NEW JERSEY DEPARTMENT of HEALTH and SENIOR SERVICES

Public Health Assessment

Ringwood Mines/Landfill Site
Ringwood
Passaic County

Public Comment Release

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Prepared Under a Cooperative Agreement with the:

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

All comments must be submitted in writing to:

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THE ATSDR HEALTH ASSESSMENT: A NOTE OF EXPLANATION

Section 104 (i) (6) (F) of the Comprehensive Response, Compensation, and Liability Act of 1980 (CERCLA), as amended, states "...the term 'health assessment' shall include preliminary assessments of potential risks to human health posed by individual sites and facilities, based on such factors as the nature and extent of contamination, the existence of potential pathways of human exposure (including ground or surface water contamination, air emissions, and food chain contamination), the size and potential susceptibility of the community within the likely pathways of exposure, the comparison of expected human exposure levels to the short-term and long-term health effects associated with identified hazardous substances and any available recommended exposure or tolerance limits for such hazardous substances, and the comparison of existing morbidity and mortality data on diseases that may be associated with the observed levels of exposure. The Administrator of ATSDR shall use appropriate data, risk assessments, risk evaluations, and studies available from the Administrator of EPA."

In accordance with the CERCLA section cited, this Health Assessment has been conducted using available data. Additional Health Assessments may be conducted for this site as more information becomes available.

The conclusions and recommendations presented in this Health Assessment are the result of site specific analyses and are not to be cited or quoted for other evaluations or Health Assessments.

Public Health Assessment

Ringwood Mines/Landfill Site

Borough of Ringwood, Passaic County, New Jersey

USEPA Facility ID: NJD980529739

Prepared by:

New Jersey Department of Health and Senior Services
Public Health Services Branch
Consumer and Environmental Health Services
Hazardous Site Health Evaluation Program

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

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Summary

The Ringwood Mines/Landfill site is located in Ringwood Borough, Passaic County, New Jersey. Between 1965 and 1972, wastes (e.g., car parts, paint sludge, solvents) from the Ford Motor Company's Mahwah, Bergen County, New Jersey assembly plant were dumped at the site. Based on an evaluation of hazards associated with site-related contamination, the site was added to the National Priorities List on September 1, 1983. Subsequent to investigation and cleanup under United States Environmental Protection Agency and New Jersey Department of Environmental Protection oversight, the site was deleted from the National Priorities List on November 2, 1994, however, the site has been proposed to be restored to the National Priorities List on April 19, 2006. Further investigations have determined that paint sludge remains widespread at the site and that multiple media (soil, sediment, ground and surface water) have been adversely impacted.

In September 2003, the Native American community residing on the site expressed health concerns allegedly related to widespread paint sludge contamination remaining at the site and requested assistance from the Agency for Toxic Substances and Disease Registry. Through a cooperative agreement with the Agency for Toxic Substances and Disease Registry, the New Jersey Department of Health and Senior Services prepared a public health assessment for the Ringwood Mines/Landfill site. Environmental contamination detected at the site and associated exposure pathways were evaluated. Contaminants of concern identified for the site were benzene, 1,2-dichloropropane, methylene chloride, pentachlorophenol, Aroclors, bis(2-ethylhexyl)phthalate, benzo[a]pyrene, antimony, arsenic, cadmium, chromium, copper, lead, mercury and thallium. It was determined that completed exposure pathways via the ingestion of contaminated surface water and the incidental ingestion of contaminated paint sludge, soil, and sediment existed in the past. Although exposures have been interrupted to a certain extent, contaminated paint sludge deposits and contaminated soil and sediment remain at the site. Potential pathways were also identified and included past inhalation of ambient air and past and current ingestion of biota and groundwater from off-site potable wells.

Past exposures associated with antimony and lead (in paint sludge), arsenic (in surface water), and lead (in soil and surface water) may have resulted in non-cancer adverse health effects in children and adults. Potential health hazard due to additive or interactive effects of chemical mixtures may be greater than estimated by the endpoint-specific hazard index, particularly for neurological effects associated with co-exposure to lead and arsenic. Lifetime excess cancer risks associated with the ingestion of paint sludge, surface soil, and sediment were estimated to be very low when compared to the New Jersey background cancer risk. Based on the maximum and mean arsenic concentrations detected in surface water, lifetime excess cancer risks were estimated to be approximately five and two excess cancer cases per 10,000 individuals, respectively.

Paint sludge is the likely source of most of the lead, as well as the antimony at the site. Paint from pre-1978 housing may also contribute to lead in the environment.

Arsenic, however, may be naturally occurring in the area. Based on health risks posed by exposures to lead and antimony, the site posed a ***Public Health Hazard*** in the past. Since there may be on-going exposure from paint sludge and soil at levels of health concern, the site currently poses a ***Public Health Hazard***.

Childhood blood lead data were evaluated for the Ringwood Mines/Landfill site. Results showed both a higher proportion of children with elevated blood lead levels and a slightly higher average childhood blood lead level in the focus area closest to the Ringwood Mines/Landfill site compared to the rest of Ringwood Borough. Although there are multiple sources of lead in a child's environment (such as peeling lead-based paint in homes), lead-containing paint sludge may have contributed to these differences in blood lead levels.

An analysis of cancer incidence for the period 1979 through 2002 in the Ringwood Mines/Landfill area indicated that overall cancer incidence was not elevated. However, lung cancer incidence was statistically elevated in males in the area closest to the Ringwood Mines/Landfill site. Information on smoking history, the most important risk factor for lung cancer, was not available. Since lung cancer incidence was not elevated in females, there is little evidence that cancer incidence has been affected by site-related contamination.

Other health concerns that residents believe are related to exposures to the Ringwood Mines/Landfill site contamination include respiratory diseases, reproductive and developmental effects, neurological disorders, heart disease, skin rashes and eye irritation, anemia, and diabetes. Many of the community's concerns are consistent with health effects of lead and arsenic exposures reported in the scientific literature; however, these health outcomes may also be caused by other environmental and non-environmental risk factors.

Recommendations for the site include the remediation of paint sludge and associated soil and groundwater contamination, characterization of potential biota contamination, further assessment of background concentrations of arsenic and other site-related contaminants, and an exposure investigation of the community living on the Ringwood Mines/Landfill site. The NJDHSS and ATSDR also recommend concurrent testing of environmental media such as indoor dust and soils close to homes.

The NJDHSS and ATSDR will begin planning for implementation of an Exposure Investigation to determine the extent of exposure to heavy metals from environmental media contaminated by paint sludge. An exposure investigation should include biological testing of adults and children for exposure to lead, antimony, and arsenic. Plans for an exposure investigation should be developed in conjunction with community members. The NJDHSS and ATSDR will also work with the USEPA and NJDEP to coordinate potential environmental testing that would be conducted in association with biological monitoring.

