HEALTH CONSULTATION

Welsbach and General Gas Mantle Contamination Sites (WGGMCS)

Camden and Gloucester City, Camden County, New Jersey
CERCLIS No. NJD986620995

March 5, 1997

Prepared by:

New Jersey Department of Health and Senior Services
Consumer and Environmental Health Services

Under Cooperative Agreement with the
Agency for Toxic Substances and Disease Registry

BACKGROUND AND STATEMENT OF ISSUES

Background

In May 1981 an aerial survey[1] conducted by EG&G Corporation under contract with the United States Environmental Protection Agency (EPA) detected elevated levels of gamma (γ) radiation in parts of Camden/Gloucester City, New Jersey. In addition to radiation from known sources, the aerial survey (20 km^2 area; approximate dimensions 4 miles by 2 miles) detected emanations from the locations of two former gas mantle factories and several residential areas. At the time of the aerial survey, the factories had been out of business for approximately 40 years. The residences had apparently been constructed on land where radioactive materials had been dumped during the period of operation of the factories.

As a result of the aerial survey, a preliminary ground radiological survey was conducted by the New Jersey Department of Environmental Protection (NJDEP) in 1983-1984 to verify the locations of the former factories and the residential areas. The Welsbach and General Gas Mantle Contamination Sites (WGGMCS), located near the Delaware River in the vicinity of 39° 55' 11" North 75° 7' 19" West, consist of five separate areas (see Figure 1) within a radius of approximately two miles. Areas 1 and 2 (see Figures 2 and 3) are the locations of the former manufacturing plants (General Gas Mantle and Welsbach, respectively). Areas 3, 4, and 5 (see Figures 3, 4, and 5) are primarily residential. The December, 1988 report of the preliminary survey[2] recommended that a more detailed survey of the areas be performed.

As a result, in 1991, at the direction of NJDEP, a detailed survey[3] of the previously identified areas was conducted which located individual residences, non-residential structures, and open areas which exceeded twice the ambient background level for γ radiation. Since then, a number of interim remedial actions have been conducted by NJDEP. A chronology of significant activities at WGGMCS is given in Table 1.

There is little information available regarding activities at the former General Gas Mantle Company, other than it used and resold radium, thorium, and mesothorium (Ra-228), and also used thorium to manufacture incandescent gas mantles. Conversely, the Welsbach Company is known to have manufactured incandescent gas mantles during the period 1896 through 1940. The factory property covered an area of about 21 acres and consisted of approximately 20 buildings. The Welsbach Company was for a number of years the largest manufacturer of gas mantles in the world, at its peak making up to 250,000 mantles per day. However, as gas lighting was gradually replaced by carbon (and later tungsten) filament electric lighting, the demand for gas mantles declined. Both companies apparently ceased manufacturing the gas mantles in the early 1940's.

The United Gas Improvement Company, which formed the Welsbach Company, had purchased the patent rights to the Welsbach process of manufacturing thorium-containing gas mantles from Dr. Carl Auer von Welsbach (near Vienna, Austria). The process for manufacturing the Welsbach gas mantle used a highly purified solution of 99% thorium nitrate and 1% cerium nitrate as the lighting fluid. Monazite sands (which contain approximately 5% thorium as ThO_2)

were the primary source of thorium and cerium. Monazite ores also contain recoverable quantities of other minerals, including rare earths (lanthanum, neodymium, praseodymium) and yttrium. However, at the time, the extraction process and purification of thorium generated large quantities of by-products "with little or no commercial value". During the years that the Welsbach and General Gas Mantle Companies operated, ore tailings apparently were used as landfill in the vicinity of the factories, which were located in the (at that time) relatively undeveloped marshlands adjacent to the Delaware River.

Site Visit

On June 19, 1995 a visit was made by representatives of NJDOH (since renamed NJDHSS), ATSDR, NJDEP, and EPA to the five areas (see Figure 1) of WGGMCS which had previously been identified as exceeding twice the ambient γ background for the vicinity.

Background γ readings taken during the site visit with a Ludlum Model 19 μR meter were approximately 7 μR/hr, in agreement with background found during the previous γ surveys. Most of the measurements taken during the site visit were less than 27 μR/hr, i.e., 20 μR/hr above background. However, the dose rate at a small outdoor area near the Gloucester City Swim Club was measured to be 30-35 μR/hr. Also, γ readings of approximately 100 μR/hr were found around the exterior of the foundation of one residence in Gloucester City. (This residence was vacated in 1991, when it was bought by the NJDEP Spill Fund.)

Statement of Issues

This Health Consultation has been initiated at the request of EPA Region 2 in order to determine potential public health issues associated with WGGMCS in conjunction with its addition to the National Priorities List (WGGMCS was listed on June 17,1996). Previously, in 1991, NJDOH and NJDEP evaluated radioactive contaminants at the location of the former General Gas Mantle Company, which resulted in the premises being vacated. In addition, several public meetings regarding WGGMCS were held in Camden and Gloucester City in 1991 to present the results of the radiological survey, and to discuss the public health implications and proposed interim remediation activities.

A Health Consultation was previously conducted by ATSDR in response to a request by EPA Region 2 on the WGGMCS properties in 1992.[4] (The conclusions and recommendations of this Consultation are discussed below.) Other written materials which have been reviewed include the Final Hazard Ranking System (HRS) Documentation[5] for WGGMCS (8 volumes, including copies of 52 references). The HRS documentation addresses radiological contamination of soil only. It does not characterize radiological contamination of surface or ground water, or ambient air. The records of NJDEP on the alpha (α) and gamma (γ) radiation contamination and the interim remediation activities carried out by NJDEP at WGGMCS have also been reviewed, as were the records of the New Jersey Department of Health which relate to the WGGMCS.

DISCUSSION

A brief discussion of the language and units of ionizing radiation is given in the Enclosure.

Natural (Background) Radiation

Ionizing radiation is naturally present nearly everywhere in the environment; however, the amount can vary considerably with location. As a result, radiological contamination must be compared with the ambient background radiation in the area in order to evaluate the public health implications of exposure. The average person in the United States is annually exposed to approximately 360 millirems [3.6 mSv] of background radiation.[6,7] (Background radiation was previously called natural radiation, but it has been re-defined to include common manmade sources of radiation such as diagnostic medical sources and consumer products). Approximately 82% of background radiation comes from naturally occurring sources, including radon, cosmic rays, and terrestrial and internal (within the body) sources. More than half of the average exposure to background radiation results from the radioactive decay of radon.

As shown in Table 2, background radiation includes approximately equal components of terrestrial radiation (i.e., γ rays from natural radionuclides in the soil) and cosmic rays. The 1981 aerial survey of Camden/Gloucester City determined that cosmic radiation contributes 3.7 μR/hr to the total "background radiation" (about 7 μR/hr) in the area. Together, cosmic rays and terrestrial γ rays result in an exposure of about 60 mrem [0.6 mSv]/yr to the average individual in the vicinity of WGGMCS.

In additon to the external sources of radiation (terrestrial and cosmic rays), some ionizing radiation is also given off by radioactive atoms that are naturally present in the body. For example, about half of the exposure from internal radiation (radiation from within the body) is due to radioactive potassium (K-40), a naturally occurring (0.01% abundance) radionuclide with a half life ($T_{½}$) of 1.26×10^9 years which primarily emits beta (β) radiation, but is also a source of γ radiation. (The definition of "half life" is given in Enclosure Table 1.)

The manmade component of background radiation (approximately 18% of the total) consists of exposures such as those from diagnostic X-rays, dental X-rays, mammograms, and smoke detectors. The average chest X-ray[8] today exposes the patient to approximately 15 millirem [0.15 mSv] (down from about 75 millirem [0.75 mSv] in the 1930's). However, the dose equivalent of dental X-rays is now about 250 millirem [2.5 mSv] (down from about 2 rem [20 mSv] in the 1930's). Similarly, a screening mammogram requires about 250 millirem [2.5 mSv], or about a tenth of the dose equivalent for one done 20 years ago. A typical home smoke detector contains about 5 μCi of americium-241, a rare earth element that is a source of α particles

Tables 3 and 4 show the results of analyses of "background" soil samples taken near WGGMCS to determine the concentration of certain radionuclides which are naturally present and consequently contribute to the background radiation level. These may be compared with the concentrations of radionuclides determined to be present in contaminated areas.

