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# Interpretation of the ORHASP Report for the Scarboro Community

by

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## I. Introduction

The Oak Ridge Health Agreement Steering Panel (ORHASP) Report is a human health risk assessment of the effects of the activities of the three United States Department of Energy facilities in Oak Ridge, Tennessee. The period covered is 1944 to 1995. The study started in 1991 and it was completed in 1999. The ORHASP Report is available to the public.

This report has three goals. These follow:
1) To put relevant results from the ORHASP Report in a more readily and easily comprehended form
2) To examine some air intake parameters used in the ORHASP Report for the Scarboro Community
3) To check some risk and hazard index results for the Scarboro Community that were presented in the ORHASP Report

### Characteristics of the Reports

This report examines only a fraction of the toxins that entered the residents of the Scarboro Community:
1) Note that Occupational Exposure is not included in the ORHASP Report
2) Note that only inhaled contaminants are included in this report. Contaminants that were in ingested water, soil, and food are not treated.

Originally the health effects of radionuclides in soils were to be evaluated separately, but this component of the evaluation has been dropped. The concentration of a contaminant in the atmosphere from soil is due to the processes of resuspension and volatilization. These components of the concentration are already included in the results in the ORHASP Report[1], so a separate evaluation is probably not useful.

The main results of a human health risk assessment are values for risks and hazard indices. Related information of interest are values for intake of specific contaminants and the effects that a specific contaminant can have on the human body. The results in most human health risk assessment reports give a limited and uncertain view of the effects of contamination. One set of reasons for these limitations and uncertainties are the uncertainties about "lifestyle", contaminant concentrations, and toxicity.

**Technical Approach**

The approach used to calculate risks and hazard indices is covered in Appendix A. The approach in Appendix A is similar to that presented in Reference 2. In principle human health risk assessments are straightforward multiplication and division of six numbers. In practice such assessments are complicated because of uncertainties in the values of two of these six numbers: concentration and toxicity. Much of what is presented in human health and ecological risk assessment reports are arguments that attempt to justify the values chosen for the six numbers. We do not need such arguments in this report since they have already been presented in the ORHASP Report.

**Measurements**

The amounts of contaminants that traveled through the atmosphere from the Y-12 Plant to the Scarboro Community are relatively accurately known because of the air monitor that was placed in the community in 1986. This belief in the relative accuracy of such results assumes that relevant weather patterns have not changed during the period of interest, 1944 through 1995, and that the amounts of materials released into the air at the Y-12 Plant are known.

Probably every human health or ecological risk assessment should be based on experimental results. The experimental results used can be for the site of interest or for a physically similar site. In the case of interest here, some of these experimental results are the air monitoring results. Theories are useful in human health risk assessments, because they are the basis for models that can be used to expand the usefulness of data. The models used in the ORHASP report for the concentration of contaminants in air are described in References 1 and 3.

**Presentation Concepts**

The results of main interest in the ORHASP Report are values of risk and hazard indices. The main concepts associated with risks and hazard indices values are given in this section. Five concepts are discussed.

**1) The Composition of Air**

Air consists mostly of nitrogen, oxygen, the noble gases, and carbon dioxide. Most of the other components of air are considered to be contaminants. Contaminants are not necessarily toxic.

**2) The Mass of Contaminants in Air**

Values for the mass or concentration of contaminants in the air in the Scarboro Community are given in Appendix B. Appendix B gives a list of contaminants and concentrations. The information in Appendix B was extracted from the ORHASP Report.

**3) The Intake**

The Intake is the mass of contaminant that a population inhales, ingests, or absorbs during a specified time period.

**4) Health Effects**

The Intake-Response function is used when the response of interest to a toxin is cancer and the Hazard Indices are used when the response of interest is non-cancerous.

**a) Intake-Response functions**

The Response to a given Intake of toxin is the fraction of the population that has responded to the specified Intake. The Intake-Response function is covered in Appendices A and B through the Slope Factor.

**b) Hazard Indices**

The hazard index is covered in Appendices A and B through the Reference Dose. Calculated values of the hazard index are given in the Results Section and in Appendix D.

**5) Uncertainties**

There are uncertainties associated with the risk and hazard indices reported in the ORHASP Report. This is the case for any such report. There are uncertainties associated with the air composition, the mass of contaminant in the air, the Intake, and health effects. These uncertainties are summarized below.

**A) Composition**

The composition of the air in the Scarboro community as reported in the ORHASP Report might be incomplete. It is possible that some contaminants that have been used in Oak Ridge are still classified. Relevant information on some of the contaminants is still classified[4]. Such information includes the amounts of some contaminants released.

**B) Mass of Contaminants**

Some contaminants reported in the ORHASP Report have no uncertainties in concentrations given, but such uncertainties always exist. When uncertainties in concentration are given they are used through the Monte Carlo method to deduce the associated uncertainties in risks and hazard indices. The Monte Carlo method is summarized in Reference 5.

**C) Intake**

There are five intake parameters. There are uncertainties associated with all five of these parameters, but the largest uncertainty is associated with contaminant concentrations.

**D) Health effects**

Uncertainties associated with toxicity are usually not incorporated into values of risk and hazard indices. These uncertainties follow.

**a) Uncertainty of Intake-Response Function**

There are three main sources of uncertainties in the Intake-Response function: 1) The variability of the genetics of test animals, 2) The extrapolation of animal data to humans, and 3) The extrapolation from high to low doses.

**b) Uncertainty of the Reference Dose**

Uncertainties of the Reference Dose or threshold of response at high doses are caused by two factors: 1) the variability of the genetics of test animals and 2) The extrapolation of animal data to humans

## II. Method

The Monte Carlo method is used here to determine values for risks and hazard indices. To use the Monte Carlo method a set of intake parameters must be chosen. At least four different sets of intake parameters were used for the air intake rate, for example, in the ORHASP Report[6-13].

The inhalation parameters used were different for iodine-131 and mercury, for example. Deterministic parameters were used for the PCBs and uranium. Probabilistic parameters were used for iodine-131 and mercury. Except for the Inhalation Rate, all intake parameters used here are the same. Different inhalation rates are used for radiation and non-radiation doses. All risk and hazard index calculations here are probabilistic.

The goal of this report is not to reproduce the results for risks and hazard indices given in the ORHASP Report. The goal is to check the statistical accuracy of these values for risks and hazard indices. All of the results for risks and hazard indices are based on statistical quantities. The calculations for risks and hazard indices in the ORHASP Report will be checked only if the statistical agreement between the ORHASP Report results and the results of this report is poor and the reason for the poor agreement is not clear.

## III. Results

Values for risks and hazard indices calculated for this report are compared with the same values in the ORHASP Report. The probable number of cancer cases in the Scarboro Community that resulted from the exposures is given. It is not possible to deduce from the hazard indices the number of persons who had non-cancerous responses. There is not enough toxicological information in the hazard indices to deduce such numbers.

The Exposure Frequency here is about three times longer than the Exposure Frequency used in the ORHASP Report. Also, the Exposure Duration used here is about 20 percent longer than the Exposure Duration used in the ORHASP Report. Risks of this report for uranium are given in Appendix C. The risk associated with each year of exposure is given in Table 5.

**Risks**

Some of the risk values reported here are given in Table 2 below. Other such risk values are given in Appendices C and D.

