranged from 0.4 pCi/L to 0.6 pCi/L. In the day care center, 21 canister readings were collected, ranging from 0.1 pCi/L to 0.6 pCi/L with an average of 0.3 pCi/L. These data are given in Appendix D of this report.

Radon/thoron measurements were also collected in the basement of the IS-384 public school after a radon/thoron gas entry point had been located and sealed. Based on instrument readings, the radon concentration was 0.9 pCi/L and the thoron concentration was 0.8 pCi/L. Before the entry point was sealed, the radon and thoron levels were 4.73 and 3.41 pCi/L, respectively. These levels were detected in the unoccupied school basement. Measurements inside the day care center in its basement showed the concentration of Rn 222 at 0.6 pCi/L and Rn 220 at 2.1 pCi/L. Thoron measurements in the basement of the deli showed that the gas concentration was 13.5 pCi/L. This finding was based on 3 10-minute measurements and a 2-hour measurement and was in agreement with an earlier 98 day measurement where the thoron was measured at 12.7 pCi/L [6].

The complete radon/thoron results are given in Appendix D of this document.

Discussion

ATSDR is evaluating the current site conditions to determine whether people are being exposed to site-related contaminants at levels of public health concern. With regard to external radiation exposure, a person will be exposed regardless of the environmental conditions. External

9 DISCLAIMER -- Reference to any specific commercial products, process, service, manufacturer, or company does not constitute its endorsement or recommendation by the U.S. Government or ATSDR.

exposure results from radiation sources originating outside the body releasing high energy electromagnetic radiation, much more energetic than visible light. As such these external sources can penetrate human skin even from a distance, no direct contact is necessary. Once the radiation enters the body, it can pass through the body or cause interactions within the body resulting in a radiation dose based on the probability of interactions and composition of the material through which the radiation passes. Because this type of radiation has no mass, is transient, and is pure energy, assessing its health effects is not determined using the typical ATSDR comparison values or environmental media guides. The best method is the determination of the amount of energy absorbed in the body and converting this to a radiological dose.

For this FWACC consultation, ATSDR reviewed the site specific data and parameters supplied by the USEPA and the City of New York. The data supplied to ATSDR is shown in the appendix. For the probability distribution of each of these parameters, ATSDR used a Monte Carlo software package [10] which evaluated the 62 site-related data points based on locations and selected the best fit to run the simulations. In the previous ATSDR Public Health Consultation for the Former Wolff-Alport Chemical Corporation site, ATSDR determined that the greatest potential for impact on public health is from the exposures to gamma radiation. Similarly, the new data analysis indicated that the gamma radiation measurements and time-in-motion study still resulted in elevated annual exposures to ionizing radiation.

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

$$(exposure\ rate \times occupancy\ factor \times exposure\ time) = exposure$$

Where exposure rate is the measured radiation reading supplied by the USEPA and the occupancy factor is the result of the time spent in that particular radiation area during the day and the exposure time is the number of working hours in a typical work year of 2200 hours as this is the average time an auto maintenance worker spends on the job according to the US Bureau of Labor Statistics [11]. The results of these simulations are shown in Appendix B.

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

11 http://www.bls.gov/news.release/atus.nr0.htm (last accessed on February 6, 2013)

Table 4. Results of simulation runs using auto shop employees performing varied tasks*

Parameter	***Lower 5th percentile***	***Mean Value***	***Upper 95th percentile***
Input time (hours)	0.054	1.57	3.71
Input Exposure rate (μR/h)†	25.4	159.1	423.6
Output (mR)†	0.004	0.246	0.581
Total exposure (mR) based on 2200 h per year	8.8	541	1,278
*The displayed results are the averages of 100 simulation runs with each run consisting of 10,000 iterations † A negative value for the minimum value is an artificiality of the computer simulation. All radiation readings were corrected for background. Thus the lowest reading would be 0 or equal to background.			

The USEPA and city proposal to place shielding material between the source (sidewalks, floors) and the workers to reduce the radiation exposure accordingly as shown in Table 2. The application of shielding does not completely block the very penetrating gamma radiation; however, it attenuates the intensity resulting in a smaller dose. In general, the attenuation of gamma radiation is determined using the following equation:

$$I = B \times I_0 e^{-\mu t}$$

Where I represents the final intensity, B is the buildup factor which takes into account radiation scattered by the shield, I_0 is the initial exposure intensity, e is symbol for the system of natural logarithms, μ is the linear attenuation coefficient in units of inches^{-1} (material and energy specific) and t is the thickness of the material in inches. Dividing I by I_0 results in the percent reduction of the radiation by the shielding materials based on the radiation energy and shielding thickness. Insufficient data exists to determine the buildup factor because the radiation readings were not determined from a single point of radiation but an area-wide distribution, that is, a planar source as the radioactive material is not located in a single location.

Applying the radiation reduction results shown in

Table 2 to the simulation results given in Table 4 the resulting doses are reduced accordingly as shown in Table 5. To account for the buildup of scattered radiation, an additional HVL of 0.7 inches should be added to shielding design. Thus the application of 3.2 inches of steel plate will reduce the radiation exposure to a level that will be protective of public health.

Table 5. Attenuation* of annual radiation exposure by selected shielding application†

Parameter (auto worker unless noted)	***Lower 5th percentile (mR)***	***Mean Value (mR) (simulation results)***	***Upper 95th percentile (mR)***
Total exposure (mR) based on 2200 h per year	8.8	541	1,278
1 inch steel (60% attenuation)	3.5	216	511
2 inches steel (80% attenuation)	1.8	108	256
2 ½ inches steel (85% attenuation)	1.3	81	192
2 inches steel office worker‡			37

* Gamma radiation attenuation is not a linear process as there can be other types of radiation interactions within the shielding material which produce additional types of scattered radiation.

† The ATSDR Minimal Risk Level (MRL) is 100 millirem per year above background for all pathways combined.

‡ No modeling was performed for the office workers because there were insufficient numbers of radiation readings and exposure times. The office worker annual unshielded exposure of 187 mR was used for this calculation.

This consultation only evaluated the radiation exposure. Radiation exposure is not synonymous to radiation dose. However, under conditions of standard temperatures and pressures, 1 mR will result in a radiation dose to muscle of approximately 0.00095 rads. For the purposes of radiation protection, the approximate relationship of 1-to-1 between exposure (Roentgen) and dose (rem) is used; therefore, the exposure levels shown in Table 5 can be considered the approximate radiation doses (within 6% of the actual value).

Assessing Health Effects

Numerous Federal regulations exist that limit the exposures and doses from ionizing radiation to the public. These agencies include the US Nuclear Regulatory Commission and its licensees, the US Department of Energy for its regulated operations, and the USEPA. These agency dose limits are regulatory. The State of New York has regulatory limit as well. Standards also exist to limit the exposures to thorium and its byproducts, typically classified as Technological Enhanced Naturally Occurring Radioactive Material (TENORM). The values of these regulations range from 10 mrem/y to 100 mrem/y based on historical or current operational conditions.

As a first step in evaluating external radiation exposures, ATSDR health physicists screen the radiation levels as compared to typical background radiation values or to area-specific background readings taken near the contaminated area. These exposure readings only pertain to the amount of exposure in air; they must be converted to an absorbed dose. This dose can be an organ specific dose which must be converted to a whole body dose or a dose to the entire body which can then be compared to the ATSDR derived Minimal Risk Level (MRL). ATSDR has established a MRL for members of the public who might be exposed to elevated levels of radiation. Because the MRL is an estimate of daily human exposure to a hazardous substance that is unlikely to have an appreciable risk of adverse 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 to the whole body regardless of the source is 100 mrem/y above ambient background levels [12]. **The data show the application of 3.25 inches of steel plate will adequately protect both auto workers and office workers as their estimated radiation dose is below this MRL**. Without any shielding, the MRL will be exceeded for all workers. Based on the nature of this type of exposure and resulting dose, the inhalation of all types of radon are not included in this portion of the ATSDR dose evaluation but will be discussed in the next section.