Radiological Contaminants at WGGMCS

The primary radionuclide of concern at WGGMCS is thorium (from monazite sands) which was used to manufacture the gas mantle lighting fluid. The Th-232 ($T_{½}$ = 1.49 x 10^{10} years) decay series with its numerous daughters, including: mesothorium (Ra-228); thoron (Rn-220) (an isotopic variant of radon); and its progeny [Po-216, Pb-212, Bi-212, and Po-212], which ends with Pb-208 (stable), is shown in Table 5.

Another potentially significant radiological material at WGGMCS is uranium which is also present in the soil (see, for example, Tables 3 and 4). Uranium contains three primary isotopes, with approximate abundances of about 99.27% U-238, 0.72% U-235, and 0.0054% U-234.[9] As the most abundant isotope, U-238 ($T_{½}$ = 4.47 x 10^9 years) and its decay series are of particular concern, since this series includes radium (Ra-226), the precursor of radon (Rn-222), and its progeny [Po-218, Pb-214, Bi-214, and Po-214]. The U-238 decay series, which ends with Pb-206 (stable), is shown in Table 6.

Potential Routes of Exposure to Radiological Contaminants at WGGMCS

As stated in the Hazard Ranking System documentation,[5] "the overall Hazard Ranking System site score is primarily generated from the γ radiation measurements exceeding two times background levels." However, in addition, indoor airborne radiological contaminants, i.e., radon and progeny, have also been substantially characterized in residential and non-residential structures.[3] A limited number of sites (two commercial properties and one residence) have also been analyzed for particulate α contamination. Based on these measurements, completed exposure pathways have existed (and continue to exist) in a number of locations for radiological exposure due to external γ radiation from the thorium and uranium decay series, and to internal α radiation due to inhalation of radon and thoron and their progeny.

As shown in Tables 7 and 8, measurements of the concentrations of thorium-232 and daughters, and uranium-238, radium-226 and its daughters have also been made in soils at a number of properties.[5] Although some of the samples do not meet the ATSDR definition of "surface soils" (that is, 0-3" in depth), these measurements indicate the potential for a completed exposure pathway which could result from possible ingestion of soil at WGGMCS properties.

Radiological contamination of the ground water and surface water was not evaluated as part of the Hazard Ranking System documentation of WGGMCS.[5] However, the entire population within 4 miles of WGGMCS relies on ground water which is drawn by municipal supply wells from an aquifer which is beneath confining layers of clay and consequently has not been contaminated by the ore tailings. Similarly, the surface waters of Newton Creek (the boundary between Camden and Gloucester City) are not believed to constitute a public health hazard due to the dilution created by flow of the creek. Consequently, these exposure pathways are not expected to be (or to have been) public health hazards. Nor has there been characterization of outdoor air for radionuclides, which is not expected to be or have been a public health hazard.

Potential Health Effects of Gamma Radiation Exposure

Ionizing radiation is a known carcinogen. The effects of exposure to radiation can be both stochastic (random occurrence; without threshold) and non-stochastic (non-random occurrence; with threshold). Radiogenic cancer is a stochastic, i.e., random, effect. In other words, the probability of developing a radiogenic cancer, such as leukemia, or esophageal or colon cancer, depends on the amount of exposure. It has been assumed that the probability of stochastic health effects such as cancer is linearly related to exposed dose. However, at low dose, the linear relationship between dose and effect, as well as the lack of threshold, i.e., an exposure dose below which there is no effect, is difficult to verify, since there are correspondingly few effects. By contrast, health effects such as cataracts of the eye and skin erythema are non-stochastic, i.e., the severity of the effect depends upon the amount of exposure. The goal for limiting exposure to radiation is to minimize stochastic effects, while preventing non-stochastic effects.

Risk of Cancer Associated with Exposure to Ionizing Radiation

For chemical contaminants, limits on exposure are frequently established in order to limit the risk of adverse health effects to an additional one per million exposed individuals over a lifetime, i.e., the so-called 10^{-6} rule. However, this rule of thumb is not easily applied to radiological contaminants, since the risk due to exposure to background radiation alone greatly exceeds this guideline. For example, according to the 1988 United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)[10] the risk of a cancer fatality associated with exposure to low levels of radiation is 0.7 to 3.5 per 10,000 health effects per rad [cGy] of exposure. More recently, the National Research Council's Committee on the Biological Effects of Ionizing Radiations (BEIR),[6] the International Commission on Radiological Protection (ICRP),[11] and the National Council on Radiation Protection and Measurement (NCRP)[12] predict a lifetime risk of a radiation-induced cancer fatality for the general population of about 5 per 10,000 per rem [10 mSv]. EPA[13] also estimates radiogenic cancer risk at about 5 per 10,000 per rem [10 mSv]. Consequently, exposure to a dose equivalent of 100 millirem [1 mSv] above background each year is expected to result in a lifetime excess cancer risk of about 50 additional radiation-induced cancer fatalities per million exposed individuals.

Regulatory Limits on Exposure to Ionizing Radiation

Regulatory limits on the maximum permissible dose from occupational exposure to external γ radiation have declined substantially over the years - from 0.1 rem [1 mSv]/day in 1934, to 0.3 rem [3 mSv]/week in 1950, to 0.1 rem [1 mSv]/week in 1956, to 1.25 rem [12.5 mSv] per calendar quarter in about 1960, to "as low as is reasonably achievable (ALARA)" in 1977. In 1991 the Nuclear Regulatory Commission (NRC) established the total effective annual dose equivalent (which includes internal exposure through ingestion and inhalation, in addition to external γ radiation) to be 5 rem [50 mSv]/year for occupational exposure of adults. Similarly, in 1993 the US Department of Energy (DOE) established a limit on total effective dose equivalent of 5 rem [50 mSv]/year for occupational exposure of employees at DOE facilities.

For members of the general public, the recommended limit on exposure to ionizing radiation is lower. In 1990 ICRP Publication 60[11] recommended that chronic exposure to members of the general public be limited to 100 millirem [1 mSv] per year above background. In 1991 this exposure limit was adopted by the NRC.[14] In 1993 NCRP Report 116[12] recommended the same exposure limit. Also in 1993, DOE proposed[15] the establishment of similar standards, i.e., the ALARA policy and a limit on effective dose equivalent of 100 millirem [1 mSv] per year, for protection of the public and the environment against radiation. However, this limit for exposure to the general public has not yet been adopted by DOE.

Other regulations which have been applied to radiologically contaminated sites include the EPA Protection Standards for Uranium and Thorium Mill Tailings.[16] This regulation established a standard for required remedial actions based on an external γ radiation of 20 μR/hr above background (continuous exposure at this dose rate is equivalent to 170 mrem [1.7 mSv]/yr). It also indicated that radium-contaminated soil be remediated to 5 pCi per gram of soil (top 15 cm) and 15 pCi per gram of soil (more than 15 cm below ground level). (Note: recently, soil has been remediated to 5 pCi radium/gram of soil, regardless of depth.) In addition, the DOE Grand Junction Remedial Action Criteria for Uranium Mill Tailings[17] required that certain remedial actions be taken when γ radiation levels exceed 50 and 100 μR/hr above background. However, these two regulations are intended to promulgate standards for remediation, they are not strictly related to the potential human health effects which may be associated with exposure to γ radiation.

In addition, NJDEP has recently drafted proposed standards for remediation of radiological contamination[18] which would require cleanup of soil to levels (according to the nuclide and depth of contamination) which would result in a total effective dose equivalent from the sum of external γ exposure (effective dose equivalent) and intake (committed effective dose equivalent) of no more than 15 mrem [0.15 mSv] per year, i.e. natural background variation. According to this proposal, for example, Th-232 in surface soil at a residence would be remediated to achieve a concentration of no greater than 6.8 pCi/gram. However, these proposed standards have not yet been adopted.

Exposures to External Gamma Radiation at WGGMCS

An individual who is continuously exposed to external γ radiation of 11.4 μR/hr above background would receive a dose equivalent of 100 millirem [1 mSv] per year. However, since a person is unlikely to be continuously exposed to a constant source of radiation contamination throughout the year, certain assumptions must be made regarding occupancy, i.e., exposure times, in order to accurately determine effective exposure dose from dose rate.