Statement of Issues

In September 2003, the Agency for Toxic Substances and Disease Registry (ATSDR) received a letter from attorney Stephen Sheller of Sheller, Ludwig and Badey, P.C., on behalf of a Native American community residing on the Ringwood Mines/Landfill site, Ringwood Borough, Passaic County, New Jersey. Mr. Sheller requested that the ATSDR provide assistance in determining whether past and current exposures to hazardous substances disposed at the site presented a public health hazard. The ATSDR considered Mr. Sheller's letter a petition and approved the request.

The Ringwood Mines/Landfill site contains abandoned magnetite mines which were in operation from the mid 1700s through the early 1900s. Between 1965 and 1972, wastes (e.g., car parts, paint sludge, solvents) from the Ford Motor Company's Mahwah Bergen County, New Jersey assembly plant were dumped at the site on the ground, in open pits, and in mine shafts. Based on an evaluation of hazards associated with site-related contamination, the site was added to the National Priorities List (NPL) on September 1, 1983. Subsequent to investigation and cleanup under U.S. Environmental Protection Agency (USEPA) and New Jersey Department of Environmental Protection (NJDEP) oversight, the site was deleted from the NPL on November 2, 1994. Further investigations have determined that paint sludge remains widespread at the site and that multiple media (soil, sediment, ground and surface water) have been adversely impacted.

Through a cooperative agreement with the ATSDR, the New Jersey Department of Health and Senior Services (NJDHSS) prepared the following public health assessment for the Ringwood Mines/Landfill site. The goal of this public health assessment was to examine environmental contamination at the Ringwood Mines/Landfill site, evaluate available health outcome data, and address community health concerns. The report provides conclusions, recommendations, and an action plan designed to protect public health.

Background

Site Description

The Ringwood Mines/Landfill site is located in the Borough of Ringwood, Passaic County, New Jersey (see Figure 1). The site is approximately 500 acres and approximately one half mile wide by one and one half miles long. The site is characterized by a variety of features including abandoned mine shafts and surface pits, an inactive landfill, an industrial refuse disposal area, small surface dumps, a municipal recycling area, a municipal garage, and 48 residences. The terrain is forested, with open areas.

Ramapough Mountain Indians

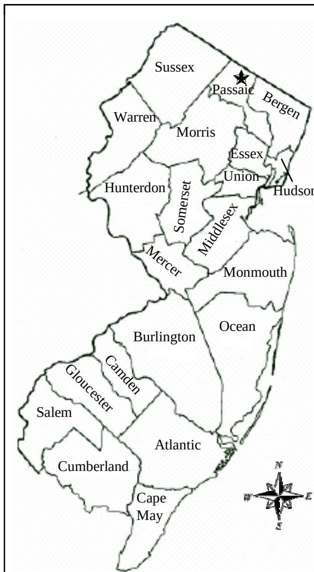

Figure 1: Location of Ringwood Mines/Landfill Site

There are approximately 900 people living within one mile of the site (see Figure 2). About 200 of these individuals are Ramapough Mountain Indians living at 48 residences on the site. The Ramapough Mountain Indians are descendants of the Lenape Indians. Many tribal members live around the Ramapo Mountains (a range of the Appalachian Mountains) of northern New Jersey and southern New York. Although not currently a federally recognized Native American tribe, the Ramapough Mountain Indians have been recognized by the state of New Jersey.

Health and economic challenges in this tribal community were documented over 30 years ago. A news article which referred to a William Paterson College health survey of Ringwood Mines area residents conducted in the early 1970s described "the cycle of poverty, poor nutrition, inadequate education, and lower standard of health" among the individuals interviewed by nursing students (Kupferstein 1973)[1]; another article reported on the "very poor" health conditions and substandard housing existing in the Ringwood Mines area (West Milford Argus Today 1975).

Ringwood Mines

The Ringwood Mines comprise a group of open pits and shafts that were mined from the mid 1700s to the early 1900s. Some of the ore deposits were well known before the American Revolution, and the older openings were reportedly made before 1760 (Pustay and Shea 1992). The principal product of the mines during the years of operation was magnetite ore, which was processed on-site and shipped to local iron foundries. Five of the pits and shafts which comprise the Ringwood Mines are the Peters, St. George, Miller, Keeler, and Cannon mines. To illustrate, the Cannon Mine was a large, open pit, measuring approximately 140 by 180 feet and 200 feet deep. In 1880, the total yield of the entire Ringwood Mines was estimated at 896,000 tons of ore. Active mining activities ceased around 1931.

In 1941, the Ringwood Mines property was purchased by the federal government and subsequently leased to the Alan Wood Steel Company. The intent was to restart mining activities to support the World War II effort. Wartime production needs did not develop, and the mines remained inactive. In July 1958, the property was sold at a government auction to the Pittsburgh Pacific Company, a Minnesota-based mining company. It is believed that Pittsburgh Pacific Company did not engage in active mining activity at the Ringwood Mines. Use of the site between 1956 and 1965 is not well

[1]Attempts by the NJDHSS to obtain the report were unsuccessful.

documented. In April 1965, the New Jersey Bureau of Mine Safety inspected the Ringwood Mines. Refuse, including municipal wastes, was present in open pits and mine shafts (YE^2ARS, Inc 1983). In an annual report of the Ringwood Borough Planning Board, it was stated that 31 of the total 33 mine shafts were sealed[2] under the supervision of the New Jersey State Department of Mines following the removal of over 500 abandoned vehicles (Ringwood Borough Planning Board 1965).

Waste Disposal at the Site

In 1965, the Ringwood Realty Corporation, a wholly-owned subsidiary of the Ford Motor Company, bought the property and subsequently began dumping wastes (e.g., car parts, paint sludge, solvents) from Ford's Mahwah, Bergen County, New Jersey assembly plant. Some wastes were deposited on the ground in natural depressions and in man-made pits associated with abandoned mine shafts or other mining activities. There are conflicting reports about the time frame for the disposal of wastes at the Ringwood Mines/Landfill site[3] (YE^2ARS 1983; Muszynski 1993; USEPA 2004; Latham-Watkins 2005).

Of the approximately 900 acres purchased by Ringwood Realty Corporation from the Pittsburgh Pacific Company in 1965, only 150 acres in the vicinity of Peters Mine (a.k.a. O'Connor Refuse Disposal Area) was permitted for dumping (YE^2ARS 1983). In 1965, Ringwood Realty Corporation began selling portions of the property to Jersey Central Power & Light and High Point Homes. In 1970, Ringwood Realty Corporation donated 290 acres to the Ringwood Solid Waste Management Authority (RSWMA). The RWSMA operated a municipal landfill on a portion of this property from 1972 until it was ordered closed by the NJDEP in 1976. In 1973, Ringwood Realty Corporation donated 150 acres, including the O'Connor Refuse Disposal area, to the NJDEP and the affordable housing authority, Housing Operation With Training Opportunity, Incorporated (HOWTO Inc.).