Radiological implications resulting from exposures to radon and thoron

The USEPA bases its recommendations for limiting exposure to radon on the concentration in residential structures. In 2003, the USEPA updated their calculations and believes about 21,000 lung cancer deaths are related to radon exposure (http://www.epa.gov/radon/risk_assessment.html, last accessed on August 16, 2013). The USEPA further recommends that the radon concentrations in residential structures not exceed 4 pCi/L. If this limit is exceeded steps should be taken to reduce the radon concentrations. For the work environment, occupational exposures to radon are regulated by the Occupational Safety and Health Administration (OSHA) in 29 CFR 1910.1096. Their radon regulations refer to an Atomic Energy Commission standard of 100 pCi/L averaged over a 40 hour work week.

Radiological dose assessment resulting from either radon or thoron exposures has not been especially successful until recently as dose assessment methodologies and epidemiological studies were not sufficiently robust to draw conclusions. The International Commission on Radiological Protection (ICRP) in 2010 stated that exposure to radon increases lung cancer at

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

least 8% for an increase "in radon concentration of 100 Bq/m^3"[13] equivalent to 2.7 pCi/L. The ICRP now recommends that doses from radon should be determined. The ICRP estimates the lung dose using their respiratory tract model to range from 1 to 2 rem per Working Level Month (WLM) for both residential and occupational environments. For radon, a WL is generally defined as 100 pCi/L and a WLM is defined as an exposure of 1 WL for 170 hours. Typically, an individual exposed to a concentration of 4 pCi/L for 170 hours would have 0.04 WLM for Rn 222. Over the course of one year of occupational exposure (2000 hours), this equates to about 0.48 WLM. These values do not consider the dust contained in the air to which radon decay products will adhere. The ICRP states the effective dose from inhaling Rn 222 and its decay products ranges from 1 to 2 rem per WLM and based on an equilibrium factor of 40 percent [13]. The equilibrium factor for the former Wolff-Alport operations was not determined; however, based on operational conditions which are a mixture of enclosed spaces and open air activities, ATSDR does not believe the 40% equilibrium would easily be obtained and could be significantly less resulting in a lower lung dose.

Thoron (Rn 220) is much different than Rn 222 because of its nuclear decay characteristics. For thoron, a WL represents 7.43 pCi/L. A similar dosimetric evaluation was carried out for thoron with the recommended range between 150 mrem/WLM and 570 mrem/WLM [13].

Estimate of radiological doses from the exposures of radon and thoron

Several methods have been developed to determine the lung dose an individual would receive upon inhaling Rn 222. In 1984, the NCRP estimated a bronchial tissue dose of 0.5 rad per WLM which is equivalent to 0.27 mrad per year per picocurie per cubic meter [14]. No estimate was made for the exposure to thoron (Rn 220). In 2000, the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) reported in their Appendix B to the annual report [15], a radon equivalent dose coefficient ranging from 16.2 nanoRem (nREM) per picocurie-hour-per liter ($pCi\text{-}h\text{-}L^{-1}$) to 40.5 nRem per $pCi\text{-}h\text{-}L^{-1}$ and for thoron, the estimated dose coefficient is 108 nRem per $pCi\text{-}h\text{-}L^{-1}$ for equilibrium-equivalent concentrations of the gas. More recently, the ICRP in 2010 reviewed radon and thoron information as discussed in the previous paragraph.

The USEPA and their contractors placed approximately 60 charcoal canisters (including duplicates) in buildings along Irving Avenue, the school and day care facility during the winter months when the levels would be expected to be highest. Radon levels above 3 pCi/L were only detected at Terra Nova, the auto shop notated as Primo 1, and the deli basement which also registered the highest concentration of thoron.

Most long-term studies evaluating the effect of radiation on the lungs, especially lung cancer are related to the production of uranium and plutonium. These studies evaluate the inhalation of long-lived alpha particle emitters, half-lives typically greater than 100 years as compared to Rn

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13 ICRP (2010). Lung cancer risk from radon and progeny and Statement on Radon. ICRP Publication 115. Annals of the ICRP, Volume 40.

14 NCRP (1984). Evaluation of occupational and environmental exposures to radon and radon daughters in the United States : recommendations of the National Council on Radiation Protection and Measurements. NCRP Report 78. Bethesda, MD. National Council on Radiation Protection and Measurements.

15 United Nations (2000). Report of the United Nations Scientific Committee on the Effects of Atomic Radiation. Annex B. Exposures from natural radiation sources. New York. United Nations.

222 half-life of less than 4 days. Currently radon and lung cancer studies are based on epidemiological studies where the concentration of radon in the structure is either measured or based on data meta-analyses. In these studies, the typical association indicates that at concentrations greater than 4 pCi/L, the risk of lung cancer is elevated. The doses to the lung from the radon are given in Table 6 and shows that an individual who works in the Terra Nova facility for a year could receive a lung dose between 200 and 500 millirem per year. This dose is similar to the estimated dose the average person living in the US will receive from background levels of radon [16].

The interpretation of OSHA regulations stipulate that the radon exposure limit is an average concentration for 40 hours during any 7 consecutive days. For adults, this limit is 100 pCi/L. For those areas where the radon concentration is less than 4 pCi/L, no additional actions are necessary; however, OSHA stipulates that if any employee is under 18 years of age, the radon levels are not to exceed 3 pCi/L (http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=24496, accessed March 15, 2013). According to OSHA, USEPA regulations are not occupational safety and health standards. Thus they do not carry the weight of law. Any USEPA levels above the OSHA levels would be in violation of OSHA and result in a de minimis violation (personal communication: Dr. Jeri Anderson, NIOSH). In the June and July 2013 timeframe, USEPA has installed a radon mitigation system and following testing, the radon concentrations were reduced to 0.4 pCi/L (communication from OSC Eric Daly, monthly conference call on July 17, 2013).

ATSDR did not evaluate thoron dose as the highest concentration was found in a basement used for storage and an employee would not be expected to spend more than 1 hour there during any particular day. Therefore, the OSHA standard of 1 WLM for thoron is not exceeded.

16 NCRP (2009). Ionizing radiation exposure of the population of the United States. NCRP Report 160. Bethesda: National Council on Radiation Protection and Measurements.

Table 6. Estimated doses to the lung from exposure to Rn 222 during the winter monitoring period

				Low Range Dose Coefficient*		High Range Dose Coefficient†	
Canister Number	**Location**	**Rn 222 pCi/L**	**Reported Measurement error**	**8 hour dose (mrem/h)**	**Annual (2000 hour) dose (mrem)**	**8 hour dose (mrem)**	**Annual dose (mrem)**
5920	Terra Nova back shelf	3.0	0.2	0.533	133	1.33	333
5906	Primo 2 middle bricks	3.1	0.2	0.551	138	1.38	344
1082	Terra Nova office	3.4	0.2	0.604	151	1.51	378
1080	Basement north	3.5	0.2	0.622	156	1.56	389
5913	Primo 1 back bricks	3.6	0.2	0.640	160	1.6	400
5917	Primo 1 back bricks	4.0	0.2	0.711	178	1.78	444
8569	primo 1 middle	4.3	0.2	0.764	191	1.91	478
8595	Terra Nova back office	4.6	0.2	0.818	204	2.04	511
5904	Terra Nova office desk	4.6	0.2	0.818	204	2.04	511

*The low range dose coefficient from the UNSCEAR report [15] was converted to conventional radiation units of 22.2 microrem $(\text{pCi/L–h}^{-1})^{-1}$

† The high range dose coefficient from the UNSCEAR report [15] was converted to conventional radiation units of 55.6 microrem $(\text{pCi/L–h}^{-1})^{-1}$

Conclusions and Public Health Implications

ATSDR has developed public health conclusion categories to help ensure a consistent approach to site hazard assessments and to clearly state these conclusions to assist the public in understanding these conclusions.