The EPA Exposure Factors Handbook[19] indicates that an average individual spends approximately 70% of the time at home (and therefore 30% away from home). While at home, the average individual will spend 92% of the time indoors (and the remaining 8% of the time outdoors). In other words, the average occupant of a radiologically contaminated residence would be exposed to contamination each day for 15.5 hours indoors, i.e., 24 hrs x 0.7 x 0.92, and 1.3 hours outdoors, i.e., 24 hours x 0.7 x 0.08. In this scenario, there would be no radiological exposure above background for the remaining 7.2 hours of each day that the individual is away from the contaminated residence. There can be great variability in occupancy times at home, since some individuals very seldom leave their homes, while others are frequently away from their homes due to employment and other activities.

Radiological contamination of open areas or non-residential structures poses a different circumstance, since an individual who is exposed to radiation in these locations will undoubtedly have different indoor and/or outdoor exposure times than when at home. Therefore, several scenarios for exposure to the radiological contamination at WGGMCS must be considered, i.e., (1) residential contamination where there may be both indoor and outdoor exposure; (2) non-residential contamination (probably both indoor and outdoor exposure); and (3) contaminated open areas (outdoor exposure only).

Estimation of the dose received due to exposure to external γ radiation depends to a large part on the assumptions made regarding occupancy (past, present or future) of the contaminated areas. For example, the previous WGGMCS Health Consultation[4] assumed an occupancy of 24 hours/day, 365 days/year in order to estimate previous residential exposures. Non-residential structures were assumed to be occupied for 12 hours/day, 5 days/week for 50 weeks/year. No assumptions were made regarding occupancy of open areas.

In 1991, the NJDEP Bureau of Environmental Radiation (BER)[20] established the dose rate action level for γ radiation for interim remediation of contamination at WGGMCS to be 27 μR/hr (i.e., 20 μR/hr above background) for indoor exposure, and 67μR/hr (i.e., 60 μR/hr above background) for outdoor exposure. These action levels, derived from a maximum annual exposure to 100 millirem [1 mSv] above background, were apparently determined by assuming either 14 hour daily exposure indoors only, or 5 hours daily exposure outdoors only. The location of the contamination, i.e., residential, non-residential, or open area, was not specified.

The γ radiation survey,[3] which was conducted at over 1100 residences, businesses, and open areas in the five areas of WGGMCS in 1991, found that approximately 95 properties showed maximum γ radiation levels that exceeded the inclusion (i.e., screening) criteria of 27μR/hr indoors (i.e., 20μR/hr above background) or 17 μR/hr outdoors (i.e., 10 μR/hr above background). Properties which exceeded these screening levels were further surveyed under so-called Short Term Remedial Action Survey (STRAS) criteria, which consisted of pairs of measurements taken on 2 meter centers at ground contact and waist level (1 meter above ground), in order to more accurately locate the sources of contamination. Approximately 39 STRAS-surveyed properties (including 23 residences occupied by approximately 70 persons) exceeded the NJDEP temporary remediation action criteria (27μR/hr contact indoor, 67μR/hr outdoor). The 1992 Health Consultation[5] estimated that radiological contamination had caused past external γ exposure in excess of 100 mrem [1 mSv]/year at one residence, three commercial businesses, and three open areas; these estimated exposures were considered to be of "public health concern".

However, starting in 1991, the majority (see Table 9) of the contaminated sites have been temporarily remediated at the direction of NJDEP, primarily in order to reduce ambient levels of external γ radiation. Interim remediation actions have been taken at the locations which were identified as areas of public health concern in the previous Health Consultation.[4] As previously mentioned, residence RES 3-1 (in Area 3) was vacated and bought by NJDEP. The location of the former General Gas Mantle Company (in Area 1) was vacated in 1991. Concrete slabs have been poured in a portion of the adjacent building (COM 1-1). Also, the Johnson Boulevard Land Preserve (OPE 3-1) has been fenced and signed to limit access (this area is relatively inaccessible due to vegetation and trees). In addition, the area in the vicinity of the intersection of Collings Avenue and Essex Street (located in Area 3) has been covered with clean fill sufficient to reduce the γ radiation level to less than 60 μR/hour. However, the area of specific concern which was previously designated as the "Gloucester City Little League Field" (but is in fact in an area adjacent to the ball field and is within the right-of-way of Conrail railroad tracks) has not yet been remediated. Also, occupancy times in portions of the Armstrong Building on the site of the former Welsbach Company, which continues to be used commercially, have been reduced to limit current exposure; however, several buildings and other areas of the property remain to be remediated. As of late 1996, additional interim remediation is planned for outdoor areas of the former Welsbach Company property (COM 2-1), the alley adjacent to the former General Gas Mantle building (COM 1-1), and the Conrail right-of-way (OPE 4-1). The Armstrong building (part of COM 2-1) is apparently being vacated, although portions may continue to be used for commercial storage. These remedial actions and site controls should, however, be considered to be temporary only, until final remedial actions have been determined and completed.

Internal Exposure to Alpha Radiation

In addition to exposure to external sources, individuals might also be exposed to ionizing radiation through inhaling or ingesting radioactive materials. For example, gaseous radionuclides which emit α particles could pose a significant health risk if they were to be inhaled. Radon, a gas, is of particular concern since it has been estimated (see Table 2) to cause the majority of background radiation exposure in the United States. Radon-222 ($T_{1/2}$ = 3.8 days) is created from the decay of naturally occurring uranium-238 in the soil (see Table 6). However, the progeny of radon-222 are species which are solid at ambient temperature. While much of the radon inhaled would be immediately exhaled, its progeny could remain in the lungs in particulate form where they would further decay to emit more α particles and, in some cases, β and γ radiation. The risk of exposure to radon (Rn-222) progeny has been estimated[21] to be approximately 350 fatal lung cancers per million individuals per Working Level Month (see Enclosure Table 1 for the definition of Working Level Month). Since Th-232 is the primary contaminant present at WGGMCS, radon-220 (an isotopic variant of radon called thoron) and its progeny in the Th-232 series could pose a substantial risk of exposure to α particles.

The action level for the equilibrium concentration of radon in indoor air which has been established by EPA and adopted by NJDEP is 4 pCi/liter; the action level for radon progeny is 0.02 Working Levels (WL). The average indoor radon concentration in New Jersey has been determined to be 1.35 $\pm$ 3 pCi/liter (1 σ),[18] so radon concentrations which exceed the action level are not uncommon. Since thorium-232, the primary contaminant at WGGMCS, decays to form radon-220, the concentrations of both radium-226 and thorium in the soil must be considered in order to estimate contamination from both isotopes of radon in the structures at WGGMCS.

The residential and nonresidential structures located within the 5 areas of WGGMCS were surveyed for radon and progeny using charcoal canisters. Charcoal canister measurements which exceeded 4 pCi/liter were confirmed with α track detector measurements. As shown in Table 10, structures at 12 properties have been found to exceed action levels for radon and/or progeny. Several structures exceeded the radon action level, but did not show significant γ contamination. It is possible that that in these locations the contamination was due to background sources only, i.e., the U-238 decay chain, or that thorium-contaminated soil was deeply buried. Six of these structures have been remediated to achieve radon levels which are below the 4 pCi/liter action level (Note: under NJDEP's proposed standard[18] for remediation of radioactive materials, an indoor radon concentration greater than 4 pCi/l would be remediated to achieve less than 3 pCi/l.) However, the radon levels in a number of structures (including some to which further access has been denied, and one residence where the initial attempt at remediation was not successful) apparently remain above 4 pCi/liter.

For particulate sources of α radiation such as radon progeny, the criterion for decontaminating α emitting particles on surfaces has been proposed as 20 disintegrations per minute (dpm) per 100 cm^2 for removable particles; similarly, the total allowable α activity on a surface has been proposed as 300 dpm/100 cm^2.[15] In 1991, swipe samples were taken at the so-called Armstrong Building at the former Welsbach Company, the former General Gas Mantle Company building, and one residence in order to analyze sources of removable particulate α radiation. Swipe samples taken in the basement of the residence were found to exceed the total allowable particulate α activity (this residence was vacated and bought by NJDEP). Several swipe samples taken in the former General Gas Mantle building exceeded allowable levels of both removable and total particulate α activity. This building had recently been used to store textiles. Since a study of decontamination of the textiles showed that they could not be sufficiently decontaminated, the materials were disposed of. (Note: the former General Gas Mantle building was vacated in 1991 due to radon levels in excess of the action level.) Some swipe samples which were taken in the so-called Armstrong Building on the former Welsbach Company property exceeded allowable levels of both removable and total particulate α activity; as a result, several rooms on the third floor are no longer in use.