**Table 1.** Total risks in the ORHASP Report[14]. The material is taken into the body by inhalation only. The number of persons in the population group is assumed to be 6000.

| **Period** | **Human Health reaction** | **Material that Cause the reaction** | **Risk per Person** | **Number of Persons who Reacted** |
|---|---|---|---|---|
| 1944-1995 | Cancer | Uranium | $2.2X10^{-5}$ | 0.1 |
| 1961-1968 | Liver Cancer | PCBs | $1.0X10^{-6}$ | 0.0 |
| 1954-1972 | Lung Cancer | Arsenic | $1.2X10^{-6}$ | 0.0 |
| 1980 | Lung Cancer | Beryllium | $6.9X10^{-9}$ | 0.0 |
| 1956-1984 | Lung Cancer | Chromium (VI) | $1.0X10^{-5}$ | 0.1 |
| 1944-1981 | Lung Cancer | Nickel | $6.1X10^{-6}$ | 0.0 |
| | | | | |

Level I risks are given in Table 6-6 of reference 15. Level II risks are given in Tables 7-9 and 7-10. Only the Level I risk was determined for the Scarboro Community[15]. Level I dose summaries for arsenic, beryllium, chromium (VI), nickel, neptunium-137, and Technitium-99 are given in Appendix I and Table 5-6. Level I and Refined Level I Screening doses for arsenic are given[16] in Table 5-5 of reference 16.

**Table 2.** Total risks of this report. The material is taken into the body by inhalation only. The number of persons in the population group is assumed to be 6000.

| **Period** | **Human Health reaction** | **Material that Cause the reaction** | **Risk per Person** | **Number of Persons who Reacted** |
|---|---|---|---|---|
| 1957-1959 | Cancer | Uranium | $3.2X10^{-5}$ | 0.2 |
| 1961-1968 | Liver Cancer | PCBs | $9.9X10^{-8}$ | 0.0 |
| 1954-1972 | Lung Cancer | Arsenic | $1.3X10^{-5}$ | 0.1 |
| 1980 | Lung Cancer | Beryllium | $2.4X10^{-11}$ | 0.0 |
| 1956-1984 | Lung Cancer | Chromium (VI) | $1.2X10^{-4}$ | 0.7 |
| 1944-1956 | Lung Cancer | Neptunium-237 | $1.4X10^{-10}$ | 0.0 |
| 1944-1981 | Lung Cancer | Nickel | $7.5X10^{-5}$ | 0.5 |
| 1953-1995 | Lung Cancer | Technetium-99 | $2.4X10^{-12}$ | 0.0 |
| | | | | |

**Uranium and Cancer**

The risk for uranium in Table 2 is for persons who lived from 1957 through 1959 in the Scarboro Community. It is not clear which years correspond to the risk from uranium given in the ORHASP Report and in Table 1 above. The ORHASP Report results in Table 1 for cancer risk seem to be the sum of the risk for the years from 1944 to 1995. The risk of cancer given in this report from the intake of uranium in the Scarboro Community is larger by a factor of three than that reported in the ORHASP Report. Note that the results in Table 2 for uranium are for a period of only three years. Summing over all 42 years would probably double the value in Table 2.

**PCBs and Liver Cancer**

The risk of lung cancer from the intake of PCBs in the Scarboro Community is smaller by a factor of about ten than that reported in the ORHASP Report. It is not clear why the risk of lung cancer from PCBs reported here is smaller than that reported in the ORHASP Report. Because of the larger exposure frequency and exposure duration used to obtain the results of this report, the risk here should be about four times bigger than that in the ORHASP Report.

**Arsenic and Liver Cancer**

The risk of developing liver cancer for inhaling arsenic for residents of the Scarboro Community was about ten times that reported in the ORHASP Report. This is expected from the differences in exposure frequency, exposure duration, and inhalation rates used.

**Beryllium and Liver Cancer**

The risk of developing liver cancer from inhaling beryllium for residents of the Scarboro Community was about 300 times higher in the ORHASP Report than that reported here. It is not clear why the risk in the ORHASP Report is higher. The difference must have been caused by differences in concentration and Slope Factor, but this should not be the case since the concentration and Slope Factor used here are those given in the ORHASP Report.

**Chromium (VI) and Liver Cancer**

The risk of developing liver cancer from inhaling chromium (VI) for residents of the Scarboro Community is about ten times that reported in the ORHASP Report. This difference is expected from the differences in exposure frequency, exposure duration, and inhalation rates used.

**Nickel and Liver Cancer**

The risk of developing liver cancer from inhaling nickel for residents of the Scarboro Community reported here is about ten times that reported in the ORHASP Report. This difference is expected from the differences in exposure frequency, exposure duration, and inhalation rate used here.

**Technetium-99 and Liver Cancer**

The risk of developing liver cancer from inhaling technetium-99 was not reported in the ORHASP Report. The risk from technetium-99 reported in the ORHASP Report is the sum of the risks for the inhalation and ingestion of technetium-99.

**Hazard Indices**

The hazard indices reported here are given in Table 4 below.

**Table 3.** Hazard Indices in the ORHASP Report. The material considered is that taken into the body by inhalation only.

| Period | Human Health Reaction | Material that Cause the reaction | Hazard Index |
|---|---|---|---|
| 1961-1968 | Immune Deficiency | PCBs | 0.04 |
| 1954-1972 | Neurological Effects | Arsenic | $1.2X10^{-6}$ |
| 1955 | Neurological Effects | Mercury | 2.5th percentile=0.033<br>97.5th percentile=0.67 |
| 1955 | Neurological Effects | Lithium | $6.0X10^{-5}$ |
| 1980 | Respiratory Disorders | Beryllium | $6.9X10^{-9}$ |
| 1956-1984 | Respiratory Disorders | Chromium (VI) | 0.21 |
| | | | |

Inhalation hazard indices for uranium are not given in the ORHASP Report[17]. Level I hazard indices of the PCBs are given in Table 6-6. Level II risks are given in Tables 7-9 and 7-10. Only the Level I hazard index was determined for the Scarboro Community[18]. The hazard index for uranium was read from the graph[19] in Figure ES-5 of reference 19.

Level I dose summaries for arsenic are given in Appendix I and Table 5-6 of reference 20. Level I and Refined Level I Screening doses for arsenic are given[20] in Table 5-5. Hazard indices for elemental mercury were obtained from Table 12-3 or Volume 2 of the ORHASP Report[21]. Level I dose summaries for lithium are given[22] on page 5-68 of reference 22. Level I dose summaries for beryllium is given[23] on pages 5-28 and 5-29 of reference 23. Level I dose summaries for chromium (VI) is given[24] on pages 5-54 and 5-55 of reference 24.

**Table 4.** Hazard Indices of this report. The material considered is that taken into the body by inhalation only.

| Period | Human Health Reaction | Material that Cause the reaction | Hazard Index |
|---|---|---|---|
| 1961-1968 | Immune Deficiency | PCBs | 0.020 |
| 1944 | Kidney Disorders | Uranium | $5.7X10^{-4}$ |
| 1954-1972 | Neurological Effects | Arsenic | - |
| 1950-1959 | Neurological Effects | Mercury | 2.5th percentile=$1.0X10^{-4}$<br>97.5th percentile=0.97 |
| 1980-1990 | Neurological Effects | Mercury | 2.5th percentile=$1.4X10^{-5}$<br>97.5th percentile=$9.7X10^{-4}$ |
| 1955 | Neurological Effects | Lithium | $1.7X10^{-4}$ |
| 1944-1981 | Non-Carcinogenic Effects | Nickel | $2.4X10^{-2}$ |
| 1980 | Respiratory Disorders | Beryllium | $7.5X10^{-9}$ |
| 1956-1984 | Respiratory Disorders | Chromium (VI) | 0.58 |

No inhalation reference dose for arsenic is given in the ORHASP Report.