For the Wolff-Alport Former Chemical Corporation site, ATSDR determined there were three important conclusions. These conclusions are based on data collected by the NYCDOHMH, the State of New York, their contractors, and the USEPA validated the radiation readings previously collected and evaluated by ATSDR in a previous public health consultation [2]. That document made specific recommendations to the USEPA and the City of New York that would protect exposed individuals and workers from the ionizing radiation. The application of shielding materials, meets the intent of the ATSDR recommendations. Since then, ATSDR has received new data corrected for meter response, results of shielding design and specifications, and measurement of radon and thoron in businesses and residential spaces.

ATSDR concludes that:

1. Radiation exposure levels, adjusted for times spent in specific tasks without appropriate shielding greatly exceeds ATSDR established recommended levels known as MRLs (Table 5). **Because of the magnitude in which these MRL values are exceeded (Table 5, row 1) ATSDR concludes that this resulted in a public health hazard to workers.**
2. The results of the shielding study show that with appropriate shielding put in place, the radiation exposures can be reduced significantly. In some cases, over 85%. Applying the shielding to those areas where workers and officer workers most frequent, will reduce their annual exposures and concomitant radiation doses as shown in Table 5. **ATSDR concludes that with the addition of 3.25 inches of steel shielding, the public health urgency will be reduced and there would be no expected harm to exposed individuals.**
3. Levels of radon 222 in several locations approach and exceed the recommended USEPA limit for residential areas and the applicable limits of the Occupational Safety and Health Administration. **ATSDR cannot conclude that the exposure to radon was harmful. Although data suggest exposure to radon can result in lung cancer, ATSDR does not have sufficient historical exposure information.**

Recommendations

As ATSDR was drafting this report and determining what recommendations to make to local, state, and Federal regulatory agencies, the USEPA and New York City initiated actions to reduce exposure. During numerous conference calls in which ATSDR participated, the determination was made to proceed with shielding design and placement. These actions are noted in the following 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. USEPA and the City of New York consider placement of shielding materials in the work areas. This is currently underway;

2. The application of 3.25 inches of steel in areas used by the auto shop workers would be protective of public health. Based on shielding studies, a modification of this recommendation has been adopted using steel and lead sheets;
3. The application of 2 inches of steel would be protective of the office workers as their initial exposure rates (without shielding) were much less than the auto shop worker exposure rates. The USEPA is still in the process of installing the radiation shielding;
4. In those areas where the radon concentration approaches 4 pCi/L, ATSDR recommends that efforts be made to reduce the radon concentrations using appropriate mitigation techniques. As of July 2013, USEPA has installed radon mitigation systems where required. The USEPA has installed radon mitigation systems in the impacted areas.

Public Health Action Plan

ATSDR will continue to work with the USEPA, US Department of Energy, New York State Department of Health, New York Department of Environmental Conservation, New York City Department of Health and Mental Hygiene, New York City Department of Environmental Protection and local organizations involved in this project to ensure the public's health is protected.

The USEPA and the city have been actively developing multi-lingual community outreach documents and educational materials. ATSDR will continue to interact, comment, and advise the agencies on product development.

Author, Technical Advisors

Paul A. Charp, Ph.D.

Appendix A

Radiological Survey of Selected Portions of the Former Wolff-Alport Chemical Company Site 1127-1129 Irving Ave., Queens, NY

Prepared by

New York State Department of Health, Bureau of Environmental Radiation Protection
New York City Department of Health and Mental Hygiene, Bureau of Environmental Emergency Preparedness and Response

Radiological Survey of Selected Portions of the Former Wolff-Alport Chemical Company Site 1127-1129 Irving Ave., Queens, NY

New York State Department of Health, Bureau of Environmental Radiation Protection New York City Department of Health and Mental Hygiene, Bureau of Environmental Emergency Preparedness and Response

June 2012

On June 19, 2012, staff from the New York State Department of Health and the New York City Department of Health and Mental Hygiene conducted a radiation survey of certain areas of the former Wolff-Alport site. The New York State Department of Environmental Conservation participated in discussions regarding the survey objectives. The purpose of this survey was to obtain accurate radiation exposure rate readings from areas previously surveyed and identified as exhibiting elevated radiation levels using sodium iodide (NaI) radiation meters.

Background

Comprehensive radiological surveys were previously conducted at the former Wolff-Alport site in 2007[17] and again in 2009-2010[18]. Those surveys used sodium iodine (NaI) detectors (Ludlum model 44-2 and 44-10 probes) to identify areas of gamma radiation that are above background. Analysis of soil samples indicate that the main contaminant is Th-232 and to a lesser extent Ra-226, which is consistent with the history of the site. NaI detectors, while very sensitive for detecting gamma radiation and good for finding radiation sources, are very energy dependent and may not provide a true exposure rate reading (see attachment A). The purpose of this survey was to compare readings using NaI meters with those collected using pressurized ionization chamber meters, which are less energy dependent and therefore representative of true exposure rates. The difference in readings will be used to calculate a correction factor for determining true exposure rates throughout the site from previous NaI values. This information will be used to estimate potential radiation doses to workers and the public from the current use of the site and might be useful in adjusting previous dose estimates that were based on readings with NaI detectors.

Procedure

Due to time and staffing resource constraints, only a limited survey of outside areas at the site was planned. The areas surveyed were the sidewalk and street in front of the auto-body shop on Irving Avenue and the yard area (an abandoned rail spur) behind the buildings at this site. These areas were previously found to have the highest radiation readings (outside). A total of four radiation meters were used in the survey; two meters each containing a one-inch NaI crystal (Ludlum 2241-2, SN

[17] 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

[18] 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

206037 with Ludlum Model 44-2 probe, SN PR 213610 (calibrated on October 7, 2011);Ludlum 2241-2, SN 237777,with Ludlum Model 44-2 probe, SN PR 251325 (calibrated on Jan 30, 2012) and two pressurized ion chambers (Inovision Model 451P, SN 1426 (calibrated Oct 18), 2011; and SN 0364 (calibrated October 14, 2011). Accessible areas in front of the auto body shop and in the rear of the property were surveyed (see figure 1) with both types of meters, with the meter probe touching the ground level and at one meter from the surface. The radiation levels are summarized in the table below:

Location	**Description**	**NaI probe, microR/hr.**	**Ion chamber, microR/hr.**	**Ratio of NaI/ion chamber**
1	**Backyard soil-surface**	**210**	**110**	**1.91**
	Backyard soil-one meter	**100**	**80**	**1.25**
2	**Backyard soil-surface**	**490**	**190**	**2.58**
	Backyard soil-one meter	**No data taken**	**No data taken**	
3	**Backyard soil-surface**	**785**	**340**	**2.31**
	Backyard soil-one meter	**160**	**90**	**1.78**
4	**Concrete sidewalk-surface**	**405**	**240**	**1.69**
	Concrete sidewalk-one meter	**205**	**130**	**1.57**
5	**Concrete sidewalk-surface**	**640**	**420**	**1.52**
	Concrete sidewalk-one meter	**555**	**390**	**1.42**
6	**Concrete sidewalk-surface**	**590**	**390**	**1.51**
	Concrete sidewalk-one meter	**555**	**330**	**1.68**
7	**Concrete sidewalk-surface**	**1205**	**770**	**1.56**
	Concrete sidewalk-one meter	**575**	**420**	**1.36**

The approximate sample locations are shown in an attached diagram(Figure 1). The data in the last column show that the ratio of exposure measurements made with a NaI probe to that made with a pressurized ion chamber range. In every sample, the NaI reported higher exposures, with the ratio of NaI:Ion ranging from 1.25 to 2.58, with a mean of 1.7.