Ingestion of Radiologically Contaminated Soil

As previously mentioned, a number of soil samples at WGGMCS have been analyzed for radiological contaminants (see Tables 7 and 8). Although not all of these samples were "surface" soils as defined by ATSDR (some of the samples taken in 1995 were composite samples as much as 12" below the surface), the results of the analyses may be used to estimate the potential risk associated with ingesting these soils. For example, ingestion of up to100 mg per day for an adult and 250 mg/day for a child of the soil samples taken at RES 4-1 and RES 5-1 (the samples with the greatest amounts of contaminants) could result in an effective whole body dose of several hundred millirem, i.e. several mSv, per year. However, since the samples at RES 5-1 were taken several inches below surface level, exposure by ingestion of soil and inhalation of dust to this dose is not considered likely. The area has since been covered with an 8" thick concrete slab, and surrounded by a chain-link fence. Nevertheless, two children (ages 10 and 16) did live in the residence in 1991 when the samples were obtained. The sample taken at RES 4-1 was taken along a sidewalk approximately 10" below the surface. If default quantities of the soil were ingested, a whole body exposure of approximately 100 millirem [1 mSv] could result during the course of a year. However, in this case, no children live in the residence and the area has since been covered with clean fill. As a result, it is not likely that ingestion or inhalation of radiologically contaminated soil would have resulted in significant exposure, and consequently this pathway is not believed to constitute a public health hazard.

Potentially Exposed Population

According to the 1990 Census, approximately 50,000 individuals currently reside in about 20,000 housing units within 1 mile of the WGGMCS (see Figure 6). Of this total, contamination in excess of the screening criteria (27 μR/hr inside and 17 μR/hr outside) has been identified (and has existed) at approximately 95 properties in the five areas of WGGMCS. As previously mentioned, approximately 70 individuals currently reside in the 26 contaminated residences[5] which exceed the interim remediation criteria (27μR/hr inside and 67 μR/hr outside). Individuals also continue to work at several contaminated commercial properties. While it is not possible to accurately reconstruct exposure doses for the variety of human exposure scenarios over this extended period of time, it is likely that over the past 50 years several hundred individuals were exposed in excess of the currently accepted standards for exposure of the public to ionizing radiation.

Determination of Health Outcomes

As mentioned above, the primary health outcome associated with exposure to ioniziing radiation is cancer. Consequently, an evaluation of cancer incidence in areas which are radiologically contaminated will be necessary in order to determine the prevalence of any cancer which might be associated with exposure to contaminated media. A focussed cancer incidence investigation is planned to be performed by NJDHSS, in which the populations in designated neighborhoods will be evaluated separately and in aggregate. The NJDHSS Cancer Registry will be used as the data base to determine if an excess cancer rate exists in the contaminated areas. Analysis will determine standardized incidence ratios (SIR) for the exposed population. SIRs will then be compared with average cancer incidence rates in New Jersey and the United States. For comparison, WGGMCS and several other radiologically contaminated sites in New Jersey will be evaluated for cancer incidence.

CONCLUSIONS

The data which are presented above summarize a large number of survey measurements taken at the former Welsbach and General Gas Mantle Companies and nearby contaminated properties. The elevated external γ surface soil, and radon and particulate progeny measurements show that monazite ore tailings and other process by-products were disposed of at many properties in Camden/Gloucester City on which residences were subsequently constructed. Radiological contamination of these properties has existed for more than 50 years. Although temporary remedial actions have been taken at many properties, the radioactive contaminants which remain continue to constitute a public health hazard at the location of the former Welsbach Company, and at the area within the Conrail railroad tracks right-of-way.

On the basis of the α and γ radiation measurements taken at WGGMCS which are discussed above, the following conclusions may be drawn:

- radiological survey has characterized γ radiation levels which result from contaminated soils in the WGGMCS. Approximately 39 locations were identified which exceeded NJDEP γ radiation STRAS action levels, of which 7 properties were considered to have been a "public health concern" in the past. The majority of these sites have been remediated to interim criteria (including background) of 27μR/hr indoors or 67μR/hr outdoors. However, one area adjacent to the Conrail railroad tracks has not yet been remediated. Interim remediation also remains to be completed at the location of the former Welsbach Company and several other locations.

- based on known contamination (defined as measurements of external γ which exceed twice background) of about 95 properties, it is likely that several hundred individuals may have been exposed to radiation in excess of 100 millirem [1 mSv] per year above background.

- survey of the WGGMCS locations identified approximately 12 structures which exceeded radon action levels. Six of these locations have been remediated to concentrations below the radon action level of 4 pCi/liter in ambient air, but concentrations in several structures apparently remain above the radon action level.

- the three structures which were tested for and found to have particulate α contamination on surfaces have been vacated and/or remediated; however, most structures which were found to have elevated radon and external γ levels have not yet been tested for particulate α contamination.

- most areas with radiologically contaminated soil have been remediated, on an interim basis, through addition of clean soil, blacktop, or concrete slabs; although ingestion or inhalation of contaminated soil was likely to have been a completed pathway of exposure in the past, this pathway is not considered to constitute a current public health hazard.

RECOMMENDATIONS

Recommendations to Limit Exposure

- NJDEP action levels for γ radiation dose rates for interim remediation at WGGMCS should be modified after determining the most likely occupancy scenarios in order to limit future exposures at contaminated residential and commercial properties and open areas to less than 100 millirem [1 mSv]/year;

- the two properties (the former Welsbach Company property and the Conrail right-of-way) which continue to constitute a public health hazard should be remediated to achieve the revised interim action levels (see above);

- external γ dose rates at all WGGMCS locations should be reviewed to confirm that post-remediation γ radiation levels do not exceed action levels (see above);

- the six structures which have been identified as exceeding radon action levels [4 pCi/liter for radon and 0.02 WL for progeny] should be remediated to achieve those levels; and

- structures which have been found to exceed the WL action level should be swipe sampled to determine levels of particulate α radiation contamination.

Health Activities Recommendation Panel (HARP) Determinations

In accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 as amended, the Agency for Toxic Substances and Disease Registry (ATSDR) and the New Jersey Department of Health and Senior Services (NJDHSS) have evaluated the data and information in this Health Consultation for the Welsbach and General Gas Mantle Contamination Sites (WGGMCS) to determine if follow-up actions may be indicated. The ATSDR's Health Activities Recommendation Panel (HARP) offers the following recommendations:

> The panel determined that a relatively large population may be continuing to experience exposures from radioactive materials in homes. Therefore, the community health education and health professional eduation being conducted by the New Jersey Department of Health and Senior Services are the appropriate follow-up health activities. Furthermore, the panel determined that the levels of past exposure at this site indicate the need for inclusion of the site in a statewide Health Outcome Data survey for radiological sites. No other follow-up actions are indicated at this time.

Public Health Actions

The Public Health Activities Plan (PHAP) for WGGMCS contains a description of the actions to be taken by ATSDR and/or NJDHSS at or in the vicinity of WGGMCS subsequent to the completion of this Health Consultation. The purpose of the PHAP is to ensure that this Consultation not only identifies public health hazards, but provides a plan of action designed to mitigate and prevent adverse human health effects resulting from exposure to hazardous substances in the environment. Included is a commitment on the part of ATSDR and NJDHSS to monitor this plan to ensure that the plan is implemented. ATSDR will provide an annual follow-up to this PHAP, outlining the actions which have been completed, and those actions in progress. This report will be placed in repositories that contain copies of this Consultation, and it will be provided to persons who request it. The public health actions to be implemented by ATSDR/NJDHSS are as follows:

Actions Undertaken:

(1) The environmental sampling data and remedial activities which have been conducted have been evaluated within the context of human exposure pathways and other relevant public health factors.