Site Investigation and Remediation

In 1976, the NJDEP sampled surface water from the vicinity of the site and detected contaminated leachate emanating from the landfill. The landfill was subsequently closed. Between November 1979 and April 1980, the NJDEP and the USEPA conducted preliminary assessments of the site, and in 1982, groundwater sampling of the Peters Mine shaft was conducted. Results indicated contamination with benzene, ethylbenzene, xylene, chloroethane, and bis(2-ethylhexyl)phthalate; samples obtained from the Peters Mine Brook showed heavy metal contamination (nickel,

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[2] "Seal" does not necessarily imply permanent closure, as with, say, a concrete cap poured over installed supports. A steel fence (to keep away children, etc.) or rocks and trees could be claimed as a "seal". Liquids or other materials may be poured or pushed through many of these "seals." (H. Black, New Jersey Department of Labor; R. Dalton, NJDEP, personal communications, March 2006.)

[3] 1963 - 1974 (YE^2ARS 1983); 1967 - mid 1970s (Muszynski 1993); 1967 - 1974 (USEPA 2004); 1967 - 1971 (Latham-Watkins 2005)

cadmium, tin, chromium), some of which may have been naturally occurring. The site was added to the NPL on September 1, 1983.

On July 1, 1987, the USEPA issued a Unilateral Order to the Ford Motor Company which required that paint sludge with high heavy metal content be excavated and disposed of at a hazardous waste landfill. Subsequently, a September 29, 1988 Record of Decision (ROD) was issued for the site. Since the selected site remedy resulted in hazardous substances remaining on-site above the health-based levels, a review was required to be conducted within five years after the commencement of remedial action and every five years thereafter to ensure that the remedy continued to provide adequate protection of human health and the environment. Also required was an operation and maintenance program consisting of the sampling of selected on- and off-site groundwater monitoring wells semi-annually for the first five years, then for another 25 years if deemed necessary.

Approximately 7,000 cubic yards of paint sludge were removed from the site in 1987 and 1988, and remediated areas were backfilled with clean soil. Groundwater, surface water, soil, and sediment samples were collected. Post-remedial sampling (Woodward-Clyde 1988) indicated continued elevation of certain contaminants, including lead, in some soils. Following the removal of the paint sludge, risks to human health and the environment associated with the site were evaluated by an environmental consulting firm retained by the Ford Motor Company (Environ 1988; Woodward-Clyde 1990). The evaluations concluded that the presence of metals[4] in environmental media at the site presented the most significant public health and environmental risk, albeit these metals occur naturally and could be the result of past mining activities or natural weathering processes. The reports further stated that there was no evidence that metal concentrations detected in site soil, sediment, and surface water were significantly higher than those measured elsewhere in the New Jersey Highlands.

In 1990 and 1991, an additional 600 cubic yards of paint sludge as well as about 54 drums containing various wastes were removed from the site. No paint sludge samples were collected; however, drum contents were analyzed. In 1995, a resident contacted the USEPA regarding the discovery of paint sludge on his property, and five cubic yards were removed (Geraghty & Miller 1996). In 1997 and 1998, additional paint sludge was identified during a USEPA site visit. One hundred cubic yards of paint sludge were removed and post-excavation soil samples were collected.

Environmental Monitoring Program

At the direction of the USEPA, Ford initiated a five-year Environmental Monitoring Program (EMP) in the fall of 1989, which continued through 1995. Ford sampled area potable and groundwater monitoring wells to determine contaminant concentrations in the upper aquifer. Surface water sampling was discontinued in 1990,

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[4]Arsenic, barium, cadmium, chromium, copper, lead, manganese, mercury, nickel, selenium, thallium, and zinc.

when sampling and analysis showed no contamination above surface water quality criteria.

In 1998, the USEPA directed Ford to conduct two additional rounds of groundwater sampling in select wells because the data showed elevated levels of lead and arsenic in four on-site monitoring wells. Beginning in August 1999, Ford conducted several sampling rounds of surface water and groundwater monitoring wells; results indicated that except for one elevated level of arsenic, lead and arsenic levels had decreased and were below health-based standards. In June 1998, the USEPA collected surface water samples in response to citizen concerns regarding discolored surface water. The discoloration was later determined to be associated with iron bacterial growth.

Throughout the remedial investigation and EMP activities, the NJDEP reviewed and commented on reports submitted to the USEPA by Ford's environmental consultant. In a 1998 review of the EMP, the NJDEP stated that it remained unclear as to whether exceedances of lead and other metals detected in monitoring wells were due to natural conditions versus former paint sludge disposal areas. Based on this uncertainty, the NJDEP rejected a No Further Action request as the contaminant source had not been adequately demonstrated by Ford (NJDEP 1998). Subsequent to reported fish deaths at the site, the NJDEP contacted appropriate wildlife officials to conduct oversight in determining further evidence of fish deaths for at least six months (Zalaskus 2000). In 2002, the USEPA, in concurrence with the NJDEP, determined that the EMP was complete at the site.

Current Site Remedial Activities

In 2004, and with the oversight from the USEPA, NJDEP, and U.S. Army Corps of Engineers, the Ford Motor Company initiated a comprehensive program to address concerns about the adequacy of past remedial activities implemented at the Ringwood Mines/Landfill site. Between January and December 2005, 13,156 tons of paint sludge and associated soil were excavated and removed from the site. Post-remedial soil samples in the vicinity of the excavations showed remaining areas of lead contamination (ARCADIS 2006). Additional areas of paint sludge have been identified and will be remediated. Drum remnants identified in the Peters Mine Area will also be addressed.

In October 2005, the NJDEP negotiated access agreements for three on-site residential properties. Paint sludge from three properties was investigated and remediated (NJDEP 2005). Edison Wetlands Association also collected sludge and post-excavation soil samples from these areas (Chapin Engineering 2005).

Site Activities by the ATSDR and NJDHSS

In 1989, the ATSDR prepared a public health assessment for the Ringwood Mines/Landfill site. The report concluded that the site posed a *"potential public health concern"* due to risks of exposures through the incidental ingestion of soil.

Recommendations included the limiting of access to contaminated areas and the performance of a detailed well inventory.

In 1994, in preparation for the site being deleted from the NPL, a Site Review and Update (SRU) for the Ringwood Mines/Landfill site was prepared (ATSDR 1994a). The purpose of this report was to perform a review of current site conditions and recommend further actions for ATSDR to take at the site. The 1994 report concluded that there were no completed human exposure pathways associated with the site. The report stated, however, that if new information became available indicating that exposures to hazardous materials may be occurring, additional actions would be taken.

Following ATSDR approval of Mr. Sheller's petition, representatives of the NJDHSS, ATSDR, and Ringwood Borough Health Department conducted a site visit of the Ringwood Mines/Landfill site on October 28, 2003. NJDHSS representatives were Christa Fontecchio, Somia Aluwalia, Tariq Ahmed, Steven Miller, and Julie Petix; Leah Escobar represented the ATSDR. Litter and trash were observed on the site (see Photograph 1), and a guardrail had been installed near the site entrance reportedly to keep out illegal dumpers. Two local residents present at the time of the site visit reported past and/or current use of the site for recreational activities (e.g., fishing, hunting, dirt riding, mountain biking, swimming, and ice-skating on an on-site pond known as "the pool") (see Photographs 2 and 3). They also reported that in the 1960s through the early 1980s, on-site residences did not have indoor plumbing or electricity. There were no potable wells on the site. Using buckets, water for all domestic household use was obtained from an on-site spring.