The highest levels were found in a one square foot area in the backyard (location 3), and in areas of about 16 feet x18 feet in front of the Terra Nova shop and Primo Auto Body (locations 4-7).

Results

The survey data show that the NaI meters that are calibrated to cesium-137 (standard calibration protocol) over-respond to low-energy gammas by a factor of 1.25 to 2.58. The biggest ratios were in the backyard on contact with the soil – suggests that there are more low-energy gammas, giving the higher over-response on contact, and also most easily attenuated by air and distance, giving the lowest over-response at 1 meter. In addition, the source in the yard area behaves as a point source given the small dimension of area affected, while the sidewalk area affected is larger. A dose rate correction factor of 1.7 was applied to existing NaI data. The corrected values are depicted in Attachment B.

Discussion

Although there has been a significant amount of work to survey and identify areas of contamination, additional work needs to be done to fully characterize the extent of contamination. Once the site has been fully characterized, a final action plan should be developed to remediate this site.

As indicated in a recent Agency for Toxic Substance and Disease Registry (ATSDR) report[19] the greatest potential for radiation exposure to workers at the site and the public is from direct gamma exposure. Although the corrected exposure rates are lower than initially projected, they are still elevated to levels above natural background radiation dose rates in a number of locations. Applying the correction factor of 1.7 to the dose calculations performed by ATSDR this suggests is remains possible for workers at these businesses to receive radiation exposure in excess of the public dose limit of 100 mrem/yr. In addition, ATSDR indicated the possibility that members of the public who frequent the sidewalk in front of the site on Irving Avenue might also be exposed to elevated levels of radiation. Although these levels are not an immediate public health threat, it is appropriate to consider taking actions – as suggested by ATSDR in their report – to reduce the radiation dose to both workers and to the public. We also note that actions taken to reduce radiation exposure to workers from the sidewalk area will necessarily serve to reduce exposure to the public.

Pending source reduction, the best means of reducing radiation doses are to reduce the time a person may be exposed, increasing the distance between people and the source, and introducing or enhancing shielding of the source. In this case, implementing these measures would include taking administrative steps (e.g. notices to workers) to reduce the amount of time workers are in the highest-dose-rate areas and taking additional steps (e.g. rearranging work areas) to increase the distance from workers to the highest-dose rate areas. However, we note that administrative actions, while potentially effective, depend on the agreement and sustained actions of employers and employees. Accordingly, we recommend taking a further step of installing engineered controls (shielding) to reduce radiation exposure to both workers and the public. The steps we recommend are:

[19] Agency for Toxic Substances and Disease Registry, Health Consultation, Former Wolff-Alport Chenical Corporation site, 1125-1139 Irving Avenue, Queens, New York, February 29, 2012.

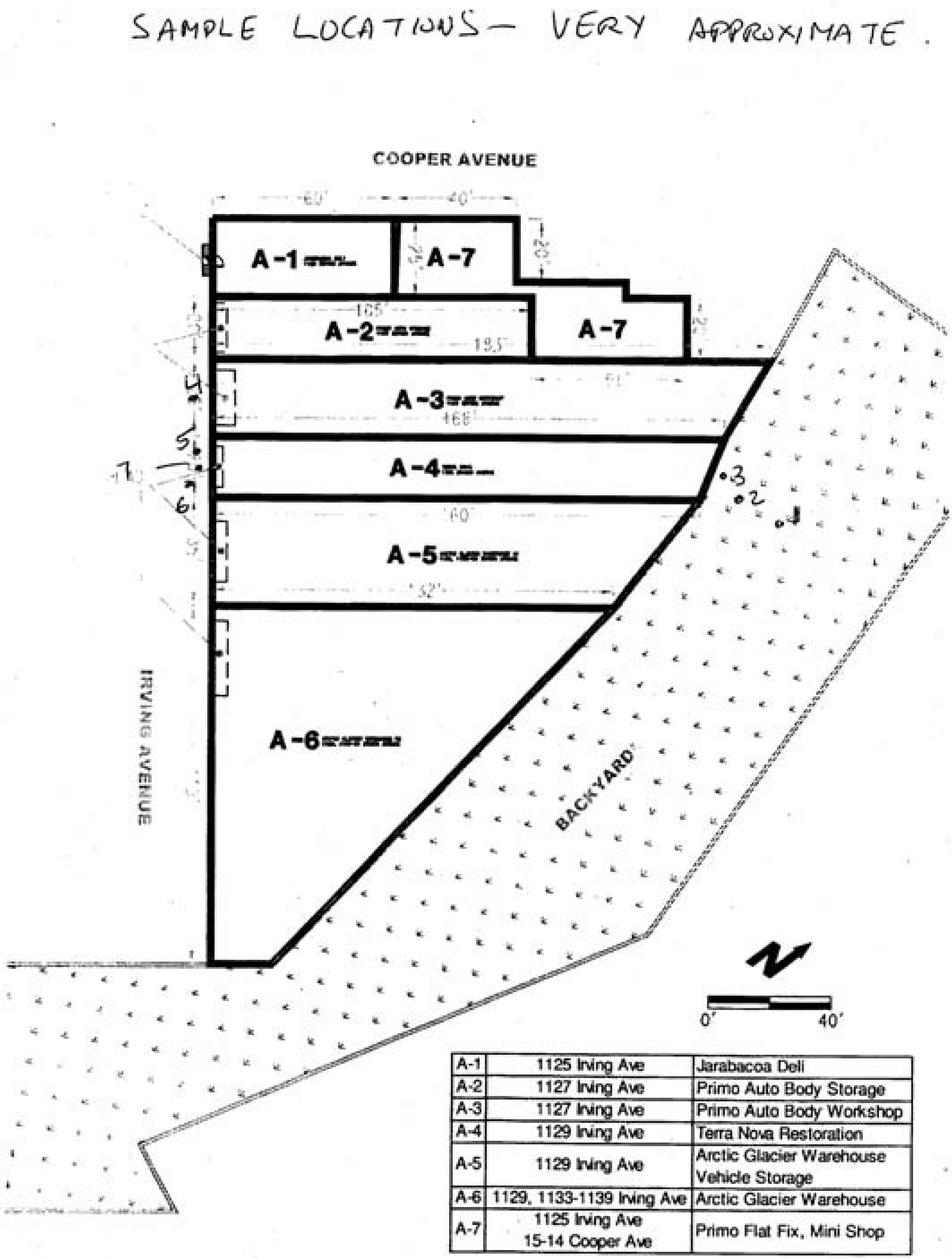
• Install fencing around the highest-exposure-rate location in the back yard area at a distance of 1 meter from the highest-exposure-rate area OR where radiation exposure rates are no more than 50 μR/hr above background.

• Install additional fencing across the entrance to the back yard area that is sufficient to exclude passersby and that is sufficiently sturdy to remain intact (unlike the current fence).

• Install four inches of concrete on top of the highest- -exposure rate areas of the sidewalk and inside the buildings. Preliminary calculations using MicroShield® indicate that this thickness of concrete will be sufficient to reduce radiation exposure rates to less than 50 μR/hr above background, which would result in exposures to workers and the public below 100 mrem/yr.

We believe that these engineering controls are preferable to administrative actions (e.g. limiting stay times, restricting access to certain areas) because, unlike administrative measures, they cannot be forgotten or ignored when inconvenient. In addition, the actions suggested should prove to be both relatively inexpensive and effective.