(2) A Physician Education Newsletter which provides information on the potential health effects of exposure to the ionizing radiation contaminants at WGGMCS has been prepared and distributed by NJDHSS to primary care physicians and other interested individuals in the Camden/Gloucester City vicinity.

Actions Planned:

(1) A Community Education Factsheet will be prepared by NJDHSS which will provide residents of Camden/Gloucester City in the vicinity of WGGMCS and other interested parties with information on the nature of and potential for health effects which could be caused by radiological contaminants.

(2) A study which describes health outcomes, including leukemia and solid tumors, of individuals in the vicinity of WGGMCS and other radiologically contaminated sites in New Jersey will be prepared by NJDHSS.

(3) ATSDR and NJDHSS will coordinate as deemed necessary with the appropriate environmental agencies to develop plans to implement the recommendations contained in this Consultation.

Certification

This Health Consultation for the Welsbach and General Gas Mantle Contamination Sites (WGGMCS) in Camden/Gloucester City was prepared by the New Jersey Department of Health and Senior Services (NJDHSS) under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with approved methodology and procedures existing at the time the Health Consultation was initiated.

David Hutchins
Technical Project Officer
Superfund Site Assessment Branch (SSAB)
Division and Health Assessment and Consultation (DHAC)
ATSDR

The Division of Health Assessment and Consultation (DHAC), ATSDR has reviewed this Health Consultation and concurs with its findings.

Sharon Williams-Fleetwood, Ph.D.
Chief, SSAB, DHAC, ATSDR

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Appendices

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Enclosure - The Language and Units of Ionizing Radiation

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Prepared By:

Bruce E. Wilcomb, Ph.D.
ATSDR Project
Consumer and Environmental Health Services
New Jersey Department of Health and Senior Services

ATSDR Technical Project Officer:

David Hutchins
Environmental Health Scientist
Superfund Site Assessment Branch
Division of Health Assessment and Consultation

ATSDR Regional Representative:

Arthur Block
Senior Regional Representative, Region 2
Regional Operations
Office of the Assistant Commissioner

Any questions concerning this document should be directed to:

James Pasqualo
ATSDR Project Manager
New Jersey Department of Health and Senior Services
Consumer and Environmental Health Services
210 South Broad Street
CN 360
Trenton, New Jersey 08625-0360

Appendices

Table 1. Chronology of Events relating to WGGMCS

Date	Activity
1886	Welsbach mantle patent granted to Dr. Carl Auer von Welsbach in Vienna
1887	United Gas Improvement Co. purchased patent rights Formed Welsbach Incandescent Light Co.
1892	Name changed to Welsbach Light Co.
1900	Welsbach Co. formed, subsidiary of Welsbach Light Co.
1912	First record of General Gas Mantle Co.
early 1900's	Welsbach manufactured 250,000 mantles/day
March 28, 1940	Welsbach Co. sold to Lindsay Light and Chemical Co.
1941	General Gas Mantle Co. closed???
June 30, 1952	Lindsay Light changed to Lindsay Chemical Co.
May 1, 1958	Lindsay merged with American Potash Chemical Co.
January 29, 1968 June 3, 1968	American Potash merged into Kerr-Magee Co. United Gas Improvement Co. renamed U.G.I.
May, 1981	Aerial survey of Camden/Gloucester City by EG&G Data reanalyzed in 1993
December, 1983	Preliminary ground survey by NJDEP
December, 1988	NJDEP report on December, 1983 survey
1991	WL, α, γ survey of WGGMCS areas Residence RES 3-1 bought June 3, 1991 Fabric decontamination study Former General Gas Mantle building vacated May, 1991 4 NJDEP/NJDOH public meetings
1991-1994	Remediation at approx. 29 sites by NJDEP
October-December, 1992	Former General Gas Mantle (textiles) cleanup
June, 1995	NJDOH Site Visit
June, 1996	WGGMCS listed on NPL

Table 2. Background Radiation in United States (mrem/yr)[7]

Source	Percentage	Dose Equivalent (mrem/yr)
Radon	55	198
Cosmic rays	8	29
Terrestrial	8	29
Internal	11	40
Medical	11	40
Nuclear medicine	4	14
Consumer products	3	11
Other	<1	4
Total	100	365

Table 3. Radionuclides in Background Soil - 1991 (pCi/g)[3]

Sample	Th-228	Pb-212	Tl-208	U-238	Ra-226	Pb-214	Bi-214	K-40
1	1.6	1.2	1.3	<1	<2	1.3	1.1	13.0
2	0.25	0.34	0.29	<0.4	0.77	0.25	0.23	7.5
2(dup)	0.35	0.27	0.31	<0.9	<0.6	0.29	0.23	9.0

Table 4. Radionuclides in Background Soil - 1995 (pCi/g)[5]

Sample	Th-232	U-238	Ra-226
1	0.9	1.7	0.95
2	0.35	<0.4	0.41

Table 5. Th-232 Decay Series[9]

Principal Decay Chain	Subchain	Nuclide	Half life
Th-232	Th-232	Th-232	1.49E10 yrs
	Ra-228 + D	Ra-228(mesothorium) Ac-228	5.75E0 yrs 6.13E0 hrs
	Th-228 + D	Th-228 Ra-224 Rn-220(thoron) Po-216 Pb-212 Bi-212 Po-212 Tl-208	1.91E0 yrs 3.62E0 days 5.56E1 sec 1.46E-1 sec 1.06E1 hrs 6.05E1 min 2.98E-7 sec 3.05E0 min
	Pb-208	Pb-208	stable

Table 6. U-238 Decay Series[9]

Principal Decay Chain	Subchain	Nuclide	Half life
U-238	U-238 + D	U-238 Th-234 Pa-234	4.47E9 yrs 2.24E1 days 1.17E0 min
	U-234	U-234	2.44E5 yrs
	Th-230	Th-230(ionium)	7.7E4 yrs
	Ra-226 + D	Ra-226 Rn-222(radon) Po-218 Pb-214 Bi-214 Po-214	1.6E3 yrs 3.8E0 days 3.0E0 min 2.68E1 min 1.99E1 min 1.64E-4 sec
	Pb-210 + D	Pb-210 Bi-210 Po-210	2.23E1 yrs 5.01E0 days 1.38E2 days
	Pb-206	Pb-206	stable

Table 7. Soil analyses* at WGGMCS - 1991 (pCi/gram)[3]

Location	Th-228	Pb-212	Tl-208	Ra-226	Pb-214	Bi-214	U-238
RES 1-1	4.3	4.3	3.7	2.6	0.91	0.82	<1
COM 1-1	650	530	410	130	50	42	270
COM 1-2	47	45	38	3.1	0.96	0.78	31
COM 1-3	500	420	340	<6	1.3	1.0	280
COM 1-4	23	21	18	<3	0.96	0.75	14
COM 1-5	36	30	29	6	3	2.5	26
RES 2-1	21	18	17	<2	1.3	1.1	14
RES 2-2	40	36	33	<2	0.66	0.58	15
RES 2-3	300	260	210	9.1	2.4	2.0	140
RES 2-4	5.6	5.2	5.0	3.3	0.9	0.8	3.3
RES 2-5	19	19	16	<2	1.0	0.77	14
RES 2-6	26	19	18	3.7	2	2	9
RES 2-7	8.9	7.5	7.1	<2	0.58	0.60	4.8
RES 2-8	2.8	2.3	2.3	1.0	0.87	0.68	1.1
COM 2-1	310	280	260	<7	4.1	4.1	340
RES 3-1	3.6	2.9	2.9	3.9	2.1	1.7	3.1
RES 3-2	14	11	11	21	10	8.9	<2
RES 3-3	1	0.92	0.83	1.8	0.97	0.82	1.6
COM 3-1	23	21	18	<3	0.96	0.75	14
OPE 3-1	540	470	450	450	480	410	190
OPE 3-2	530	450	450	420	230	210	330
OPE 3-3	32	27	26	56	26	22	31
RES 4-1	780	500	600	1100	1000	930	1700
OPE 4-1	690	640	550	98	75	64	530
RES 5-1	1500	820	1200	160	100	95	1300

BOLD - exceeds 5 pCi/gram Ra or U

* Soil samples taken at location of highest STRAS γ dose rate measurement on property

Locations: RES - residential property; COM - commercial property; OPE - open area