On April 14, 2004, a second site visit was conducted. Participants included representatives of the NJDHSS, ATSDR, NJDEP, USEPA, Ringwood Borough (Mayor, Deputy Mayor, Health Officer), an aide to Senator Frank Lautenberg, local media, community members (including attorneys representing the community), and the Passaic County Department of Health. The site visit began with a meeting at the Church of the Good Shepherd located in Ringwood Borough near the site. An environmental consultant for the community's law firm described concerns about the adequacy of the USEPA-supervised cleanup of the site prior to and after deletion from the NPL. Film footage believed to be taken by a local resident sometime in the 1960s was shown. In the film, children could be seen playing in an area where waste materials were being dumped and moved around with a backhoe. The film also showed fires in the mine shafts. According to local residents, the fires would burn for weeks and emit black smoke that would sicken residents. The USEPA spoke briefly about recent environmental sampling events at the site.

After the meeting, a three-hour tour of the site was conducted. Hardened paint sludge was observed in several areas throughout the site (see Photograph 4). A 55-gallon metal drum and a drum lid were also spotted in one area of the site (see Photographs 5 and 6). The site visit ended with a visit to "Sludge Hill" where the USEPA had conducted a major removal action in 1998 (see Photographs 7 and 8). Along with an occasional 55-gallon drum, some small pieces of sludge were seen on the slope of the hill. Large piles of garbage and old tires were observed near residences and particularly in the vicinity of the hill. Ammunition casings were also observed at the top of the hill.

On February 24, 2004, the NJDHSS and ATSDR sponsored two availability sessions (afternoon and evening) at the Ringwood Borough municipal building. The purpose of the sessions was to provide an opportunity for residents to meet one-on-one with NJDHSS and ATSDR staff to discuss personal health concerns suspected to be associated with site-related contamination. In concurrence with the decision of the Ringwood Neighborhood Action Association (RNAA) President, Mr. Wayne Mann, about 60 community members chose to attend only the evening session. Mr. Mann read a prepared statement expressing concerns pertaining to the presence of paint sludge at the site (see Appendix A).

On September 23, 2004, NJDHSS and ATSDR staff attended a meeting with the Ringwood Mines area residents to discuss a draft Public Health Response Plan (PHRP) proposed by the NJDHSS (see Appendix B). The meeting was attended by approximately 20 residents and began with a statement read by RNAA President Mr. Mann (see Appendix C). Essentially, Mr. Mann stated that the draft PHRP did not adequately address the full range of community health concerns expressed by residents.

On June 15, 2005, the NJDHSS and ATSDR arranged a public meeting to discuss the progress on the public health assessment being prepared for the Ringwood Mines/Landfill site. During the meeting, past and current exposure pathways were discussed and methods and preliminary results of health outcome data analysis (cancer incidence, childhood blood lead) were presented. Feedback from meeting participants, particularly as related to historic exposure pathways, was solicited and encouraged.

On October 27, 29, and November 5, 2005, the NJDHSS sponsored free medical screenings for Ringwood Mines area residents. Medical professionals affiliated with the North Hudson Community Action Corporation mobile facility provided age-appropriate health screening evaluations to both children and adults. Although not part of the public health assessment for the Ringwood Mines/Landfill site, the screenings were conducted to ensure that basic health care services were available to the community.

Community Concerns

Community exposure and health concerns have been expressed through written communications from legal counsel, prepared statements by the RNAA, and by residents during site visits and community meetings. The inadequacy of past cleanups at the site, and resultant exposure to toxic chemicals, is of foremost importance. In order to emphasize the extent of the problem, one individual brought chunks of hardened paint sludge to the February 2004 meeting which had been collected near a residence. He described a volatile organic smell and skin irritation of his hands from picking up the paint sludge. Residents expressed concern that the extent of past dumping was not fully appreciated. One resident reported observing an average of 12 trucks with a carrying capacity of 20 cubic yards dumping Ford waste on the site five days per week, and approximately three to four truckloads of waste were dumped on the site on weekends.

Community members expressed concerns that the PHRP drafted by the NJDHSS in response to the petition would not fully address the range of community concerns about the site. The scope of planned health outcome data reviews (using existing surveillance data assembled by the NJDHSS) was viewed as inadequate in showing the overall health impact experienced by the community. In early 2005, the RNAA proposed an Environmental Health Intervention Program (EHIP) which would include full participation of the community, in conjunction with the NJDHSS and ATSDR, in the investigation of the extent and causes of health problems experienced by community members (RNAA 2005). The EHIP also included components to document the history and culture of the Ramapough Mountain Indians.

On November 15, 2004, the RNAA petitioned the New Jersey Environmental Justice Task Force to obtain Environmental Justice designation for the Ringwood Mines/Landfill site. A description of resident health concerns allegedly related to the dumping of wastes by the Ford Motor Company at the site was provided in the petition letter.

Health concerns that community members feel are related to exposures associated with the Ringwood Mines/Landfill site contamination include: cancer (ovarian, cervical, leukemia, breast, lung, Ewing sarcoma, colon), respiratory disease (asthma, emphysema), reproductive and developmental effects (female reproductive disorders, miscarriages, birth defects, learning disabilities, behavioral problems), neurological disorders, heart disease, skin rashes, eye irritation, anemia, diabetes, and shorter lifespan.

A series of articles in the Bergen Record extensively documented the history of the site and the scope of the community's concerns about environmental exposure and health (Bergen Record 2005).

Environmental Contamination

An evaluation of site-related environmental contamination consists of a two-tiered approach: 1) a screening analysis; and 2) a more in-depth analysis to determine public health implications of site-specific exposures. First, maximum concentrations of detected substances are compared to media-specific environmental guideline comparison values (CVs). If concentrations exceed the environmental guideline CV, these substances, referred to as Contaminants of Concern (COC), are selected for further evaluation. Contaminant levels above environmental guideline CVs do not mean that adverse health effects are likely, but that a health guideline comparison is necessary to evaluate site-specific exposures. Once exposure doses are estimated, they are compared with health guideline CVs to determine the likelihood of adverse health effects.