- **Figure 2**



A-1	1125 Irving Ave	Jarabacoa Deli
A-2	1127 Irving Ave	Primo Auto Body Storage
A-3	1127 Irving Ave	Primo Auto Body Workshop
A-4	1129 Irving Ave	Terra Nova Restoration
A-5	1129 Irving Ave	Arctic Glacier Warehouse Vehicle Storage
A-6	1129, 1133-1139 Irving Ave	Arctic Glacier Warehouse
A-7	1125 Irving Ave 15-14 Cooper Ave	Primo Flat Fix, Mini Shop

Attachment A

Most NaI detectors are calibrated to Cs-137 which has a gamma energy of 662keV. As depicted in the graph below, these detectors will under-respond to gamma energies greater than 662 keV and over respond to energies less than 662keV. The main contaminant at Wolff-Alport is Th-232. Th-232 and progeny emit gammas with energies over a wide range with a higher abundance of low energy x-rays and gamma photons (see: http://www.radiochemistry.org/periodictable/gamma_spectra/pdf/th232.pdf).

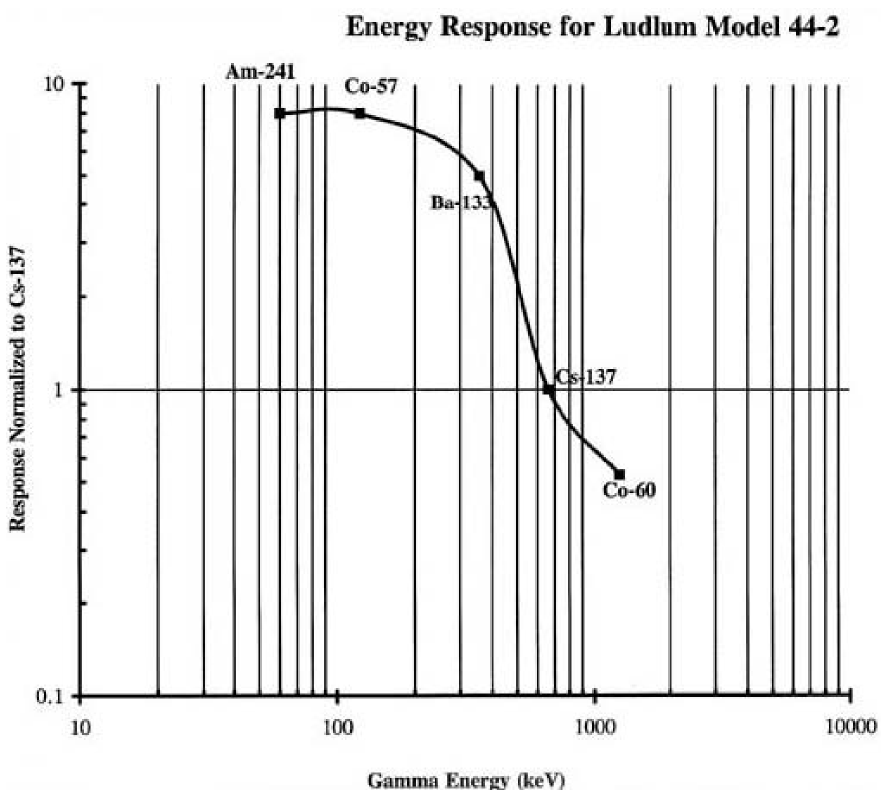
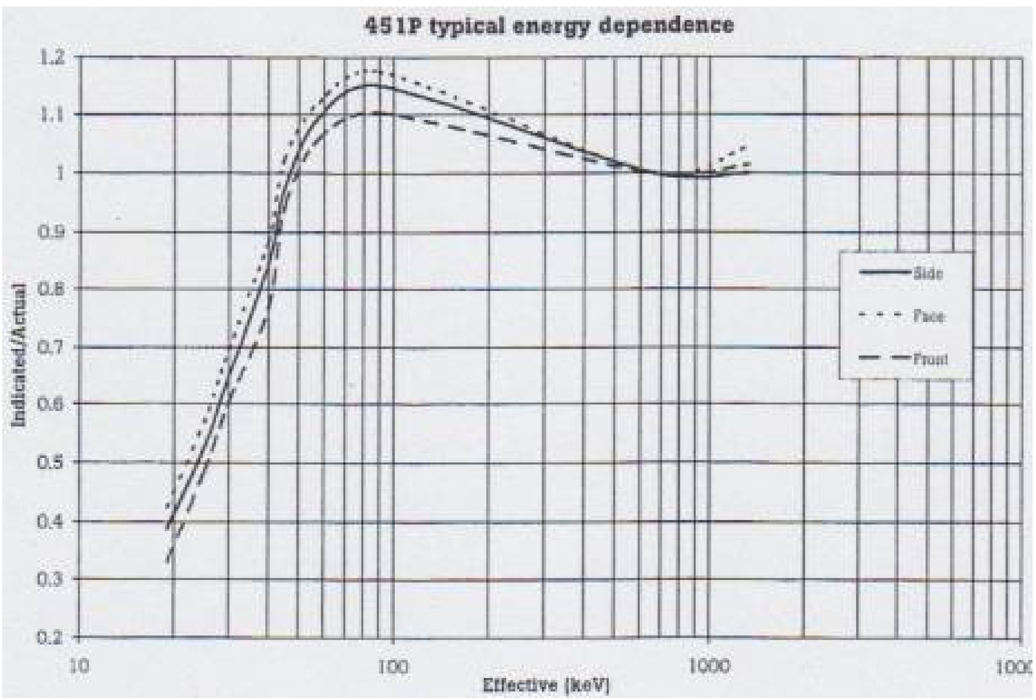


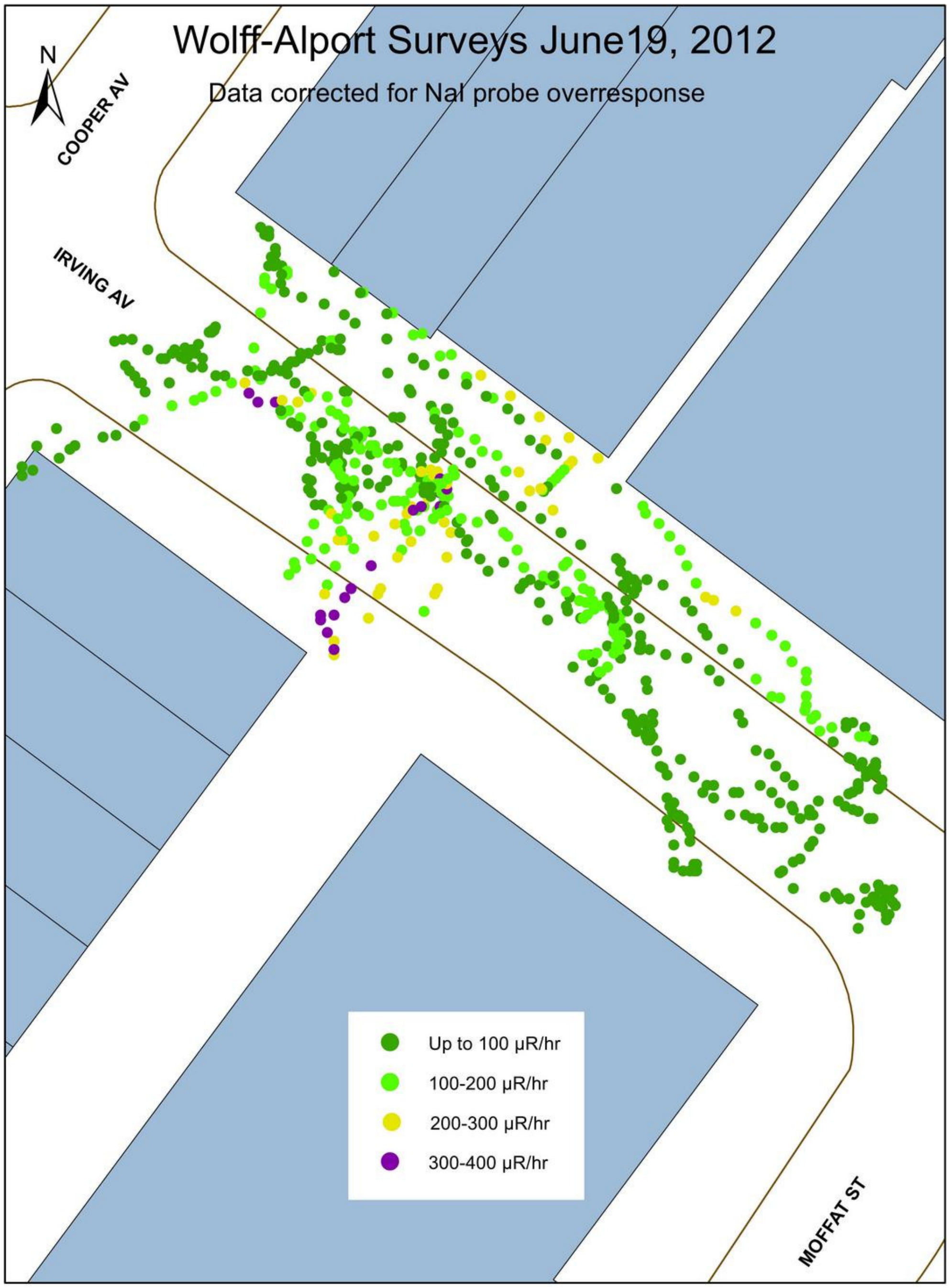
Chart obtained from:
http://www.ludlums.com/component/virtuemart/?page=shop.product_details&flypage=flypage_ludlum.tpl&product_id=171&category_id=71