Table 8. Soil Samples -1995 (pCi/gram)[5]

Location	Th-232	U-238	Ra-226
RES 3-1	2880	**67**	**270**
COM 2-1	940	**45**	**93**
COM 2-1	1450	**<56**	**15**
COM 1-1	1690	**110**	**41**
OPE 3-1	2810	**<91**	**2650**
OPE 3-2	530	**55**	**327**
RES 5-1	1940	**<160**	**254**
COM 1-1	2970	**71**	**550**
OPE 3-3	56	**<13**	**85**

BOLD - exceeds 5 pCi/gram Ra or U
Location: RES - residential area; COM - commercial property; OPE - open area

Table 9. WGGMCS Properties which exceed NJDEP γ action levels for remediation[5]
(Properties exceeding guideline/properties remediated)

Area	Residential	Nonresidential	Open area	Total
1	2/--	6/4	4/3	12/7
2	12/12	--/--	1/--	13/12
3	5/1	1/1	3/3	9/5
4	1/1	--/--	--/--	1/1
5	3/1	--/--	1/--	4/1
Total	23/15	7/5	9/6	39/26

Table 10. WGGMCS Properties which exceed radon/progeny action levels[5]
(Properties exceeding guideline/properties remediated)

Area	Residential	Nonresidential	Total
1	2/0	2/2	4/2
2	2/1	1/0	3/1
3	2/2	1/0	3/2
4	1/0	1/1	2/1
5	--	--	--
Total	7/3	5/3	12/6