Environmental Guideline Comparison

There are a number of CVs available for the screening environmental contaminants to identify COCs. These include ATSDR Environmental Media Evaluation Guides (EMEGs) and Reference Media Evaluation Guides (RMEGs). EMEGs are estimated contaminant concentrations that are not expected to result in adverse noncarcinogenic health effects. RMEGs represent the concentration in water or soil at which daily human exposure is unlikely to result in adverse noncarcinogenic effects. If the substance is a known or a probable carcinogen, ATSDR's Cancer Risk Evaluation Guides (CREGs) were also considered as comparison values. CREGs are estimated contaminant concentrations that would be expected to cause no more than one excess cancer in a million (10^{-6}) persons exposed during their lifetime (70 years). In the absence of an ATSDR CV, other comparison values may be used to evaluate contaminant levels in environmental media. These include New Jersey Maximum Contaminant Levels (NJMCLs) for drinking water, and USEPA Region 3 Risk-Based Concentrations (RBCs). RBCs are contaminant concentrations corresponding to a fixed level of risk (i.e., a hazard quotient[5] of 1, or lifetime excess cancer risk of one in one million, whichever results in a lower contaminant concentration) in water, air, biota, and soil. For soils and sediments, other CVs include the New Jersey Residential and Non-Residential Direct Contact Soil Cleanup Criteria (RDSCC, NRDSCC). Based primarily on human health impacts, these criteria may also take into account natural background concentrations, analytical detection limits, and ecological effects.

Substances exceeding applicable environmental guideline CVs were identified as COCs and evaluated further to determine whether these contaminants pose a health threat to exposed or potentially exposed receptor populations. In instances where an environmental guideline CV was unavailable, the substance was retained for further evaluation. There are exceptions, however. For example, some naturally occurring substances such as sodium, calcium, potassium, and magnesium are typically not harmful under most environmental exposure scenarios and may not necessarily be retained for further analysis.

Site Conditions

The Ringwood Mines/Landfill site is located at the southeastern extension of the New Jersey Highlands Physiographic Province (Woodward-Clyde 1988). The terrain is mountainous with peaks up to 900 feet above sea level. Bedrock at the site consists primarily of Precambrian gneiss. The topographic low areas throughout the site consist of overburden material including weathered bedrock, excavated rock, mine tailings, refuse, and fill soil. Three perennial surface water bodies drain the site: Mine Brook, Peters Mine Brook, and Park Brook (see Figure 3). Surface water flowing from the site ultimately discharges to the Wanaque Reservoir located approximately one mile south of the site. Park Brook flows into Ringwood Creek approximately one mile upstream of its confluence with the Wanaque Reservoir. Along the southern site boundary, Peters Mine

[5]The ratio of estimated site-specific exposure to a single chemical in a particular medium from a site over a specified period to the estimated daily exposure level, at which no adverse health effects are likely to occur.

Brook joins Mine Brook to flow into Ringwood Creek upstream of the Wanaque Reservoir. The intake for the North Jersey District Water Supply Commission water treatment plant, which supplies drinking water to more than two million people, is located approximately eight miles downstream of the Ringwood Mines/Landfill site at the southern end of the Wanaque Reservoir (NJDWSC 2005).

Regional groundwater flow has not been evaluated, although it is known that groundwater flow through a fracture network is strongly influenced by the orientation and geometry of bedrock fractures. At the site, there is an upper aquifer (consisting of overburden and shallow bedrock) and a lower aquifer (deep bedrock). Groundwater in the upper aquifer ranges from a few feet to approximately 60 feet below ground surface. Flow generally follows the topography, recharging surface water bodies that discharge into the Wanaque Reservoir (see Figure 4). The direction of groundwater flow in the lower aquifer is uncertain, although it is believed to consist of three components: shallow flow to local streams; intermediate flow to regional streams; and deep flow towards the ocean. The upper and lower aquifers interconnect throughout the area, but the flow between the aquifers is limited by poor vertical permeability (Woodward-Clyde 1988).

Pre Remedial Investigation

A Remedial Action Master Plan for the Ringwood Mines/Landfill site was prepared based on information obtained from the USEPA, NJDEP, New Jersey Geological Survey, New Jersey Bureau of Mine Safety, and the Ringwood Borough Planning Board (YE^{2}ARS 1983).

Results of analyses for volatile organic compounds (VOCs), metals, and cyanide in Mine Brook surface water and municipal landfill leachate obtained between July 1974 and April 1975 indicated concentrations of cadmium, copper, iron, and manganese above drinking water standards. Although the maximum concentration of lead detected (24 ppb) was below the 50 ppb standard applicable at that time, it is above the current action level of 15 ppb. Groundwater samples collected (three rounds of sampling conducted; some parameters were not analyzed) from the Peters Mine shaft were analyzed for a number of contaminants including VOCs, metals, and pesticides (YE^{2}ARS 1983). Pesticides and polychlorinated biphenyls (PCBs) were not detected; concentrations of VOCs and metals are provided in the table below. The concentrations of benzene, bis(2-ethylhexyl)phthalate, chloroethane, methylene chloride, iron, lead, and beryllium were above the corresponding environmental guideline CV. A high concentration of iron (32,000 micrograms per liter (μg/L)) exceeded the secondary NJMCL of 300 μg/L, which is based on aesthetic (color or taste) rather than health effects.

VOCs and Metals Results Peters Mine Shaft Groundwater, October 1980		
Contaminant	**Concentration (µg/L)**	**Environmental Guideline CV (µg/L)**
Volatile Organic Compounds		
Benzene	**19**	**1 (NJMCL)**
Bis(2-ethylhexyl)phthalate	**304**	**4.8 (RBC)**
Chloroethane	**150**	**3.6 (RBC)**
1,1-Dichloroethane	10.2	50 (NJMCL)
Ethylbenzene	95	700 (NJMCL)
Methylene Chloride	**4**	**3 (NJMCL)**
Xylenes	150	1,000 (NJMCL)
Metals		
Beryllium	**7.8**	**4 (NJMCL)**
Chromium (IV)	7[1]	100 (NJMCL)
Copper	15	1,300 (AL[2])
Lead	**70[1]**	**15 (AL)**
Zinc	61	3,000 (RMEG)

[1]approximate value; [2]Action Level
Bold font indicates environmental guideline CV was exceeded

In 1982, samples collected from the Ringwood Water Department water supply wells (i.e., the Mine Supply spring and the Windbeam municipal supply well) were analyzed for standard drinking water parameters (YE^{2}ARS 1983). No contaminants were reported in the Mine Supply sample. Contaminants detected in the Windbeam municipal supply well and the corresponding NJMCLs are provided in the following table; concentrations of all parameters were below the NJMCLs.

Results of Ringwood Borough Water Department Water Supply Sampling, June 1982		
Contaminant	**Windbeam Municipal Supply Well (µg/L)**	**NJMCL (µg/L)**
Chromium	1	100
Fluoride	50	4,000
Lead	10	15 (AL[1])
Nitrate - N	750	10,000

[1]Action Level

Remedial Investigation: Site Contamination

Subsequent to the site being added to the NPL, a Remedial Investigation (RI) was conducted to determine the nature and extent of site contamination (Woodward-Clyde 1988). Test pit locations were reportedly selected based on site reconnaissance, literature review, terrain conductivity, and resistivity surveys. During test pit excavation, waste materials (e.g., garbage, construction material and debris, rubber hoses) were encountered. Samples of paint sludge, soil (fill and indigenous), contents of 55-gallon drums, and surface and groundwater were collected and analyzed for metals, VOCs, semi-volatile organic chemicals (SVOCs including PCBs), total petroleum hydrocarbons (TPH), and cyanide.