Attachment A (cont.)

A pressurized ionization chamber is less dependent on gamma energies and will provide values which are more representative of a true exposure rate. The Inovision 451P energy response chart is below:



Attachment B



Attachment C

Personnel performing surveys:

New York City Department of Health and Mental Hygiene, Bureau of Environmental Emergency Preparedness and Response:

P. Andrew Karam, Director of Radiological Operations
Hailu Tedia, Health Physicist,

New York State Department of Health, Bureau of Environmental Radiation Protection:

James Mull, Associate Radiophysicist
Brajesh Kothari, Ph.D., Associate Radiophysicist

Observers:

US Environmental Protection Agency:

Eric Daly, On-Scene Coordinator
Cecilia Echols, Community Involvement Coordinator

Appendix B

Occupational Study

Performed and prepared by

USEPA
and
New York City Department of Health and Mental Hygiene
December 18, 2012

The USEPA and City of New York representatives monitored workers from Primo and Terra Nova for a typical work day beginning at 9 am and concluding at 5 pm. This study was to determine where works spent their time during the work day. The locations were then correlated to the radiation levels in those locations.

The following tables report the numbers from the USEPA report and reflects the time spent by five Primo workers and two Terra Nova employees.

Table 7. Primo #2, Employee 1 work locations and times.

Time of Day	Elapsed time (minutes)	Location of work	Radiation exposure reading (μR/h)
1400 to 1410	10	5' to 10'	140
1000 to 1010	10	Car Lift	70
1240 to 1300	20	Car Lift	70
1450 to 1500	10	Car Lift	70
1615 to 1700	45	Car Lift	70
0900 to 0955	55	Office	100
1015 to 1017	2	Office	100
1030 to 1035	5	Office	100
1053 to 1115	22	Office	100
1350 to 1400	10	Office	100
1410 to 1415	5	Office	100
1430 to 1450	20	Office	100
0955 to 1000	5	Sidewalk	300
1010 to 1015	5	Sidewalk	300
1017 to 1030	13	Sidewalk	300
1035 to 1053	18	Sidewalk	300
1115 to 1240	85	Sidewalk	300
1300 to 1350	50	Sidewalk	300
1415 to 1430	15	Sidewalk	300
1500 to 1615	75	Sidewalk	300

Table 8. Primo #2, Employee 2 work locations and times.

Time of Day	Elapsed time (minutes)	Location of work	Radiation exposure reading (μR/h)
1005 to 1010	5	80' to 90' Center	50
1110 to 1240	90	80' to 90' Center	50
1505 to 1700	115	80' to 90' Center	50
0900 to1005	65	80' to 90' SE Side	50
1240 to 1500	140	80' to 90' SE Side	50
1010 to 1110	60	Sidewalk	250
1500 to 1505	5	Sidewalk	300

Table 9. Primo #2, Employee 4 work locations and times.

Time of Day	Elapsed time (minutes)	Location of work	Radiation exposure reading (μR/h)
0900 to 0915	15	40' to 60' NW Side	80
0930 to 0945	15	40' to 60' NW Side	80
0950 to 1200	130	40' to 60' NW Side	80
1340 to 1700	200	40' to 60' NW Side	80
0945 to 0950	5	80' to 90' NW Side	50
1325 to 1340	15	80' to 90' NW Side	50
0915 to 0930	15	Sidewalk	300
1200 to 1325	85	Sidewalk	300

Table 10. Primo #2, Employee 3 work locations and times.

Time of Day	Elapsed time (minutes)	Location of work	Radiation exposure reading (μR/h)
0900 to 1010	70	40' to 60' SE Side	75
1017 to 1020	3	40' to 60' SE Side	75
1025 to 1120	55	40' to 60' SE Side	75
1125 to 1200	35	40' to 60' SE Side	75
1215 to 1225	10	40' to 60' SE Side	75
1230 to 1245	15	40' to 60' SE Side	75
1347 to 1415	28	40' to 60' SE Side	75
1020 to 1025	5	80' to 90' NW Side	50
1325 to 1347	22	80' to 90' NW Side	50
1200 to 1215	15	Lunch	0
1015 to 1017	2	Office	100
1010 to 1015	5	Sidewalk	300
1120 to 1125	5	Sidewalk	300
1225 to 1230	5	Sidewalk	300
1245 to 1325	40	Sidewalk	300
1415 to 1700	165	Sidewalk	300

Table 11. Primo #2, Employee 5 work locations and times.

Time of Day	Elapsed time (minutes)	Location of work	Radiation exposure reading (μR/h)
1515 to 1540	25	40' to 60' SE Side	75
1325 to 1343	18	80' to 90' NW Side	50
0900 to 1150	170	Car Lift	70
1215 to 1225	10	Car Lift	70
1235 to 1325	50	Car Lift	70
1343 to 1430	47	Car Lift	70
1150 to 1215	25	Sidewalk	300
1225 to 1235	10	Sidewalk	300
1430 to 1515	45	Sidewalk	300
1540 to 1700	80	Sidewalk	300

Table 12. Terra Nova Employees work locations and times.

Time of Day	Elapsed time (minutes)	Location of work	Radiation exposure reading (μR/h)
Terra Nova Employee No. 1			
0900 to 0930	30	40’ at Desk	80
0930 to 1020	50	20’ at Desk	95
1020 to 1500	280	40’ at Desk	80
Terra Nova Employee No. 2			
0915 to 0930	15	40’ at Desk	80
0930 to 0950	20	20’ at Desk	95
0950 to 1515	325	40’ at Desk	80

Monte Carlo Analysis Discussion

When the necessity of determining the uncertainty of data that can impact exposures, doses, clean-up costs, or other activities that involve numerous variables and interactions, a statistical evaluation known as Monte Carlo has been developed. For example, during screening calculations using conservative estimates, if these estimates are greater than a predetermined level of concern, running a Monte Carlo simulation can give an evaluation of how much the uncertainty in each variable adds to the total interaction. Typically the total interaction is based on a defined mathematical equation.