**PCBs and Immune Deficiency**

The hazard index for immune deficiency from the inhalation of PCBs given here is one half as large as that given in the ORHASP Report. From the exposure frequency, exposure duration, and inhalation rate used in the calculations, the hazard index reported here was expected to be about four times as big as that given in the ORHASP Report.

**Uranium and Kidney Disorders**

A hazard index for kidney disorder from the inhalation of uranium is not given in the ORHASP Report.

**Arsenic and Neurological Effects**

No Reference Dose for arsenic was presented in the ORHASP Report.

**Mercury and Neurological Effects**

The hazard indices for mercury presented here and those in the ORHASP Report are in good agreement.

**Lithium and Neurological Effects**

The hazard index for neurological effects from the inhalation of lithium reported here and that in the ORHASP Report are within a factor of three of each other. The hazard index reported here is larger than that reported in the ORHASP Report.

**Beryllium and Respiratory Disorders**

The agreement between the hazard index for respiratory disorders from the inhalation of beryllium given in this report and that given in the ORHASP Report is good.

**Chromium (VI) and Respiratory Disorders**

The hazard index for respiratory disorder from the inhalation of chromium (VI) given in this report is about three times larger than that given in the ORHASP Report.

## IV. Conclusions

The risks and hazard indices found in this report are about four times larger than the risks and hazard indices presented in the ORHASP Report or they are smaller than the values in the ORHASP Report. The risks and hazard indices reported here are about four times the size of the risks and hazard indices reported in the ORHASP Report, because the product of exposure frequency, exposure duration, and inhalation rate is about four times those used in the ORHASP Report. It is not clear why some values of risks in the ORHASP Report are larger than the corresponding risks presented here. Perhaps different values of the slope factors and concentrations were used in the two reports. For this report, we used the values of slope factors and concentrations that were supposedly used in the ORHASP Report.

Some significant conclusions, observations, and questions about the ORHASP Report follow:

1) The concentration of elemental mercury was very high in the 1950s and 1960s.

2) Perhaps a further study of uranium exposure is desirable. The further study risk limit is $1.0X10^{-4}$. The risk limit estimated in Scarboro is $0.83X10^{-4}$ in the ORHASP Report.

3) Did the population of Scarboro ever exceed 1200? Is the number of persons who have ever lived in the Scarboro Community in the range 6000 to 10,000?

4) Four different sets of intake parameters were used in the ORHASP Report. It is not clear why more than one set was used, except in the case of iodine-131 where the toxicity is a function of the age of the exposed person.

## Appendix A: Scarboro Study Technical Approach

### Atmospheric Transport

The data to be analyzed and the methods to be used in the analysis were presented in the ORHASP Report. The goal of the study described in this report was to determine the effects on the health of the residents of the Scarboro Community caused by atmospheric contaminants from the three United States Department of Energy plants in Oak Ridge, Tennessee.

The ORHASP Report presents a list of contaminants and the amount of a number of contaminants emitted from 1941 to 1995. The formula used to determine the atmospheric concentrations in Scarboro during the entire period is based on measurements of uranium concentrations from 1986 to 1995 and the amount of contaminants emitted during this period. The ratio between the amount emitted and the concentration measured in Scarboro was used to determine concentrations in years for which there were no measurements and also to determine the concentrations of contaminants for which there are no measurements.

The Pasquill-Gifford model relates the emission rate at a source to the concentration at a specific location from the source. This concentration ratio depends on the direction of the wind relative to the location of interest and on the amount of atmospheric turbulence.

A good way to use this method for prediction of atmospheric concentrations is to develop a probability distribution model for the ratio. This was done in the ORHASP Report. A 95% confidence limit for the ratio was used in calculations.

### Risk and Hazard Index

The crucial variable to determine for risk as defined in the ORHASP Report is the intake for each substance:

$$Intake = \frac{C\ X\ ED\ X\ EF\ X\ (IR/BW)}{AT}$$

For radiation the intake is

$$Intake = C\ X\ ED\ X\ EF\ X\ IR$$

The quantities BW, C, ED, and EF are probability distributions and should be treated as such. The IR should be a function of age and BW. Here AT is the averaging time in units of days, BW is the body mass in units of kilograms, C is the contaminant concentration in units of mass per cubic meter, ED is the exposure duration in units of years, EF is the yearly exposure frequency in units of days per year, and IR is the inhalation rate in units of cubic meters per day.

For carcinogens AT=(70 yearsX365 days/year). For non-carcinogenic responses, AT=ED. The non-carcinogen AT is only valid for determining hazard indices. For hazard indices AT is usually taken to be 365 days.

For non-carcinogenic responses, the intake is the yearly dose if EF is constant. For carcinogenic responses, the intake is the average yearly dose, since ED is often not equal to AT.

The intake formula that should be used is

$$Intake = \sum_i \frac{C_i \ X \ ED_i \ X \ EF_i \ X \ (IR/BW)}{AT}$$

where

$$AT = \sum_i ED_i$$

for non-carcinogens. Here the summation variable i denotes the year or month and $ED_i$ = 1 year or $ED_i$=(1/12) year. For radiation the intake formula that should be used is

$$Intake = \sum_i \sum_j Intake_{i,j} = \sum_i \sum_j C_i \ X \ ED_i \ X \ EF_i \ X \ IR_j$$

where $IR_j$ is the inhalation rate for human being of age j. It is assumed that ($IR_j$/$BW_j$) is independent of j here.

The risk for the total population may be expressed as

$$risk = Intake \ X \ Slope \, Factor \ X \ Population \, size$$

The $BW_i$, $C_i$, $ED_i$, and $EF_i$ are for the entire population under consideration whether or not the population as a whole was exposed. The factors $ED_i$ and $EF_i$ account for the degree of exposure of the whole population.

Both deterministic and probabilistic risks will be determined. The Slope Factors and Reference Doses used will be taken either from the Integrated Risk Information System (IRIS) Database or the ORHASP Report.

The risk is computed for given intervals of time. The total risk is the sum over intervals of time. The quantity $Intake_i$ was used where

$$Intake_i = \frac{C_i \ X \ ED_i \ X \ EF_i \ X \ (IR/BW)}{AT}$$

$$Intake = \sum_i Intake_i$$

and for radiation

$$Intake_{i,j} = C_i \ X \ ED_i \ X \ EF_i \ X \ IR_j$$

and

$$Intake = \sum_i \sum_j Intake_{i,j}$$

These forms of the risk expression were used in the ORHASP Report. The risk associated with a particular population distribution is

$$risk = \left( \sum_i \left[ Intake_i \ X \ population_i \right] \right) X \ Slope \ factor$$

The Hazard Index for a particular population distribution is

$$Hazard \ index_i = \frac{Intake_i}{RfD}$$

where RfD denotes the Reference Dose.  The Hazard index for the total population is

$$Hazard \ index = \sum_i \ Hazard \ index_i = \sum_i \ \frac{Intake_i}{RfD}$$

Here $population_i$ is the population during year or month i.  The formula above for risk is based on the assumption that a specified dose has a given chance of inducing a response. It does not matter how the dose is distributed among the organisms.  For iodine-131 the slope factor is a function of the age at which a person is exposed, so the formula above for risk must be modified for iodine-131:

$$risk = \sum_i \ \sum_j \ \left[ Intake_{i,j} \ X \ population_i \, X \ Slope \ factor_j \right] = \sum_i \ \sum_j \ risk_{i,j}$$

where j is the slope factor for a human being of age j and

$$risk_{i,j} \ = Intake_{i,j} \ X \ population_i \, X \ Slope \ factor_j$$

**Appendix B: Tool for Human Health Risk Assessment**

**A) List of Chemicals of Concern**

| |
|---|
| Arsenic, Asbestos, Beryllium, Copper, Chromium (hexavalent), Iodine-131 (elemental), Iodine-131 (inorganic), Iodine-131 (particulate), Lead, Lithium, Mercury (elemental), Mercury (inorganic), Mercury (methyl), Mercury (particulate), Neptunium-237, Nickel, Niobium, Plutonium, PCBs, Technetium-99, Tetramethyl-ammonium borohydride, Tritium, Uranium, Zirconium |

It is not clear if all of the toxic materials used in Oak Ridge that should be of concern are in the list above. Mention is made in the report of "the highly acidic nature of sampled gas streams". The size range for most uranium particles was 0.05 to 5 micrometers[25].