Drum Content

Drums disposed of at the site contained waste oil, sludge, brake fluid, antifreeze, "Speedy Dry", gloves, rags, and cloths. Laboratory analysis of drum content was conducted in June and September of 1990; results indicated the presence of VOCs, PCBs (Aroclor[6] 1254 and 1262), and metals (see Table 1) (A. Robinson, ARCADIS, personal communication, 2005).

Surface Soil[7]

As presented in Figure 3, four primary areas of surficial paint sludge contamination were identified:

- Peters Mine Area, a.k.a. O'Connor Disposal Area;
- St. George Pit/Miller-Keeler Pit Area;
- Cannon Mine Area; and
- Borough Landfill Area.

Test pits were dug in each area and soil samples were obtained. Surface soil from test pit 3 (TP-3) indicated the presence of VOCs, with benzene above its environmental guideline CV (Table 2). Low levels of barium were reported for test pits 3 and 12; lead was also detected in test pit 3.

Paint Sludge

Paint sludge from each of the four primary paint sludge areas was sampled in March and April 1987 and analyzed to determine waste disposal classification. The sludge was classified as "EP toxic[8] for lead", excavated, and disposed off-site, and the areas were backfilled with fill soil. Ten surficial paint sludge samples collected from the four primary paint sludge disposal areas were analyzed for VOCs, SVOCs, pesticides, PCBs, and metals (A. Robinson, ARCADIS, personal communication, 2004). The range and mean of contaminant concentrations detected are provided in Table 3. Levels of PCBs, (Aroclor 1248 and 1254), other SVOCs (bis(2-ethylhexyl)phthalate), and metals (antimony, arsenic, cadmium, chromium, copper, lead) were present above their

[6]Commercial mixtures of PCBs.
[7]Specific soil depths unavailable.
[8]A test defined by the USEPA to check a substance for the presence of arsenic, barium, cadmium, chromium, lead, mercury, selenium, or silver for hazardous waste classification.

corresponding environmental guideline CV. Antimony and lead comprised nearly 5% and over 6% of the sludge material, respectively.

It should be noted that from the time that paint sludge was disposed of at the site until the time of sampling, the paint sludge had been subjected to various degrees of physical, chemical, and biological degradation over a period spanning 20 years. As such, contaminant concentrations reported in Table 3, particularly for VOCs, SVOCs, and PCBs, may not represent conditions close to the time of sludge disposal.

Soil

Pre-remediation surface soil sampling conducted at the site was limited to test pits TP-3 and TP-12 (see Table 2). However, apparent natural soil in proximity to the excavated paint sludge was collected from each of the four primary paint sludge areas and analyzed for VOCs, SVOCs, PCBs, metals, and cyanide. The range and mean of contaminant concentrations detected are provided in Table 4. Maximum concentrations of benzo[a]pyrene, arsenic, lead, and thallium exceeded their corresponding environmental guideline CVs.

Sediment

Sixteen sediment samples were collected (July 1984 and March 1988) from the Mine, Peters Mine, and Park Brooks during two sampling rounds. Samples were analyzed for VOCs, SVOCs, pesticides, PCBs, and metals. Concentrations of benzo[a]pyrene, arsenic, iron, manganese, and thallium exceeded their respective environmental guideline CVs (see Table 5). Arsenic was detected in 14 of 16 samples; the maximum concentration was 31.4 mg/kg. Polycyclic aromatic hydrocarbons (PAHs), including benzo[a]pyrene, were detected in less than half of the samples at concentrations less than 1.0 mg/kg. Pesticides and PCBs were not detected in the samples analyzed. The presence of iron and manganese were attributable to natural sources and eliminated from further consideration. Although arsenic is known to occur naturally in the Ringwood Mines/Landfill area (NJGS 2005), the source of arsenic detected in the sediment could not be determined.

Surface Water from Brooks

Between July 1984 and March 1988, surface water samples were collected from the Mine, Peters Mine, and Park Brooks. Samples were analyzed for metals, VOCs, SVOCs, PCBs, pesticides, and other drinking water parameters. Arsenic was detected in one of 20 samples at a concentration of 40 micrograms of arsenic per liter of water (μg/L), above its environmental guideline CV (see Table 6). It should be noted that arsenic occurs naturally in the groundwater in that area (NJGS 2005). PCBs were not detected in any samples.

Surface Water from Springs/Seeps

Twenty samples from seeps/springs, collected during two sampling rounds (July 1984 and March 1988) were analyzed for VOCs, SVOCs, PCBs, and metals. Concentrations of benzene, 1,2-dichloropropane, arsenic, lead, and mercury exceeded their respective environmental guideline CV (Table 7). Benzene was detected in two of 10 samples at a maximum concentration of 2 μg/L; 1,2- dichloropropane was detected in one sample at a concentration of 12 μg/L. The maximum arsenic concentration was 21 μg/L. Lead was detected in two samples with a maximum concentration of 120 μg/L. Mercury was detected in six samples with a maximum concentration of 8.7 μg/L.

Maximum concentrations of iron and manganese detected in springs/seeps water were above their respective environmental guideline CV. Since iron and manganese are considered to be naturally occurring metals, they were not retained for further evaluation.

Groundwater

Between July 1984 and March 1988, 45 groundwater samples were collected (August and September 1984, June 1986 and March 1988) from 15 on-site monitoring wells during three sampling rounds; one of these samples was from a Peters Mine air shaft. Monitoring well depths ranged from 14 - 543 feet below ground surface. Samples were analyzed for metals, VOCs, SVOCs, and other drinking water parameters; results are presented in Table 8. The concentrations of benzene, methylene chloride, bis(2-ethylhexyl)phthalate, pentachlorophenol, arsenic, cadmium, lead, and thallium exceeded their respective environmental guideline CV. Though infrequently detected, the maximum concentration of cadmium was 93,000 μg/L.

Maximum concentrations of iron and manganese detected in groundwater were above their respective environmental guideline CV. As mentioned earlier, since iron and manganese are considered to be naturally occurring metals, they were not retained for further evaluation.

Potable Wells

There were no known on-site private potable wells.

Remedial Action Summary

As discussed above, remedial actions for the site consisted of the removal of paint sludge and soil contaminated by paint sludge, institutional controls (e.g., controls on the drilling of groundwater wells and/or deed restrictions) and implementation of an EMP. In 1987 and 1988, Ford removed approximately 7,000 cubic yards of paint sludge and associated soil from four areas of the site. The EMP was designed to monitor long-term on- and off-site groundwater and surface water quality to ensure the future protection of public health and the environment. After the implementation of the removal action, soil erosion and earthwork activities uncovered remnants of paint sludge at the site. In 1990, 54 waste containing drums were discovered and were disposed off-site. In 1995, five cubic yards of surficial paint sludge and soil were removed from the site. In December 1997 and January 1998, an additional 30 cubic yards of paint sludge was discovered and disposed off-site. Workplans have been developed for further site investigation and removal of additional paint sludge from the site (ARCADIS 2004; USEPA 2004) including residential properties (J. Seebode, NJDEP, personal communication, 2005).