Basically, Monte Carlo uses a predetermined distribution of the individual variables and randomly selects numbers from each variable. The distributions that are used on based on how well the existing data fit a defined distribution or the distribution can be based on known distributions commonly seen is similar types of data. Current computer models allow the user to either select the distribution or the computer will evaluate the numbers and select the best distribution to fit the data. The most common method to select the appropriate distribution is a statistic called the Chi-Square test. Other statistical methods include the Kolmogorov-Smirnov test and the Anderson-Darling test. Each of these tests has its strengths and weaknesses and it is the user who must decide which of tests give the most relevant results.

Monte Carlo then takes the randomized values from each distribution and applies the value to the mathematical equation. This is called an iteration and a group of iterations is called a simulation. The advantage of a Monte Carlo set of simulations is that it produces a range of possible results and the probability of any result occurring, from the least probable to the most extreme case. It also will show the probability of occurrence for any other result in that range. One limitation of the process is that if the values comprising the distribution are limited, then the results will not be as accurate as a distribution with a large number of values.

For the Former Wolff-Alport Chemical Site, ATSDR performed 100 Monte Carlo simulations, each simulation consisted of 10,000 iterations. The variables included a distribution of the exposure times and the exposure rates for the locations in around the auto shop and Terra Nova, where possible. Because of the number of iterations and simulations performed in the analysis of these data, only a portion of the inputs and outputs will be given in the following tables.

Table 13. Partial listing of simulations.

Input	Minimum Value	Mean Value	Maximum Value	5%	95%		Input (X-Sq)*	Minimum Value	Mean Value	Maximum Value	5%	95%
Est Time	0.03120003	1.523889	2095.854	0.05418906	3.715124		rad reading	-5.858364	158.7025	7329.177	25.43979	423.5102
Est Time	0.03127929	1.528484	2060.418	0.05422218	3.713186		rad reading	-5.563582	158.9581	9894.006	25.43814	423.7811
Est Time	0.03120939	1.620209	2822.381	0.05420679	3.710789		rad reading	-6.095795	158.777	8186.104	25.42923	423.4032
Est Time	0.03128688	1.43362	1189.703	0.05419713	3.715115		rad reading	-5.338899	158.7383	7200.75	25.44938	423.547
Est Time	0.03125826	1.977096	6651.355	0.05420776	3.71035		rad reading	-5.726918	160.6073	26747.02	25.44077	423.7524
Est Time	0.03124257	1.410465	923.4984	0.05419736	3.714511		rad reading	-5.280864	159.7397	16768.84	25.42345	423.6576
Est Time	0.03127753	1.766542	4436.861	0.05420498	3.714082		rad reading	-5.754987	158.6606	7065.471	25.42711	423.4433
Est Time	0.03126239	1.589674	2765.362	0.05419615	3.71316		rad reading	-5.754326	159.8169	18361.02	25.42771	423.7172
Est Time	0.03119905	1.501618	1671.923	0.05419768	3.709459		rad reading	-5.914587	159.2984	12387.06	25.42685	423.4846
Est Time	0.03122754	1.670842	3418.104	0.05420929	3.713941		rad reading	-6.323969	159.3015	12064.26	25.43894	423.705
Est Time	0.03123412	1.461174	1576.851	0.05419319	3.709988		rad reading	-5.677917	159.0114	9826.831	25.45026	423.7524
Est Time	0.03125009	1.415429	1025.476	0.05418776	3.713472		rad reading	-5.356961	158.9455	9102.629	25.44283	423.732
Est Time	0.0312835	1.68225	3769.239	0.0541911	3.712626		rad reading	-6.005051	162.2853	43546.91	25.42102	423.4468
Est Time	0.03127762	1.504458	1966.84	0.05422241	3.711388		rad reading	-5.130823	158.6683	6928.137	25.42889	423.5796
Est Time	0.03127959	1.515309	1940.484	0.05420772	3.710176		rad reading	-6.331322	159.0421	10087.3	25.42484	423.5349
Est Time	0.03127552	1.917153	5923.635	0.05419248	3.714812		rad reading	-6.622049	159.4512	14131.04	25.44927	423.6928
Est Time	0.03123586	1.462505	1528.552	0.05419437	3.715103		rad reading	-6.235048	158.6614	7175.282	25.44122	423.506

Est Time	0.03124731	1.398656	897.4722	0.05421158	3.713812		rad reading	-6.056405	159.7634	17045.25	25.42657	423.6528
* X-sq represents the Chi Square distribution used for the simulation. Each row represents 1 simulation consisting of 10,000 iterations. The values listed are the averages of each column heading for that particular iteration											

Table 14. Tabulated Average values

Input	Minimum Value	Mean Value	Maximum Value	5%	95%		Minimum Value	Mean Value	Maximum Value	5%	95%
mR											
average	**0.03124717**	**1.5767**	**2609.9**	**0.054204**	**3.7123**		**-5.68409**	**159.1212**	**11325.49**	**25.43626**	**423.5905**
stdev p	**2.86048E-05**	**0.2444**	**2437.8**	**1.19E-05**	**0.002**		**0.506229**	**0.55756**	**5544.602**	**0.008918**	**0.120536**
The values in this table are the averages of 1,000,000 estimates (10,000 iterations run 100 times)											

Appendix D

Indoor Radon Measurements of businesses in the Vicinity of Irving, Moffat, and Cooper Avenues

Measurements by USEPA

The determination of radiation dose can be a complex process as exposures do not always result in dose; that is, the radiation has to be absorbed prior to the delivery of a dose. In the case of alpha particles, external contamination does not typically result in a dose so either ingestion or inhalation is required before a dose can be delivered. Beta particles can deliver a dose both externally and internally as long as the particle is absorbed by tissue. Gamma radiation, like beta particles can impart a dose externally as well as internally; the probability of their being absorbed is also dependent on the density of the tissue as well as the energy of the gamma ray.

Once the amount of radiation absorbed has been determined, the dose to the organ, tissue, or whole body can be determined through the use of weighting factors for the type of radiation as well as the organ or tissue receiving the radiation dose. The radiation dosimetry used in these radon calculations is specific to the lung and is called the equivalent dose because it is the amount of radiation absorbed by a specific tissue. A whole body dose is not determined as radon is considered an inhalation hazard. The equation used to calculate the equivalent dose is shown in the following generalized equation:

$$H_{T}=\sum_{R} W_{R}\times D_{T,R}$$

Where H_T is the equivalent dose to the lung, W_R is the radiation weighting factor that is specific for the type and energy of the radioactive decay, and $D_{T,R}$ is the absorbed radiation averaged over the mass of the lung, in this case the bronchial epithelial tissues with an estimated mass of 1.3 grams [20]. The equivalent dose calculated has the units of the Sievert where 1 Sievert equals 100 rem.

The data in the follow tables show the results of the indoor radon monitoring performed by the USEPA during the winter months of December 2012 through June 2013. The radon was measured using charcoal canisters. The canisters were exposed for three days to allow for the radon decay products to adhere to the charcoal. The time the canisters were opened and closed was noted. The canisters were then sealed and sent out for analysis. The analysis consisted of determining the radioactivity on the charcoal and using these data to determine the concentration of radon in the room in which the canister was at the time the canister was sealed.

Recently, the ICRP Publication 65 recommended that guidance on dose conversions for radon exposure. The ICRP guidance is to use a single value which includes implicit assumptions as to particle size and its distribution as well as aerosol and breathing rates for both occupational and public exposures. To convert the radon measurements to estimated effective radiation dose to the lung tissue, the following dose coefficients were used:

For a low range, the coefficient used was 6 nanoSieverts (nSv) per Becquerel (Bq)-hour per cubic meter. For the high range, the coefficient used was 15 nanoSieverts per Becquerel-hour per cubic meter.