For Task 7 chemicals of concern, "If, in the future, more extensive document searching is performed, some of the conclusions reached in this screening evaluations described herein might well change." The Screening-Level Evaluation indicated that arsenic and lead should be further studied[26].

**B) Concentrations of Materials of Concern**

The airborne model used to estimate concentrations in the Scarboro Community is summarized in Table 2-1 of reference 27 and 28. Information on the concentration in air of most of the material of concern are given in the rest of this section.

**Material of concern**: Arsenic[29]
**Medium:** Air

| **Period** | **Probability Distribution** | **Distribution Parameters** |
|---|---|---|
| 1954 - 1972 | Point | $1.7X10^{-5}$ mg/m$^3$ |
| | | |

**Material of concern**: Asbestos[30]
**Medium:** Air

| **Period** | **Probability Distribution** | **Distribution Parameters** |
|---|---|---|
| 1942 - 1999 | Point | 0 fibers/m$^3$ |
| | | |

**Material of concern**: Beryllium[31]
**Medium:** Air

| **Period** | **Probability Distribution** | **Distribution Parameters** |
|---|---|---|
| 1980 | Point | $4.7X10^{-11}$ mg/m$^3$ |
| | | |

**Material of concern**: Chromium (VI)
**Medium:** Air

| **Period** | **Probability Distribution** | **Distribution Parameters** |
|---|---|---|
| 1956-1984 | Point | $5X10^{-5}$ mg/m$^3$ |
| | | |

The concentration for hexavalent chromium was computed for one location and apparently used at all other locations in the Oak Ridge area[32].

**Material of concern:** Iodine-131 (See Reference 33)
**Medium:** Air

| **Period** | **Probability Distribution** | **Distribution Parameters** |
|---|---|---|
| 1944 - 1956 | Statistical | Central=0.060 Bequerel/m$^3$<br>2.5th percentile=0.041 Bequerel/m$^3$<br>97.5th percentile=0.089 Bequerel/m$^3$ |
| | | |

Iodine-131 concentrations during the April 29, 1954 accident were studied using the mathematical model SORAMI[34]. Annual iodine-131 releases in Oak Ridge from 1944 to 1956 are given[35] in Tables 3.15 and 3.16 of reference 35. The iodine-131 release during the April 29, 1954 accident is given[36] in Table 3.17. Inhalation of Iodine-131 is considered to be an exposure pathway for iodine-131 of secondary importance[37].

The annual average ground level concentration of iodine-131 was obtained using iodine-131 release data, weather data, and the SORAMI model. The concentration was taken[38] from Figure 4.9. The indoor and outdoor air concentration ratio probability distribution functions are given[39] in Figure 8.11.

**Material of concern:** Lead[40]
**Medium:** Air

| **Period** | **Probability Distribution** | **Distribution Parameters** |
|---|---|---|
| 1955 | Point | $1.200X10^{-3}$ mg/m$^3$ |
| | | |

**Material of concern:** Lithium[41]
**Medium:** Air (outdoor, gas plus particulate bounded)

| **Period** | **Probability Distribution** | **Distribution Parameters** |
|---|---|---|
| 1955 | Point | $1.70X10^{-4}$ mg/m$^3$ |
| | | |

**Material of concern**: Mercury (elemental)
**Medium:** Air

| Period | Probability Distribution | Distribution Parameters |
|---|---|---|
| 1950 - 1959 | Statistical | 2.5th percentile=$2.8X10^{-8}$ mg/m$^3$<br>97.5th percentile=$2.60X10^{-4}$ mg/m$^3$ |
| 1960 - 1969 | Statistical | 2.5th percentile=$1.5X10^{-8}$ mg/m$^3$<br>97.5th percentile=$2.6X10^{-5}$ mg/m$^3$ |
| 1970 - 1979 | Statistical | 2.5th percentile=$2.1X10^{-9}$ mg/m$^3$<br>97.5th percentile=$6.1X10^{-6}$ mg/m$^3$ |
| 1980 - 1990 | Statistical | 2.5th percentile=$3.8X10^{-9}$ mg/m$^3$<br>97.5th percentile=$2.6X10^{-7}$ mg/m$^3$ |
| | | |

Table W-2 of reference 42 presents estimated annual average daily mercury doses to residents of the Scarboro Community from 1950 through 1990. Concentrations of mercury in Scarboro were determined by using results of airborne uranium measurements in Scarboro[42].

**Material of concern:** Neptunium-237 (See Reference 43)
**Medium:** Air (indoor, particulate bounded)

| Period | Probability Distribution | Distribution Parameters |
|---|---|---|
| 1944 - 1956 | Point | $6.6X10^{-7}$ pCurie/m$^3$ |
| | | |

**Material of concern**: Nickel
**Medium:** Air

| Period | Probability Distribution | Distribution Parameters |
|---|---|---|
| 1944-1981 | Point | $1.5X10^{-3}$ mg/m$^3$ |
| | | |

The concentration for nickel was computed for one location and apparently used at all other locations in the Oak Ridge area[44].

**Material of concern:** PCBs
**Medium:** Air

| Period | Probability Distribution | Distribution Parameters |
|---|---|---|
| 1961-1968 | Point | $4.1X10^{-6}$ mg/m$^3$ |
| | | |

It is possible that PCBs were present in the air in Scarboro during various time periods, but concentrations were not estimated. PCBs in the air in Oak Ridge from the Y-12 plant mostly likely resulted from the burning of oil that contained PCBs. At the K-25 site, it is likely that PCBs escaped into the air by vaporizing. PCBs may have entered the air at K-25 from the Toxic Substances Control Act (TSCA) Incinerator there[45].

No inhalation pathway was included in the Level II Risk Evaluation[46]. The air concentration of PCBs was modeled using the computer software package[47] SCREEN3. Level II concentrations are given in Table 7-7 of reference 48.