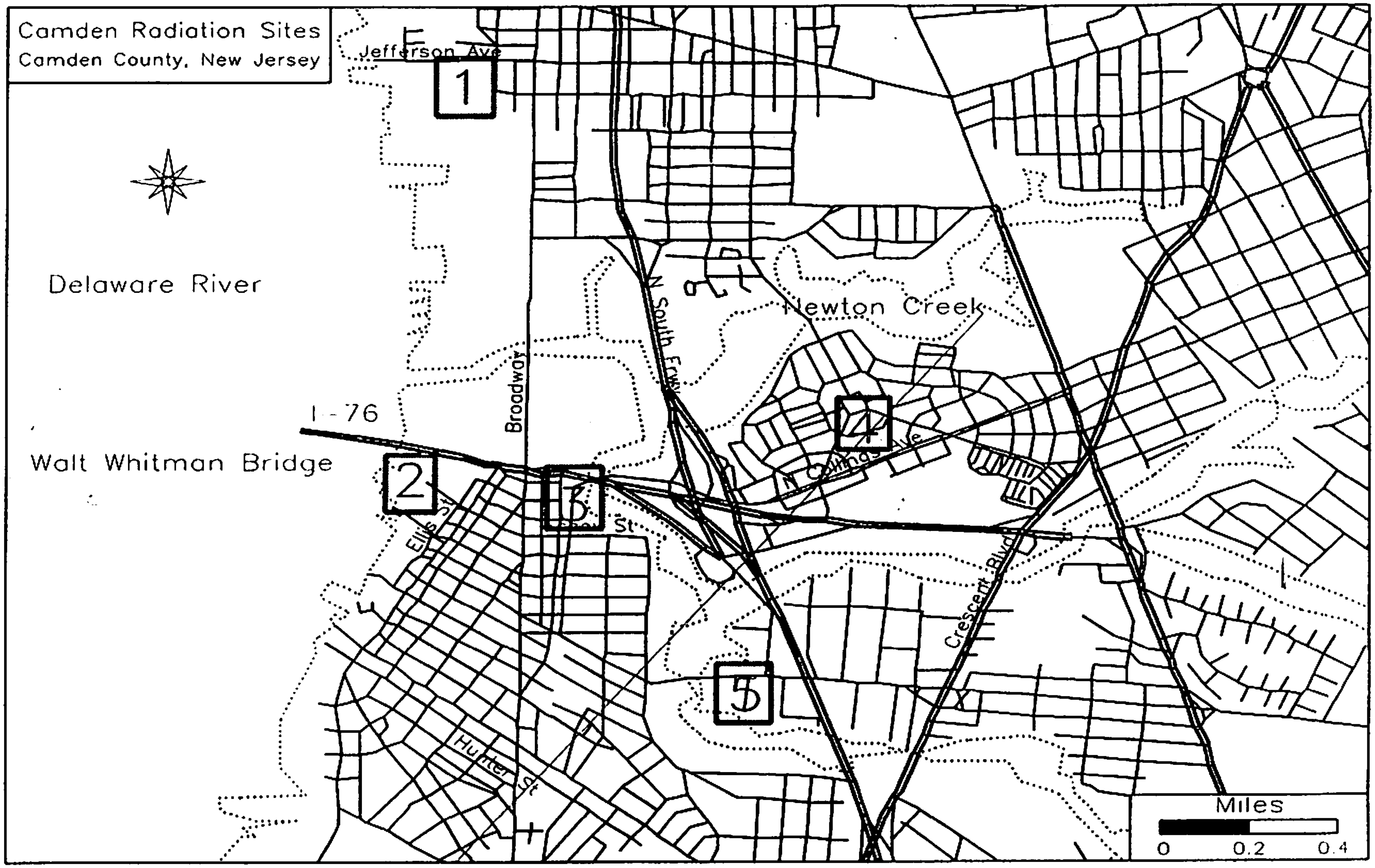

Figure 1. Vicinity of WGGMCS

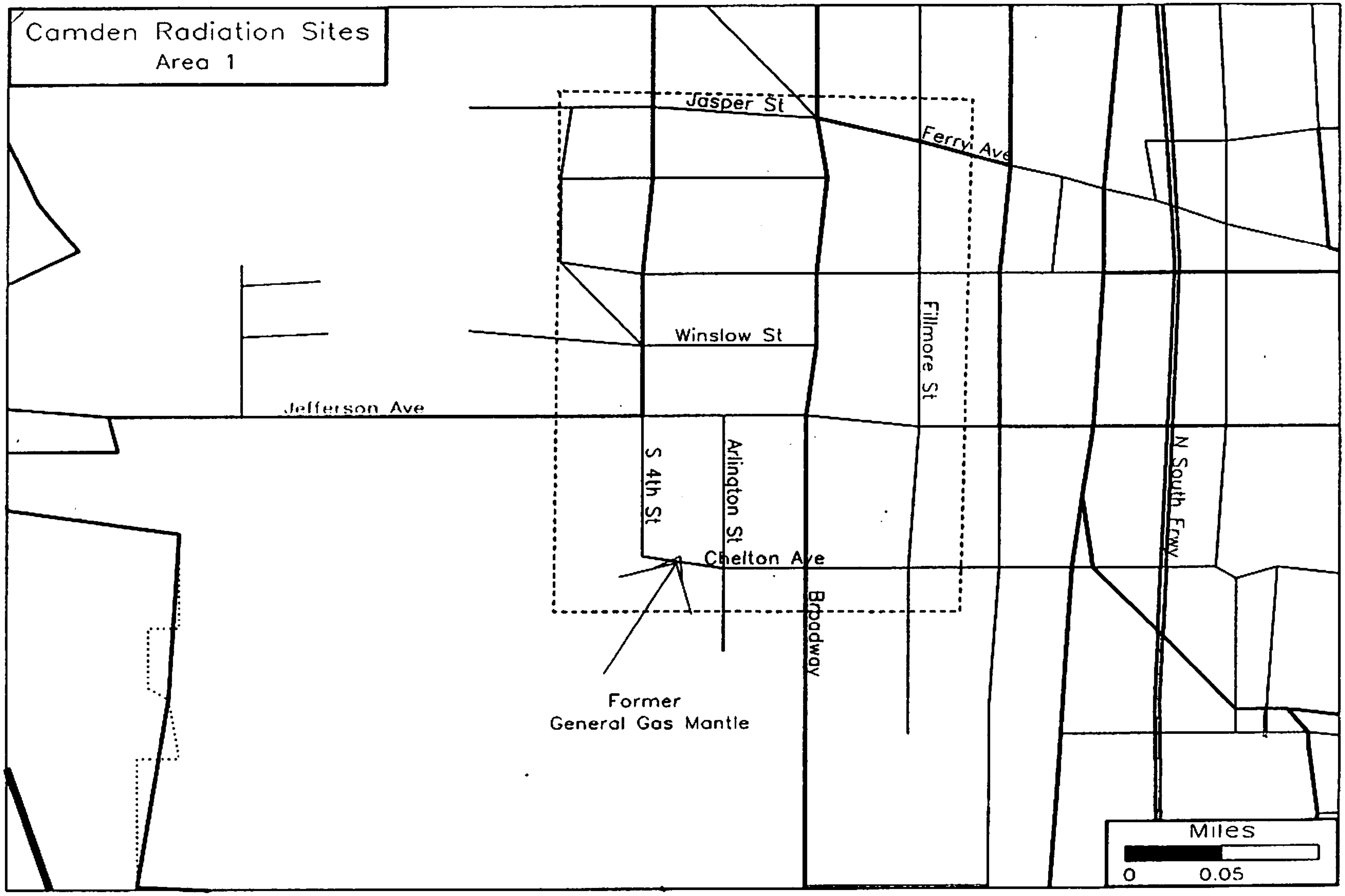

Figure 2. WGGMCS Area 1

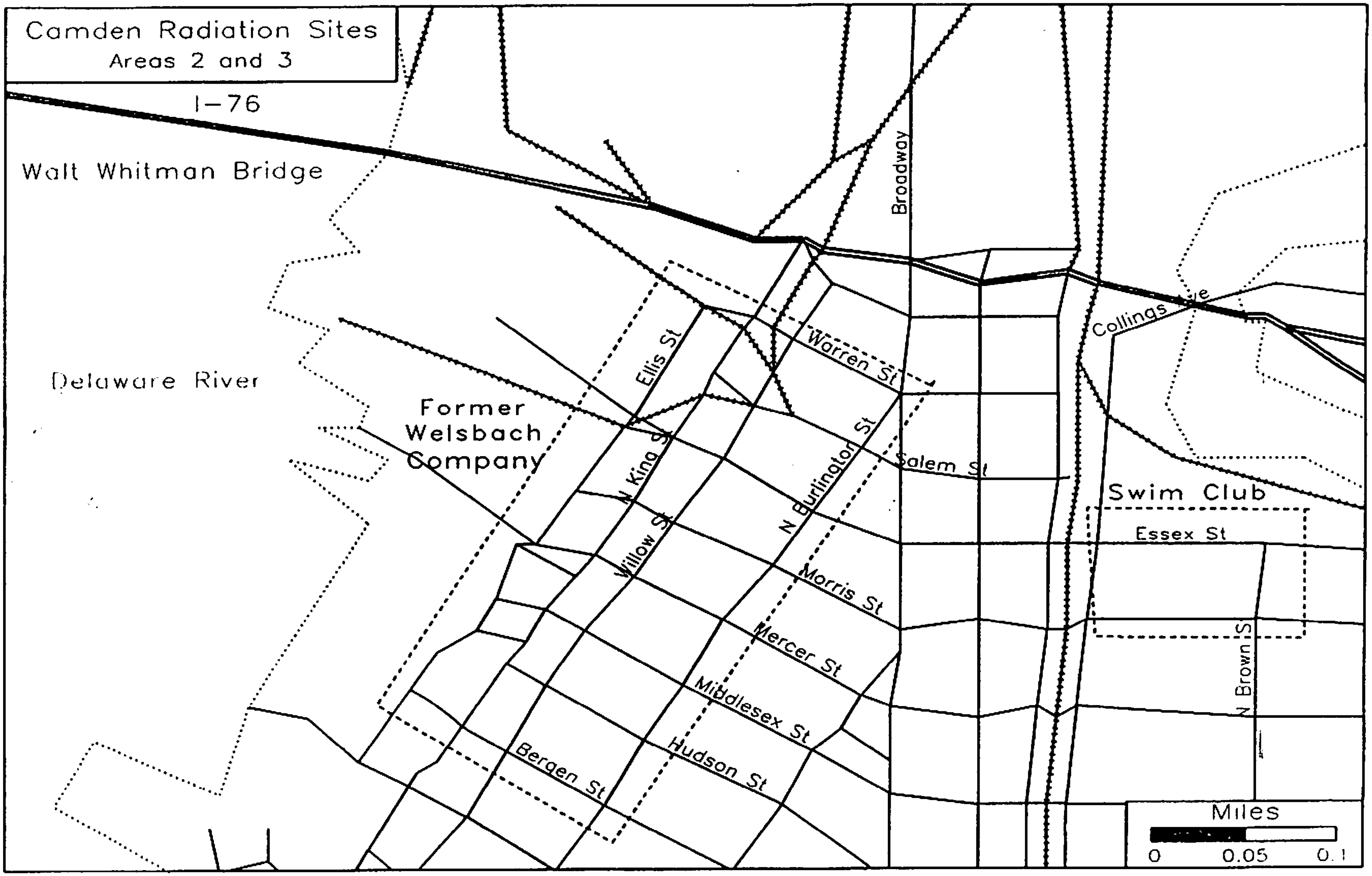

Figure 3. WGGMCS Areas 2 and 3

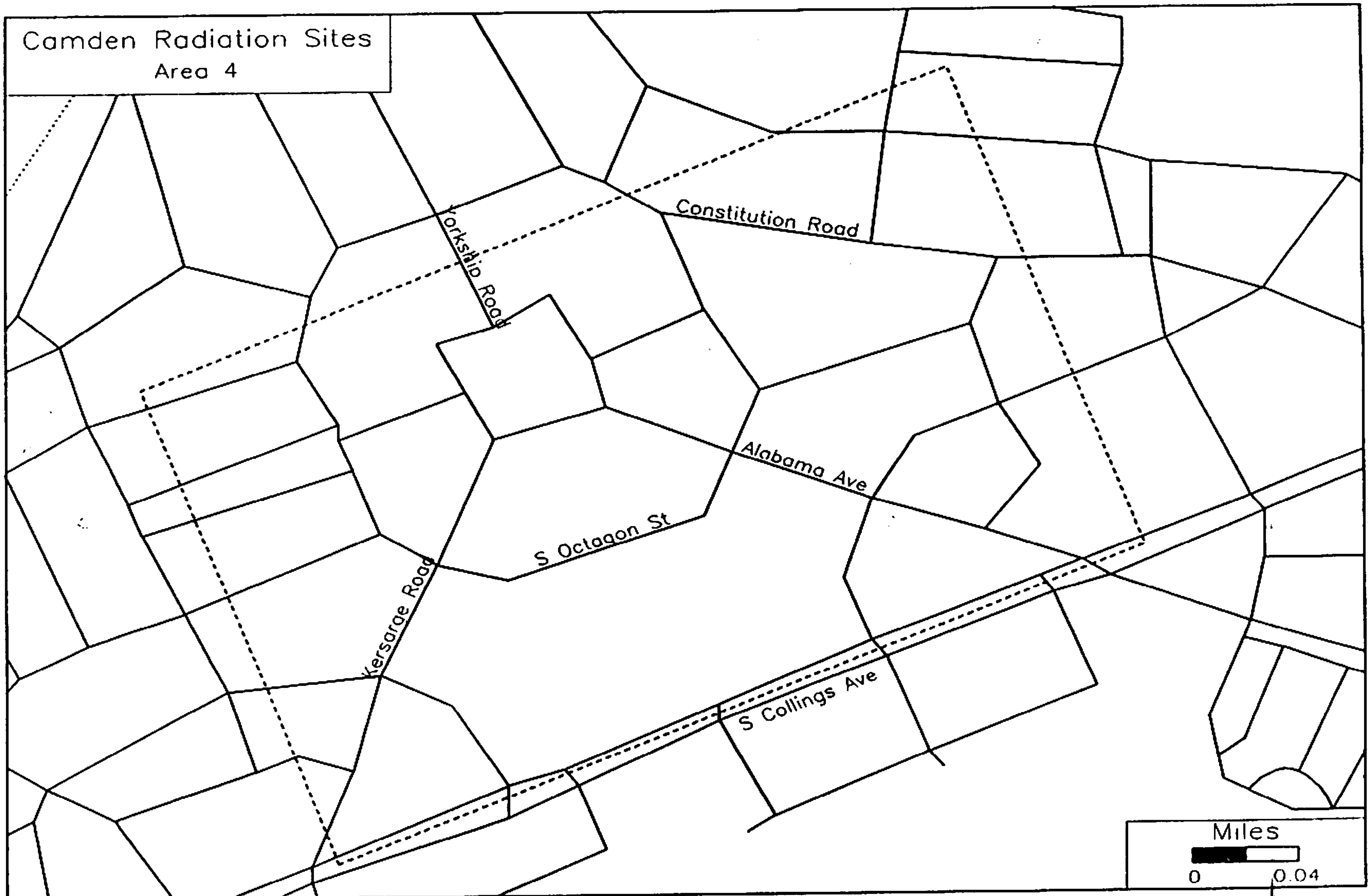

Figure 4. WGGMCS Area 4

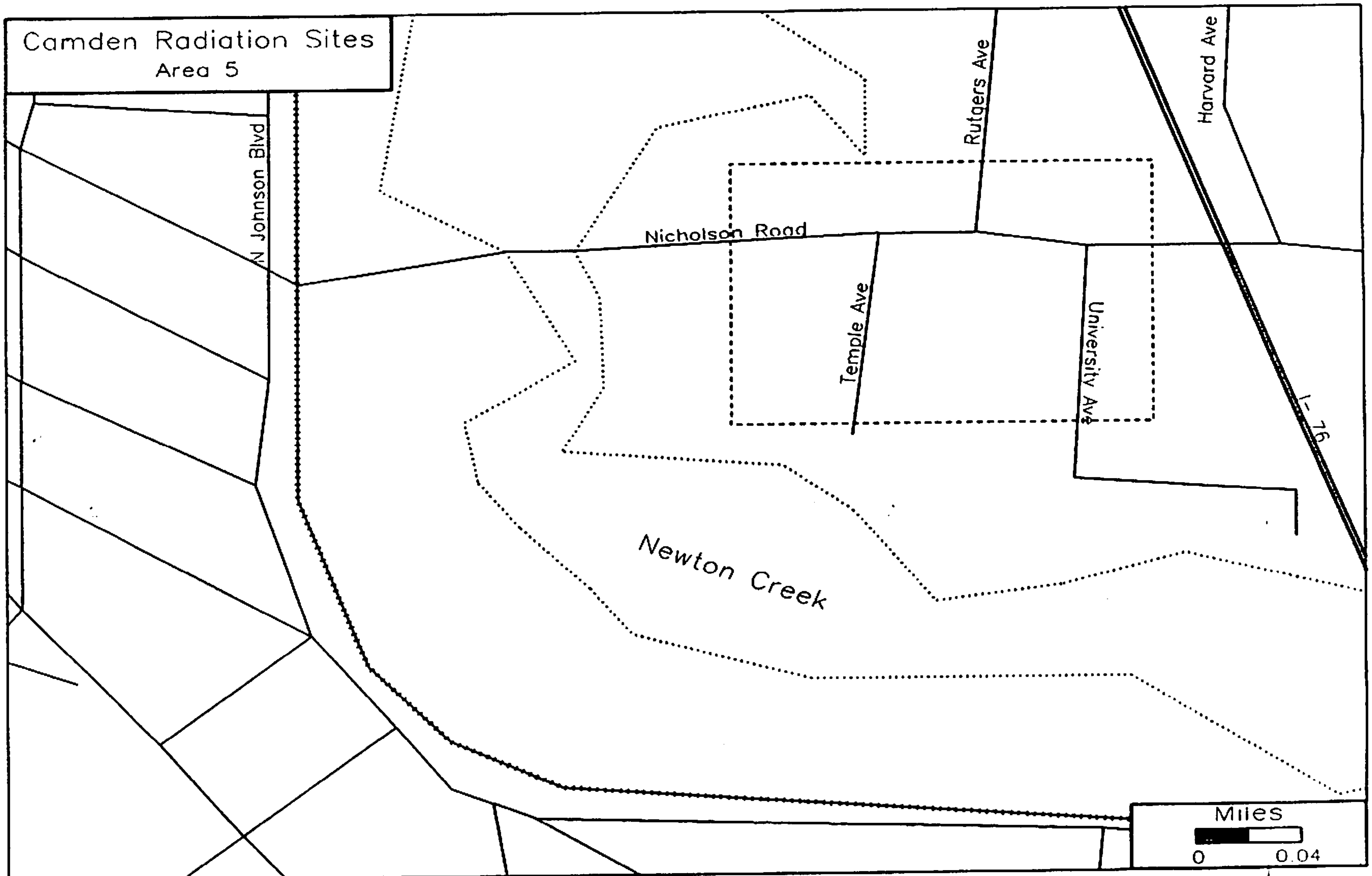

Figure 5. WGGMCS Area 5

Enclosure

The Language and Units of Ionizing Radiation

The definitions of radioactivity[9] and some associated terms are given in Table 1. As used in this document, "radiation" means ionizing radiation, i.e., particles and photons which are capable of ionizing matter. Ionizing radiation includes particulates [alpha (α) particles, beta (β) particles, neutrons, and protons] and photons [gamma (γ) rays, X-rays, and cosmic rays]. It does not include so-called non-ionizing radiation, such as microwaves, radiowaves, or infrared, visible, and ultraviolet light.

Ionizing radiation is generally quantified by its activity (measured in bequerel or Curie) and/or its specific activity, as defined in Table 1. A radioactive element (radionuclide) is also characterized by its rate of decay as expressed by the half life ($T_{½}$). Other definitions in Table 1 include: absorbed dose (in units of Roentgen, rad, or Gray); dose equivalent (units of rem or Sievert); and dose rate (measured in µR/hr).

Some of the common mathematical conversion factors relating activity, dose, and dose equivalent are given in Table 2. Other useful mathematical relationships and conversions include:

(1) Specific Activity (Curies/gram) = N x 1.873 x $10^{-11}/T_{½}$, where N is the number of radioactive atoms per gram of material (Note: 1 picoCurie (pCi) = 10^{-12} Curie, and 1 microCurie (µCi) = 10^{-6} Curie); and

(2) Dose Equivalent (rem, Sievert) = dose (rad) x Q, where Q is the quality factor [Q = 1 for gamma, X-ray, and beta; Q = 10 for neutrons and protons; Q = 20 for alpha].