Environmental Monitoring Program (Post 1987/1988 Remediation)

Groundwater from on-site monitoring wells and off-site potable wells were sampled during the EMP (1989 -1995). Nine off-site potable wells, eight on-site monitoring wells, and tributaries to the Wanaque Reservoir were sampled (see Figure 5). Surface water sampling was discontinued in 1990 when analytical results showed no contamination above the NJDEP surface water quality criteria (Geraghty & Miller 1998).

Potable Wells

Off-site potable wells are located on Margaret King Avenue (see Figure 5); the closest one is approximately 3,000 feet southwest from the intersection of Peters Mine Road and Margaret King Avenue. These wells supply residences and commercial/light industrial facilities with potable water (ARCADIS 1999). Samples from potable wells were collected during the EMP and analyzed for metals, VOCs, and cyanide. The maximum concentration of tetrachloroethene, antimony, beryllium, iron, lead, manganese, and silver detected in the potable wells exceeded their respective environmental guideline CV (see Table 9). The presence of iron and manganese may be attributable to natural sources and were eliminated from further consideration.

Monitoring Wells

Groundwater samples were collected from the on-site monitoring wells located in the northern part of the site and analyzed for VOCs, metals, and cyanide (see Figure 5). The maximum concentration of benzene, chloroethane, 1,1,2,2-tetrachloroethane, aluminum, antimony, arsenic, beryllium, cadmium, chromium, cobalt, iron, lead, manganese, mercury, nickel, thallium, and vanadium detected in the groundwater exceeded their respective environmental guideline CV (see Table 10). The presence of iron and manganese may be attributable to natural sources and were eliminated from further consideration.

In 1998, two additional sampling rounds were performed in select monitoring wells; an elevated arsenic level was detected in one of the wells (ARCADIS 2001). Subsequent sampling showed that lead and arsenic levels had decreased and were below health-based standards, except for one elevated level of arsenic.

Surface water

In March 1998, two surface water samples were collected by the USEPA in response to community concerns regarding areas of standing, discolored water. The samples were collected (from a ponded seep area located north of the end of Peters Mine Road and beneath a culvert along Peters Mine Road south of the municipal recycling area) and analyzed for metals and VOCs (USEPA 1998). Results indicated the presence of VOCs (chloroethane, 1,1-dichloroethane, naphthalene, acetone, and N-nitrosodiphenylamine) and metals (iron, manganese, and zinc). The concentration of all VOCs and zinc were below their respective NJMCLs. Iron and manganese were present above their secondary NJMCLs.

In April 2000, USEPA requested the sampling of Park Brook which runs adjacent to the O'Connor Disposal Area (ARCADIS 2001). Three surface water samples were collected, one upstream, one downstream, and one adjacent to the O'Connor Disposal Area. The samples were analyzed for metals, VOCs, and SVOCs. Concentrations of metals detected in the adjacent and downstream samples did not exceed NJDEP surface water quality criteria.

In response to the discovery of paint sludge by residents, the USEPA collected two surface water samples (from the entrance to an abandoned mining structure and from runoff along the west side of Cannon Mine Road) and one soil sample (from material located in monitoring well OB-8) in May 2004 (USEPA 2004; J. Gowers, USEPA Region II, personal communication, 2006). The aqueous sample results were compared to the New Jersey Groundwater Quality Standards and the National Primary Drinking Water Regulations; iron and manganese detected in one of the samples exceeded NJMCLs. Contaminants concentrations detected in the soil sample were below RDCSCCs.

Public Supply Water

Sampling data available for public supply springs (including cistern number 10) which supplied the upper Ringwood area were reviewed (Edward Haack, Borough of Ringwood, personal communication, 2003). The data included 11 sampling events between May 1988 and December 1997. The cistern number 10 was in use until 2000. Concentration of lead detected in cistern water was 2 µg/L; lead levels at other supplies were non-detect. Three VOCs (bromodichloromethane, chloroform, dibromochloromethane) were also detected. These VOCs are disinfection byproducts associated with water chlorination and are unrelated to the site.

Residential Soil

In November 2005, the NJDEP collected a limited number of surface soil samples from an unpaved driveway, front lawn, and side and backyard of three residential properties and one municipal property located on the Ringwood Mines/Landfill site (NJDEP 2005). The samples were analyzed for VOCs, SVOCs, and lead. Results indicated the presence of VOCs (ethylbenzene, toluene, xylenes, chlorobenzene, trichloroethene) and lead. SVOC data from all four properties and lead data from one residential property were rejected due to laboratory calibration problems. The maximum VOC concentrations detected were below environmental guideline CVs. Both the maximum and mean lead concentrations detected in the surface soil of Residence 1 exceeded the RDCSCC of 400 mg/kg:

Results of Residential Surface Soil Sampling for Lead (mg/kg)			
Concentration	**Residence 1**	**Residence 2**	**Residence 3**
Maximum	3,857	68.5	Rejected
Mean	634	43.17	

Paint sludge and contaminated soil at the three residential properties were excavated and disposed off-site.

The Edison Wetlands Association also collected sludge and soil samples from these areas (Chapin Engineering 2005). Sludge sample results indicated the presence of antimony, arsenic and lead above their respective environmental guideline CVs, and that lead was leachable from the paint sludge. The post-excavation soil samples were "split samples" (with NJDEP) collected from the bottom of excavations. These results were comparable to those reported by the NJDEP.

Contaminants of Concern: Summary

Pre 1987/1988 Remediation

Paint Sludge, Soil, and Sediment - The maximum concentrations of contaminants detected in paint sludge, soil, and sediment, along with appropriate environmental guideline CVs, are presented in Tables 3 - 5. The following contaminants exceeded their corresponding CV, and as such, are designated as COCs:

COCs			
	Paint Sludge	**Soil[1]**	**Sediment**
VOCs	-	Benzene[2]	-
SVOCs	Aroclor 1248 and 1254, Bis(2-ethylhexyl)phthalate	Benzo[a]pyrene	Benzo[a]pyrene
Metals	Antimony, Arsenic, Cadmium, Chromium, Copper, Lead	Arsenic, Lead, Thallium	Arsenic, Thallium

[1]Post-remediation soil; [2]Pre-remediation test pit sample (see Table 2)

A brief discussion of the toxicologic characteristics of these COCs is presented in Appendix D.

Surface Water (Springs/Seeps, Brooks) - Maximum contaminant concentrations detected in surface water along with the respective environmental guideline CVs are presented in Tables 6 and 7. The following contaminants exceeded their CV, and as such, are selected as COCs:

Surface Water COCs	
VOCs	Benzene, 1,2-Dichloropropane
Metals	Arsenic, Lead, Mercury

A brief discussion of the toxicologic characteristics of these COCs is presented in Appendix D.