**Material of concern:** Technetium-99 (See Reference 49)
**Medium:** Air (indoor, particulate bounded)

| **Period** | **Probability Distribution** | **Distribution Parameters** |
|---|---|---|
| 1953 - 1995 | Point | $5.9X10^{-6}$ pCurie/$m^3$ |
| | | |

**Material of concern:** Tritium[50]
**Medium:** Air

| **Period** | **Probability Distribution** | **Distribution Parameters** |
|---|---|---|
| 1955 - 1995 | Point | 0 mg/$m^3$ |
| | | |

**Material of concern:** Uranium
**Medium:** Air

| **Period** | **Probability Distribution** | **Distribution Parameters** Uranium-234/235, femtoCurie/$m^3$ | **Distribution Parameters** Uranium-238, femtoCurie/$m^3$ |
|---|---|---|---|
| 1944 | Point | 2.4 | 1.1 |
| 1945 | Point | 4.0 | 2.2 |
| 1946 | Point | 3.0 | 1.3 |
| 1947 | Point | 2.5 | 0.81 |
| 1948 | Point | 1.6 | 2.1 |
| 1949 | Point | 1.6 | 2.1 |
| 1950 | Point | 1.6 | 2.1 |
| 1951 | Point | 1.6 | 2.1 |
| 1952 | Point | 1.6 | 2.1 |
| 1953 | Point | 6.5 | 13 |
| 1954 | Point | 5.6 | 12 |
| 1955 | Point | 5.7 | 12 |
| 1956 | Point | 31 | 10 |
| 1957 | Point | 56 | 7.8 |
| 1958 | Point | 170 | 17 |
| 1959 | Point | 120 | 19 |
| 1960 | Point | 24 | 3.0 |
| 1961 | Point | 38 | 4.2 |
| 1962 | Point | 41 | 4.5 |
| 1963 | Point | 20 | 6.8 |
| 1964 | Point | 6.5 | 8.8 |
| 1965 | Point | 33 | 2.0 |
| 1966 | Point | 11 | 3.0 |
| 1967 | Point | 4.9 | 1.1 |
| 1968 | Point | 2.2 | 1.4 |
| 1969 | Point | 9.4 | 0.77 |
| 1970 | Point | 15 | 0.91 |
| 1971 | Point | 20 | 1.8 |
| 1972 | Point | 36 | 2.7 |
| 1973 | Point | 31 | 1.2 |
| 1974 | Point | 2.7 | 0.67 |
| 1975 | Point | 5.0 | 0.67 |
| 1976 | Point | 3.2 | 0.67 |
| 1977 | Point | 1.6 | 0.67 |
| 1978 | Point | 1.7 | 0.67 |
| 1979 | Point | 2.3 | 0.67 |
| 1980 | Point | 4.6 | 0.71 |
| 1981 | Point | 2.8 | 0.67 |
| 1982 | Point | 4.7 | 0.66 |
| 1983 | Point | 4.0 | 0.67 |
| 1984 | Point | 3.4 | 1.1 |
| 1985 | Point | 2.7 | 0.68 |
| 1986 | Point | 3.4 | 0.69 |
| 1987 | Point | 5.7 | 0.48 |
| 1988 | Point | 2.9 | 0.47 |
| 1989 | Point | 1.4 | 0.024 |
| 1990 | Point | 0.77 | 0.014 |
| 1991 | Point | 0.38 | 0.063 |
| 1992 | Point | 0.36 | 0.022 |
| 1993 | Point | 0.29 | 0.0093 |
| 1994 | Point | 0.31 | 0.078 |
| 1995 | Point | 0.17 | 0.0055 |
| | | | |

A database of 1200 documented uranium releases is available. Annual uranium releases from the Y-12 Plant are presented in Tables ES-1 and 2-1 of reference 51. For uranium releases from the Y-12 Complex, the Scarboro Community was selected to be the reference location. Annual uranium releases from the K-25/S-50 Complex are presented in Tables ES-2, 2-5, 2-6, and 2-7. "The data that are currently available are not sufficient to support a defensible analysis of average or typical exposures to members of the Scarboro community from the community's inception to the present. The data used to develop the $\chi/Q$ approoach for estimating air concentrations of contaminants from the Y-12 plant in the Scarboro community may have caused the concentration in the Scarboro community to be overestimated. It was recommended that further work be done on evaluating the effects of ridges and valleys on the flow of air from Y-12 to the Scarboro community, finding additional monitoring data, and evaluating uncertainties in concentration estimates further." The "largest, single source of uncertainty in estimating uranium releases are unmonitored releases that occurred from 1943 through the 1970s." Appendix I discusses the quality of the Scarboro Air Monitoring data[51].

Uranium air concentrations are presented in Tables 3-9 through 3-15. Air exposure pathways for uranium are given[52] in Table 4-1.

**C) List of Human Health Reactions of Concern**

| |
|---|
| Acne, Anemia, Cancer, Immune deficiency, Kidney disorders, Liver cancer, Lung cancer, Neurological effects, Non-neoplastic abnormalities, Respiratory disorders, Thyroid cancer |

The non-carcinogenic toxicity of PCBs depends on the degree of chlorination of the PCB mixture[53].

**D) Human Health Reactions of Each Material of Concern**

| **Human Health Reaction** | **Materials that Cause the Reaction** |
|---|---|
| Acne | PCBs |
| Anemia | PCBs |
| Cancer | Uranium |
| Immune deficiency | PCBs |
| Kidney disorders | Mercury (Inorganic), Uranium |
| Liver cancer | PCBs |
| Lung cancer | Arsenic, Beryllium, Chromium (hexavalent), Neptunium-237, Nickel, Technetium-99 |
| Neurological effects | Arsenic, Mercury (Elemental and Methyl), Lithium |
| Non-neoplastic abnormalities | Iodine-131 |
| Respiratory disorders | Beryllium, Chromium (hexavalent) |
| Thyroid cancer | Iodine-131 |
| | |

Kidney disorders are associated with inorganic mercury[54]. Kidney disorders are also associated with uranium exposure[55]. Toxic effects associated with the inhalation of arsenic[56], beryllium[57], hexavalent chromium[58], and lithium[59] are discussed.

**E) Slope Factor or Threshold for Each Human Health Reaction and for Each Material of Concern**

References doses for copper, lithium, niobium, and zirconium are not available. Reference doses for copper, niobium, and zirconium were determined by the Task 7 Team. The slope factor for all radionuclides was assumed[60] to be 0.073/Sievert.

The IEUBK pharmacokinetics model for lead assessment was used to estimate the concentration of lead in blood. "USEPA guidelines for evaluating lead exposure advocate the use of the IEUBK model" rather than a Reference Dose. The average background lead concentration in urban areas of the United States was used for the Scarboro Community[61].

**Reaction:** Cancer[62]
**Pathway:** Inhalation

| **Material** | **Response Characteristic** | **Characteristic Value** |
|---|---|---|
| Uranium-234/235 | Dose Conversion Factor | $9.4X10^{-6}$ Sievert/Bequerel |
| Uranium-234/235 | Slope Factor | 0.073/Sievert |
| Uranium-238 | Dose Conversion Factor | $8.0X10^{-6}$ Sievert/Bequerel |
| Uranium-238 | Slope Factor | 0.073/Sievert |
| | | |

**Reaction:** Immune Deficiency
**Pathway:** Inhalation

| **Material** | **Response Characteristic** | **Characteristic Value** |
|---|---|---|
| PCB (aroclor) | Reference Dose | $7X10^{-5}$ mg/(kg-day) |
| | | |

The Reference Dose[63] used for the PCBs is that for aroclor 1254.

**Reaction:** Kidney Disorder
**Pathway:** Inhalation

| **Material** | **Response Characteristic** | **Characteristic Value** |
|---|---|---|
| Uranium | Reference Dose | 0.003 mg/(kg-day) |
| | | |

Uranium toxicity is evaluated in Appendix M[64-65] of reference 64.