The relationships between dose and dose equivalent for gamma radiation are given by:

1 µR/hr (air) = 0.869 µrad/hr (air) = 0.96 µrad/hr (tissue) = 0.96 µrem/hr (tissue)

Therefore, the absorbed dose rate for γ radiation in µR/hr for air is taken to be equal to (within 4%) the dose equivalent rate in µrem/hour for tissue.

Non-volatile radionuclides, such as radon progeny, which decay by emission of α particles are characterized by Working Levels (WL). Gaseous species, such as Rn-222, are quantified in terms of pCi/liter of air.

Table 1. The Language of Ionizing Radiation

Term	Definition
Radioactivity	a property of some nuclides of spontaneously emitting particles or gamma radiation, emitting X-radiation after orbital electron capture, or undergoing spontaneous fission
Activity	the mean number of decays per unit time of a radioactive nuclide
Specific activity	the activity per gram of compound, element, or nuclide
Half life	the time required for a radioactive substance to lose 50% of its activity by decay
Dose, whole body dose, absorbed dose	the mean energy imparted by ionizing radiation to an irradiated medium per unit mass
Effective dose, effective dose equivalent	the product of the absorbed dose in tissue, quality factor, and any other modifying factors at the location of interest
Working Level (WL)	any combination of radon daughters in 1 liter of air which will result in emission of 1.3×10^5 MeV of potential alpha energy
Working Level Month (WLM)	exposure resulting from inhalation of air with a concentration of 1 Working Level of radon daughters for 170 working hours

Table 2. The Units of Ionizing Radiation

Unit	Measures	Conversion factor
Becquerel (Bq)	activity	1 dis/s; 2.7×10^{-11} Ci
Curie (Ci)	activity	3.7×10^{10} dis/s
Roentgen (R)	absorbed dose	0.00869 J/kg (air) 0.0096 J/kg (tissue)
Gray (Gy)	absorbed dose	1 J/kg; 100 rad
Rad	absorbed dose	100 erg/g; 0.01 Gy
Sievert (Sv)	dose equivalent	100 rem
Rem	dose equivalent	0.01 sievert