To convert to the conventional units of this report, the following conversions were made:

1 nanoSievert equals 100 nanorems (equivalent dose)

1 Becquerel equals 27.03 picocuries

1 cubic meter equals 1000 liters

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[20] ICRP (2001). Basic anatomical and physiological data for use in radiological protection: reference values. ICRP Publication 89. International Commission on Radiological Protection.

To convert the radon 222 concentrations to a lung dose, the following equations were used:

$$\frac{pCi}{L} \times \frac{1}{1000} \times \frac{1}{27.03} = \quad q/m^3$$

and

$$\frac{q}{m^3} \times \frac{nSv - m^3}{q - h} \times \frac{100\ nrem}{nSv} \times \frac{1\ mrem}{1000000\ nrem} \times \frac{2200\ h}{year} = \frac{mrem}{year}$$

These dose coefficients also encompass the UNSCEAR recommendation of 9 nSv per Becquerel (Bq)-hour per cubic meter.

Table 15. Radon levels at IS -384

Canister number	Canister location	Radon level (pCi/L)	Error in measurement (pCi/L)	Estimated range of annual dose associated with radon exposure (low to high) mrem/y*	
8542	blank	0.4	0.2	8.89E-06	2.22E-05
8549	Crawl space, P1 Front	0.4	0.2	8.89E-06	2.22E-05
8575	duplicate P2	0.6	0.2	1.33E-05	3.33E-05
*The dose range is based on the dose coefficients recommended by both the ICRP and UNSCEAR					

Table 16. Radon levels in Terra Nova

Canister number	Canister location	Radon level (pCi/L)	Error in measurement (pCi/L)	Estimated range of annual dose associated with radon exposure (low to high) mrem/y*	
1094	Terra Nova back	2.4	0.2	5.33E-05	1.33E-04
8563	terra nova back	2.6	0.1	5.78E-05	1.44E-04
1093	Terra Nova back	2.3	0.2	5.11E-05	1.28E-04
8595	terra nova back office	4.6	0.2	1.02E-04	2.56E-04
5911	terra nova back shelf	2.8	0.2	6.22E-05	1.56E-04
5920	terra nova back shelf	3.0	0.2	6.67E-05	1.67E-04
1082	Terra Nova office	3.4	0.2	7.56E-05	1.89E-04
5904	terra nova office desk	4.6	0.2	1.02E-04	2.56E-04
*The dose range is based on the dose coefficients recommended by both the ICRP and UNSCEAR					

Table 17. Radon Levels at Audrey Johnson Day Care Center.

Canister number	Canister location	Radon level (pCi/L)	Error in measurement	Estimated range of annual dose associated with radon exposure

			(pCi/L)	(low to high) mrem/y *	
8558	1st floor nurses room	0.5	0.2	1.11E-05	2.78E-05
8561	basement shelf P6	0.2	0.2	4.44E-06	1.11E-05
8562	P 9	0.1	0.1	2.22E-06	5.56E-06
8564	basement bathroom P4	0.4	0.2	8.89E-06	2.22E-05
8565	1st floor play room 5	0.1	0.1	2.22E-06	5.56E-06
8567	1st floor Room 4a, P19	0.5	0.2	1.11E-05	2.78E-05
8568	blank	0.1	0.2	2.22E-06	5.56E-06
8571	1st floor director's room	0.1	0.7	2.22E-06	5.56E-06
8572	1st floor bookkeeper's office	0.3	0.2	6.67E-06	1.67E-05
8574	1st floor room 1a	0.5	0.2	1.11E-05	2.78E-05
8576	basement far R room	0.1	0.4	2.22E-06	5.56E-06
8577	1st floor play room 4	0.4	0.2	8.89E-06	2.22E-05
8578	1st floor Room 2b, P12	0.2	0.1	4.44E-06	1.11E-05
8602	basement bathroom P5	0.1	0.1	2.22E-06	5.56E-06
8609	1st ffloor room 2a	0.4	0.2	8.89E-06	2.22E-05
9039	1st floor room 3a P20	0.5	0.2	1.11E-05	2.78E-05
9042	1st floor room 3b P 13	0.3	0.2	6.67E-06	1.67E-05
9045	1st floor secretary's office	0.6	0.2	1.33E-05	3.33E-05
9047	1st floor mulipurpose room	0.3	0.2	6.67E-06	1.67E-05

9050	1st floor Room 1b	0.3	0.2	6.67E-06	1.67E-05
9051	basement 1st room L	0.2	0.2	4.44E-06	1.11E-05
9054	1st floor staff lounge	0.4	0.2	8.89E-06	2.22E-05
*The dose range is based on the dose coefficients recommended by both the ICRP and UNSCEAR					

Table 18. Radon levels in Primo auto businesses

Canister number	Canister location	Radon level (pCi/L)	Error in measurement (pCi/L)	Estimated range of annual dose associated with radon exposure (low to high) mrem/y*	
8560	Primo 1 back	2.2	0.1	4.89E-05	1.22E-04
9048	Primo 1 back	2.3	0.1	5.11E-05	1.28E-04
1089	Primo 1 back	1.1	0.2	2.44E-05	6.11E-05
1101	Primo 1 back	1.0	0.2	2.22E-05	5.56E-05
5913	Primo 1 back bricks	3.6	0.2	8.00E-05	2.00E-04
5917	Primo 1 back bricks	4.0	0.2	8.89E-05	2.22E-04
8569	Primo 1 middle	4.3	0.2	9.56E-05	2.39E-04
1084	Primo 1 Middle	0.7	0.1	1.56E-05	3.89E-05
5918	Primo 1 middle bricks	2.5	0.1	5.56E-05	1.39E-04
5909	Primo 2 back	2.4	0.2	5.33E-05	1.33E-04
5919	Primo 2 back	2.3	0.2	5.11E-05	1.28E-04
8566	Primo 2 bay back	1.4	0.1	3.11E-05	7.78E-05
9041	Primo 2 bay middle	1.6	0.1	3.56E-05	8.89E-05
5906	Primo 2 middle bricks	3.1	0.2	6.89E-05	1.72E-04

*The dose range is based on the dose coefficients recommended by both the ICRP and UNSCEAR

Table 19. Radon levels in the deli and associated apartments

Canister number	Canister location	Radon level (pCi/L)	Error in measurement (pCi/L)	Estimated range of annual dose associated with radon exposure (low to high) mrem/y*	
1092	1st floor deli kitchen	0.5	0.1	1.11E-05	2.78E-05
1087	2nd floor apartment 2 bedroom	0.7	0.2	1.56E-05	3.89E-05
1098	2nd floor apartment 2 bedroom	0.3	0.1	6.67E-06	1.67E-05
1103	2nd floor apt desk	0.4	0.1	8.89E-06	2.22E-05
1095	apartment 1 bedroom	0.4	0.1	8.89E-06	2.22E-05
5779	apartment 1 desk	0.5	0.1	1.11E-05	2.78E-05
5905	apartment 1 desk	0.5	0.1	1.11E-05	2.78E-05
1107	basement middle	1.7	0.2	3.78E-05	9.44E-05
1080	Basement north	3.5	0.2	7.78E-05	1.94E-04
1090	Basement north	3.5	0.2	7.78E-05	1.94E-04
1086	Basement south	2.1	0.2	4.67E-05	1.17E-04
5914	deli basement north	1.7	0.1	3.78E-05	9.44E-05
5915	deli basement north	2.0	0.1	4.44E-05	1.11E-04
5908	deli basement opening	1.1	0.1	2.44E-05	6.11E-05

*The dose range is based on the dose coefficients recommended by both the ICRP and UNSCEAR