**Reaction:** Liver Cancer
**Pathway:** Inhalation

| Material | Response Characteristic | Characteristic Value |
|---|---|---|
| PCBs | Slope Factor | 0.4 (kg-day)/mg |
| | | |

A slope factor of 2 (kg-day)/mg was used in Level I studies. The Reference Dose[66] is for aroclor 1254.

**Reaction:** Lung cancer
**Pathway:** Inhalation

| Material | Response Characteristic | Characteristic Value |
|---|---|---|
| Arsenic | Slope factor | 15 (kg-day)/mg |
| Beryllium | Slope factor | 8.4 (kg-day)/mg |
| Chromium (hexavalent) | Slope factor | 42 (kg-day)/mg |
| Neptunium-237 | Dose Conversion factor | $2.30X10^{-5}$ Sievert/Bequerel |
| Neptunium-237 | Slope factor | 0.073 /Sievert |
| Nickel | Slope factor | 0.84 (kg-day)/mg |
| Technetium-99 | Dose Conversion factor | $4.00X10^{-9}$ Sievert/Bequerel |
| Technetium-99 | Slope factor | 0.073 /Sievert |
| | | |

Toxicity values for arsenic[67], beryllium[67], hexavalent chromium[68], neptunium-237 (reference 69), nickel[70], andtechnetium-99 (reference 71) were discussed.

**Reaction:** Neurological effects
**Pathway:** Inhalation

| Material | Response Characteristic | Characteristic Value |
|---|---|---|
| Lithium | Reference Dose | 0.33 mg/(kg-day) |
| Mercury (elemental, methyl) | Reference Dose | $8.6X10^{-5}$ mg/(kg-day) |
| | | |

There is no definitive data that suggests "that any form of mercury is carcinogenic through any route of exposure". The Exposure Duration and Averaging Time are both one year. So, these factors cancel in the intake formula[72]. The toxicity of lithium is discussed[73].

**Reaction:** Non-carcinogenic effects
**Pathway:** Inhalation

| **Material** | **Response Characteristic** | **Characteristic Value** |
|---|---|---|
| Nickel | Reference Dose | $2.0X10^{-2}$ mg/(kg-day) |
| | | |

Toxicity values for nickel were discussed[74].

**Reaction:** Respiratory Disorders
**Pathway:** Inhalation

| **Material** | **Response Characteristic** | **Characteristic Value** |
|---|---|---|
| Beryllium | Reference Dose | $2.0X10^{-3}$ mg/(kg-day) |
| Chromium (hexavalent) | Reference Dose | $2.9X10^{-5}$ mg/(kg-day) |
| | | |

Toxicity values for beryllium were discussed[75]. Toxicity values for hexavalent chromium were discussed[76].

**Reaction:** Thyroid Cancer, Non-neoplastic abnoramlities (female)
**Pathway:** Inhalation

| **Material** | **Age in Years** | **Response Characteristic** | **Characteristic Value** |
|---|---|---|---|
| Iodine-131 | 1 | Dose Conversion Factor | $2.4X10^{-6}$ Gray/Bequerel |
| Iodine-131 | 1 | Slope Factor | $3.0X10^{-2}$ 1/Gray |
| Iodine-131 | 2 | Dose Conversion Factor | $2.5X10^{-6}$ Gray/Bequerel |
| Iodine-131 | 2 | Slope Factor | $3.0X10^{-2}$ 1/Gray |
| Iodine-131 | 3 | Dose Conversion Factor | $2.1X10^{-6}$ Gray/Bequerel |
| Iodine-131 | 3 | Slope Factor | $3.0X10^{-2}$ 1/Gray |
| Iodine-131 | 4 | Dose Conversion Factor | $2.2X10^{-6}$ Gray/Bequerel |
| Iodine-131 | 4 | Slope Factor | $3.0X10^{-2}$ 1/Gray |
| Iodine-131 | 5 | Dose Conversion Factor | $1.8X10^{-6}$ Gray/Bequerel |
| Iodine-131 | 5 | Slope Factor | $1.5X10^{-2}$ 1/Gray |
| Iodine-131 | 6 | Dose Conversion Factor | $1.6X10^{-6}$ Gray/Bequerel |
| Iodine-131 | 6 | Slope Factor | $1.5X10^{-2}$ 1/Gray |
| Iodine-131 | 7 | Dose Conversion Factor | $1.5X10^{-6}$ Gray/Bequerel |
| Iodine-131 | 7 | Slope Factor | $1.5X10^{-2}$ 1/Gray |
| Iodine-131 | 8 | Dose Conversion Factor | $1.4X10^{-6}$ Gray/Bequerel |
| Iodine-131 | 8 | Slope Factor | $1.5X10^{-2}$ 1/Gray |
| Iodine-131 | 9 | Dose Conversion Factor | $1.4X10^{-6}$ Gray/Bequerel |
| Iodine-131 | 9 | Slope Factor | $1.5X10^{-2}$ 1/Gray |
| Iodine-131 | 10 | Dose Conversion Factor | $1.3X10^{-6}$ Gray/Bequerel |
| Iodine-131 | 10 | Slope Factor | $6.7X10^{-3}$ 1/Gray |
| Iodine-131 | 11 | Dose Conversion Factor | $1.3X10^{-6}$ Gray/Bequerel |
| Iodine-131 | 11 | Slope Factor | $6.7X10^{-3}$ 1/Gray |
| Iodine-131 | 12 | Dose Conversion Factor | $1.1X10^{-6}$ Gray/Bequerel |
| Iodine-131 | 12 | Slope Factor | $6.7X10^{-3}$ 1/Gray |
| Iodine-131 | 13 | Dose Conversion Factor | $9.8X10^{-7}$ Gray/Bequerel |
| Iodine-131 | 13 | Slope Factor | $6.7X10^{-3}$ 1/Gray |
| Iodine-131 | 14 | Dose Conversion Factor | $7.3X10^{-7}$ Gray/Bequerel |
| Iodine-131 | 14 | Slope Factor | $6.7X10^{-3}$ 1/Gray |
| Iodine-131 | 15 | Dose Conversion Factor | $7.0X10^{-7}$ Gray/Bequerel |
| Iodine-131 | 15 | Slope Factor | $8.8X10^{-4}$ 1/Gray |
| Iodine-131 | 16 | Dose Conversion Factor | $6.5X10^{-7}$ Gray/Bequerel |
| Iodine-131 | 16 | Slope Factor | $8.8X10^{-4}$ 1/Gray |
| Iodine-131 | 17 | Dose Conversion Factor | $5.9X10^{-7}$ Gray/Bequerel |
| Iodine-131 | 17 | Slope Factor | $8.8X10^{-4}$ 1/Gray |
| Iodine-131 | 18 | Dose Conversion Factor | $5.4X10^{-7}$ Gray/Bequerel |
| Iodine-131 | 18 | Slope Factor | $8.8X10^{-4}$ 1/Gray |
| Iodine-131 | 19 | Dose Conversion Factor | $4.9X10^{-7}$ Gray/Bequerel |
| Iodine-131 | 19 | Slope Factor | $8.8X10^{-4}$ 1/Gray |
| Iodine-131 | 20 - 29 | Dose Conversion Factor | $4.4X10^{-7}$ Gray/Bequerel |
| Iodine-131 | 20 - 29 | Slope Factor | $4.7X10^{-4}$ 1/Gray |
| Iodine-131 | 30 - 39 | Dose Conversion Factor | $4.4X10^{-7}$ Gray/Bequerel |
| Iodine-131 | 30 - 39 | Slope Factor | $3.4X10^{-4}$ 1/Gray |
| | | | |

**Reaction:** Thyroid Cancer (male)
**Pathway:** Inhalation

| Material | Age in Years | Response Characteristic | Characteristic Value |
|---|---|---|---|
| Iodine-131 | 1 | Dose Conversion Factor | $2.4X10^{-6}$ Gray/Bequerel |
| Iodine-131 | 1 | Slope Factor | $7.6X10^{-3}$ 1/Gray |
| Iodine-131 | 2 | Dose Conversion Factor | $2.5X10^{-6}$ Gray/Bequerel |
| Iodine-131 | 2 | Slope Factor | $7.6X10^{-3}$ 1/Gray |
| Iodine-131 | 3 | Dose Conversion Factor | $2.1X10^{-6}$ Gray/Bequerel |
| Iodine-131 | 3 | Slope Factor | $7.6X10^{-3}$ 1/Gray |
| Iodine-131 | 4 | Dose Conversion Factor | $2.2X10^{-6}$ Gray/Bequerel |
| Iodine-131 | 4 | Slope Factor | $7.6X10^{-3}$ 1/Gray |
| Iodine-131 | 5 | Dose Conversion Factor | $1.8X10^{-6}$ Gray/Bequerel |
| Iodine-131 | 5 | Slope Factor | $3.9X10^{-3}$ 1/Gray |
| Iodine-131 | 6 | Dose Conversion Factor | $1.6X10^{-6}$ Gray/Bequerel |
| Iodine-131 | 6 | Slope Factor | $3.9X10^{-3}$ 1/Gray |
| Iodine-131 | 7 | Dose Conversion Factor | $1.5X10^{-6}$ Gray/Bequerel |
| Iodine-131 | 7 | Slope Factor | $3.9X10^{-3}$ 1/Gray |
| Iodine-131 | 8 | Dose Conversion Factor | $1.4X10^{-6}$ Gray/Bequerel |
| Iodine-131 | 8 | Slope Factor | $3.9X10^{-3}$ 1/Gray |
| Iodine-131 | 9 | Dose Conversion Factor | $1.4X10^{-6}$ Gray/Bequerel |
| Iodine-131 | 9 | Slope Factor | $3.9X10^{-3}$ 1/Gray |
| Iodine-131 | 10 | Dose Conversion Factor | $1.3X10^{-6}$ Gray/Bequerel |
| Iodine-131 | 10 | Slope Factor | $1.5X10^{-3}$ 1/Gray |
| Iodine-131 | 11 | Dose Conversion Factor | $1.3X10^{-6}$ Gray/Bequerel |
| Iodine-131 | 11 | Slope Factor | $1.5X10^{-3}$ 1/Gray |
| Iodine-131 | 12 | Dose Conversion Factor | $1.1X10^{-6}$ Gray/Bequerel |
| Iodine-131 | 12 | Slope Factor | $1.5X10^{-3}$ 1/Gray |
| Iodine-131 | 13 | Dose Conversion Factor | $9.8X10^{-7}$ Gray/Bequerel |
| Iodine-131 | 13 | Slope Factor | $1.5X10^{-3}$ 1/Gray |
| Iodine-131 | 14 | Dose Conversion Factor | $7.3X10^{-7}$ Gray/Bequerel |
| Iodine-131 | 14 | Slope Factor | $1.5X10^{-3}$ 1/Gray |
| Iodine-131 | 15 | Dose Conversion Factor | $7.0X10^{-7}$ Gray/Bequerel |
| Iodine-131 | 15 | Slope Factor | $2.2X10^{-4}$ 1/Gray |
| Iodine-131 | 16 | Dose Conversion Factor | $6.5X10^{-7}$ Gray/Bequerel |
| Iodine-131 | 16 | Slope Factor | $2.2X10^{-4}$ 1/Gray |
| Iodine-131 | 17 | Dose Conversion Factor | $5.9X10^{-7}$ Gray/Bequerel |
| Iodine-131 | 17 | Slope Factor | $2.2X10^{-4}$ 1/Gray |
| Iodine-131 | 18 | Conversion Dose Factor | $5.4X10^{-7}$ Gray/Bequerel |
| Iodine-131 | 18 | Slope Factor | $2.2X10^{-4}$ 1/Gray |
| Iodine-131 | 19 | Conversion Dose Factor | $4.9X10^{-7}$ Gray/Bequerel |
| Iodine-131 | 19 | Slope Factor | $2.2X10^{-4}$ 1/Gray |
| Iodine-131 | 20 - 29 | Conversion Dose Factor | $4.4X10^{-7}$ Gray/Bequerel |
| Iodine-131 | 20 - 29 | Slope Factor | $1.2X10^{-4}$ 1/Gray |
| Iodine-131 | 30 - 39 | Conversion Dose Factor | $4.4X10^{-7}$ Gray/Bequerel |
| Iodine-131 | 30 - 39 | Slope Factor | $1.0X10^{-4}$ 1/Gray |
| | | | |

For iodine-131 Dose Factors are given in Table 9.3 and Slope Factors are given[77] in Table 10.6.

**F) Intake Parameters for All Media**
**Medium:** Air[78,78a,78b,79]

| **Parameter** | **Probability Distribution** | **Distribution Parameters** |
|---|---|---|
| Exposure Frequency | Triangular | Minimum=180/365<br>Most Likely=345/365<br>Maximum=365/365 |
| Exposure Duration | Lognormal | Arithmetic Mean=11.36<br>Standard Deviation=13.72 |
| Inhalation Rate/(Body Mass) | Lognormal | Arithmetic Mean=0.4<br>Standard Deviation=0.5 |
| | | |

The averaging time used, AT, was 70 years for carcinogens[80]. For References Doses, AT=1 year. Level II intake parameter probability distribution functions are given[81] in Tables 7-2 through 7-6. The intake parameters used for iodine-131 are presented[82] in Figures 8.11 and 8.12. Exposure parameters for mercury are given[83] in Table 9-2. (These intake parameters are different from those in the table above.) The bioavailability of mercury vapor was discussed. It was assumed to have a value of one[84]. Exposure parameters for uranium are given in Appendix K[85].

Intake parameters for Potential Materials of Concern are given in Appendix C of The Report of Project Task 7. The exposure duration of 10 years for Level II Screening seems to be too short for residents of the Scarboro Community. The exposure duration for the Level I Screening was 50 years[86]. Point distribution functions were used for all concentrations.

The parameters for radiation intake when the slope factor does not depend on the age of the person being exposed are given in the table below.

**Medium:** Air

| **Parameter** | **Probability Distribution** | **Distribution Parameters** |
|---|---|---|
| Exposure Frequency | Triangular | Minimum=180/365<br>Most Likely=345/365<br>Maximum=365/365 |
| Exposure Duration | Lognormal | Arithmetic Mean=11.36<br>Standard Deviation=13.72 |
| Inhalation Rate | Uniform | Minimum=5.05 $m^3$/day<br>Maximum=17.76 $m^3$/day |
| | | |

For Iodine-131 the Exposure Frequency and Exposure Duration probability distributions are the same as those in the Table above. When the slope factor depends on age, the inhalation rate must be given as a function of age rather than as one probability distribution function. The inhalation rate parameters in this case are given in the following table:

**Medium:** Air

| Age in Years | Parameters | Probability Distribution | Distribution Parameters |
|---|---|---|---|
| 0-1 | Intake Rate | Lognormal | Geometric Mean=3.5 $m^3$/day<br>Standard Deviation=1.3 $m^3$/day |
| 1-2 | Intake Rate | Lognormal | Geometric Mean=7.0 $m^3$/day<br>Standard Deviation=1.3 $m^3$/day |
| 3-4 | Intake Rate | Lognormal | Geometric Mean=7.0 $m^3$/day<br>Standard Deviation=1.3 $m^3$/day |
| 5-9 | Intake Rate | Lognormal | Geometric Mean=12.0 $m^3$/day<br>Standard Deviation=1.3 $m^3$/day |
| 10-14 | Intake Rate | Lognormal | Geometric Mean=17.0 $m^3$/day<br>Standard Deviation=1.3 $m^3$/day |
| 15-17 | Intake Rate | Lognormal | Geometric Mean=18.0 $m^3$/day<br>Standard Deviation=1.3 $m^3$/day |
| | | | |

**Medium:** Air (female)

| Age in Years | Parameters | Probability Distribution | Distribution Parameters |
|---|---|---|---|
| 18-19 | Intake Rate | Lognormal | Geometric Mean=18.0 $m^3$/day<br>Standard Deviation=1.3 $m^3$/day |
| 19 plus | Intake Rate | Lognormal | Geometric Mean=18.0 $m^3$/day<br>Standard Deviation=1.3 $m^3$/day |
| | | | |

**Medium:** Air (male)

| Age in Years | Parameters | Probability Distribution | Distribution Parameters |
|---|---|---|---|
| 18-19 | Intake Rate | Lognormal | Geometric Mean=19.0 $m^3$/day<br>Standard Deviation=1.3 $m^3$/day |
| 19 plus | Intake Rate | Lognormal | Geometric Mean=23.0 $m^3$/day<br>Standard Deviation=1.3 $m^3$/day |
| | | | |

**G) Population**

Stastistical information on the population of the Scarboro Community follows[87].

| Period | Age in Years | Probability Distribution | Population |
|---|---|---|---|
| 1950 to 1990 | | | 6,000 to 10,000 (total) |
| Each year | All ages | Statistical (Uniform) | 800 to 1200 |
| | | | |

**H) Intake and Risk**

Risk information is presented in the Results Section of this report and in Appendices C and D. Scarboro was not one of the population groups evaluated[88] at Level II for risk from exposure to the PCBs. Level I risks are given in Table 6-6 of reference 88. Level II risks are given[89] in Tables 7-9 and 7-10. Exposure of Scarboro Community residents to mercury are given[90] from 1950 through 1990. Sensitivity analysis results for mercury exposure are given[91] in Appendix Y of reference 91.

Screening indices for Task 6 are presented in Table ES-3 of reference 92. The Level II screening index is $8.3X10^{-5}$. To one significant figure, this screening index is equal to $1.0X10^{-4}$. It was not treated this way in the report and thus uranium in the Scarboro Community was not recommended for further study. The kidney burdens of uranium in the Scarboro Community are presented in Figures ES-4. Screening indices are given in Tables 4-6 and 4-7. Hazard Indices for uranium are given[92] in Figure 4-8.

Effects of K-25/S-50 air releases on the Scarboro Community are discussed[93]. "Further evaluation of blood level concentrations that may have resulted from exposure to lead from the ORR may not be warranted[94]. Level I dose summaries for arsenic are given in Appendix I and Table 5-6 of reference 95. Level I and Refined Level I Screening doses for arsenic are given[95] in Table 5-5 of reference 95.

**Appendix C: Risk as a Function of Year of Exposure for Uranium**

**Table 5.** Total risks of this report. The material is taken into the body by inhalation only.

| **Year** | **Human Health reaction** | **Material that Cause the reaction** | **Risk per Person** |
|---|---|---|---|
| 1944 | Cancer | Uranium-234/235 | $2.02X10^{-7}$ |
| 1944 | Cancer | Uranium-238 | $7.29X10^{-8}$ |
| 1957 | Cancer | Uranium-234/235 | $4.73X10^{-6}$ |
| 1957 | Cancer | Uranium-238 | $5.55X10^{-7}$ |
| 1958 | Cancer | Uranium-234/235 | $1.44X10^{-5}$ |
| 1958 | Cancer | Uranium-238 | $1.17X10^{-6}$ |
| 1959 | Cancer | Uranium-234/235 | $1.01X10^{-5}$ |
| 1959 | Cancer | Uranium-238 | $1.36X10^{-6}$ |
| 1995 | Cancer | Uranium-224/235 | $1.37X10^{-8}$ |
| 1995 | Cancer | Uranium-238 | $3.33X10^{-10}$ |
| | | | |

**Appendix D: Risk as a Function of Period of Exposure and Age for Iodine -131**

**Table 6.** Total risks of this report for females. The material is taken into the body by inhalation only.

| **Period** | **Gender** | **Age in Years** | **Human Health reaction** | **Material that Cause the reaction** | **Risk per Person** |
|---|---|---|---|---|---|
| 1944-1956 | Female | 1 | Cancer | Iodine-131 | $4.90X10^{-6}$ |
| 1944-1956 | Female | 2 | Cancer | Iodine-131 | $9.76X10^{-6}$ |
| 1944-1956 | Female | 3 | Cancer | Iodine-131 | $8.20X10^{-6}$ |
| 1944-1956 | Female | 4 | Cancer | Iodine-131 | $8.59X10^{-6}$ |
| 1944-1956 | Female | 5 | Cancer | Iodine-131 | $5.94X10^{-6}$ |
| 1944-1956 | Female | 6 | Cancer | Iodine-131 | $5.28X10^{-6}$ |
| | | | | | |

**Table 7.** Total risks for females of this report. The material is taken into the body by inhalation only.

| **Period** | **Gender** | **Age** | **Human Health reaction** | **Material that Cause the reaction** | **Risk per Person** |
|---|---|---|---|---|---|
| 1944-1956 | Female | 18 | Cancer | Iodine-131 | $1.56X10^{-7}$ |
| 1944-1956 | Female | 19 | Cancer | Iodine-131 | $1.42X10^{-7}$ |
| | | | | | |

**Table 8.** Total risks of this report for males. The material is taken into the body by inhalation only.

| **Period** | **Gender** | **Age in Years** | **Human Health reaction** | **Material that Cause the reaction** | **Risk per Person** |
|---|---|---|---|---|---|
| 1944-1956 | Male | 1 | Cancer | Iodine-131 | $1.24X10^{-6}$ |
| 1944-1956 | Male | 2 | Cancer | Iodine-131 | $2.47X10^{-6}$ |
| 1944-1956 | Male | 3 | Cancer | Iodine-131 | $2.08X10^{-6}$ |
| 1944-1956 | Male | 4 | Cancer | Iodine-131 | $2.18X10^{-6}$ |
| 1944-1956 | Male | 5 | Cancer | Iodine-131 | $1.55X10^{-6}$ |
| 1944-1956 | Male | 6 | Cancer | Iodine-131 | $1.37X10^{-6}$ |
| | | | | | |

**Table 9.** Total risks for males of this report. The material is taken into the body by inhalation only.

| **Period** | **Gender** | **Age** | **Human Health reaction** | **Material that Cause the reaction** | **Risk per Person** |
|---|---|---|---|---|---|
| 1944-1956 | Male | 18 | Cancer | Iodine-131 | $4.12X10^{-8}$ |
| 1944-1956 | Male | 19 | Cancer | Iodine-131 | $4.53X10^{-8}$ |
| | | | | | |

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