Groundwater - The maximum contaminant concentrations detected in groundwater, along with the respective environmental guideline CVs, are presented in Table 8. The following contaminants exceeded their CVs, and as such, are selected as the COCs:

Groundwater COCs	
VOCs	Benzene, Methylene Chloride, Pentachlorophenol
SVOCs	Bis(2-ethylhexyl)phthalate
Metals	Arsenic, Cadmium, Lead, Thallium

A brief discussion of the toxicologic characteristics of these COCs is presented in Appendix D.

Post 1987/1988 Remediation

Groundwater – The maximum contaminant concentrations detected in groundwater, along with their respective environmental guideline CVs, are presented in Table 9. The following contaminants exceeded their CVs, and as such, are selected as the COCs:

Groundwater COCs	
VOCs	Benzene, Chloroethane, 1,1,2,2-Tetrachloroethane
Metals	Aluminum, Antimony, Arsenic, Beryllium, Cadmium, Chromium, Cobalt, Lead, Mercury, Nickel, Thallium, Vanadium

A brief discussion of the toxicologic characteristics of these COCs is presented in Appendix D.

Off-site Potable Wells - The maximum concentrations of contaminants detected in off-site potable wells along with appropriate environmental guideline CVs are presented in Table 10. The following contaminants in the potable wells exceeded their corresponding CVs, and as such, are selected as the COCs for the site:

COCs in the Off-site Potable Wells	
VOCs	Tetrachloroethene
Metals	Antimony, Beryllium, Lead, Silver

A brief discussion of the toxicologic characteristics of these COCs is presented in Appendix D.

On-site Residential Soil - As discussed earlier, the maximum concentrations of VOCs detected in three on-site residential properties did not exceed their corresponding CVs. Lead was identified as the COC for these properties.

Discussion

Since the presence of contaminated environmental medium does not necessarily mean that there are exposures, the next step in the public health assessment process is to determine whether there is a completed exposure pathway from a contaminant source to a receptor population.

Exposure Pathway Evaluation

An exposure pathway is a series of steps starting with the release of a contaminant to an environmental medium, movement of the contaminant, and ending at the interface with the human body. A completed exposure pathway consists of five elements:

1. source(s) of contamination;
2. environmental media and transport mechanisms;
3. point of exposure;
4. route of exposure; and
5. receptor population.

Generally, the ATSDR categorizes exposure pathways as follows: 1) *completed* exposure pathways, that is, all five elements of a pathway are present; 2) *potential* exposure pathways, that is, one or more of the elements may not be present, but information is insufficient to eliminate or exclude the element; and 3) *eliminated* exposure pathways, that is, one or more of the elements is absent. Exposure pathways are used to evaluate specific ways in which people were, are, or will be exposed to environmental contamination in the past, present, and future. Completed and potential pathways may be *interrupted* by remedial or public health interventions that disrupt the pathway. Information provided by Ringwood Mines area residents regarding circumstances of exposure to environmental contaminants was taken into consideration in evaluating exposure pathways for the Ringwood Mines/Landfill site.

Site exposures reported by residents included using on-site spring water for all domestic household use until the early 1980s, consuming vegetables from residential gardens, riding bicycles through the paint sludge and playing on Sludge Hill as children, inhaling smoke from on-site fires which occurred during the 1960s, and consuming fish and game which foraged on-site (although residents do not consume fish and game to the extent that they had in the past).

Completed Exposure Pathways

Incidental Ingestion - Paint Sludge, Soil, Sediment

Paint sludge disposal areas were located in close proximity to residences and in other areas that were easily accessible to residents (including children) and others. Children and adults reportedly accessed the contaminated areas for recreational activities (e.g., dirt riding, swimming, hiking), scavenging (auto parts, scrap metal, salvaged food dumped at the site by a local supermarket), and for subsistence fishing and hunting. At the time of disposal, the paint sludge was described by residents as a semi-soft material. Over time, the surficial paint sludge slowly solidified; it is assumed that the surface solidification took place in weeks to months. Direct exposure to fresh paint sludge during the years 1965 - 1972 was assumed to have occurred through incidental ingestion.

Due to the weathering and leaching of paint sludge, contaminants have migrated into on-site soils and sediments resulting in exposures via the incidental ingestion pathway. Four primary paint sludge areas were remediated in 1987/1988 serving to interrupt this exposure pathway to some degree. Actions to remove paint sludge deposits during the 1990s, and the November 2005 removal by NJDEP of paint sludge at three residential properties, have also served to interrupt exposures. However, paint sludge deposits and contaminated soils presently remain in scattered areas at the site, accessible to residents and others, and the site is not yet fully characterized (see Figure 6). Exposures to this contamination may have begun in 1965 when the dumping of Ford Motor Company wastes began.

Dermal Contact - Paint Sludge, Soil, Sediment, Surface Water

Dermal contact with paint sludge and contaminated soil and sediment was possible during household and recreational activities. The extent of dermal absorption of contaminants depends on the area and duration of contact, chemical and physical attraction between the contaminant and the media (loosely or tightly bound), and the ability of the contaminant to penetrate the skin. Although the potential for exposure by dermal absorption of chemicals exists, ATSDR generally considers dermal exposure to be a minor contributor to the overall exposure dose relative to contributions from ingestion and inhalation for most exposure scenarios (ATSDR 2005). However, direct dermal contact with certain contaminants (e.g., chromium, which was found in paint sludge) may elicit dermal reactions based on chemical reactivity or allergic sensitivity (Stern et al. 1993; Bagdon and Hazen 1991).

Ingestion - Surface Water

Public water was not available to all Ringwood Mines/Landfill site residents until the 1980s. Before that time, community members used buckets to collect surface water (seeps/springs, brooks) for domestic uses such as drinking and cooking. Therefore, contaminant exposures through ingestion of surface water are assumed to have occurred for about 20 years (1965 through mid 1980s). Incidental ingestion of surface waters during recreational activities may also have occurred.

A summary of completed exposure pathways identified for the site is presented in Table 11.

Potential Exposure Pathways

Inhalation - Ambient Air

Ringwood Mines area residents and others may have been exposed to organic vapors from the paint sludge as volatile chemicals off-gassed into the ambient air. Although organic vapor was not detected above background levels during site survey, drilling or excavation of test pits, and paint sludge removal activities (Woodward-Clyde 1988), it should be noted that these activities were conducted about 15 to 20 years after the paint sludge dumping. Odors were noticed during recent paint sludge delineation and remediation activities (A. Robinson, ARCADIS, personal communication, 2005) indicating that organic vapors may still be present within the sludge. Since no data are available to evaluate exposures, this exposure pathway is considered potential.

Another potential ambient air exposure pathway is associated with the mine shaft fires reported at the site. Exposure to combustion products from burning waste material associated with paint sludge may have occurred during these episodes. Residents reported being sickened by smoke from these fires. However, no air monitoring data are available to evaluate this exposure pathway.

Ingestion - Biota

Biota (e.g., fish, small game, deer, plants) living or foraging in the Ringwood Mines/Landfill site may have been exposed to contaminants in paint sludge, soil, and sediment. Contaminants may accumulate in the tissue, fat, and bone of animals, and some plants grown in contaminated soil may absorb these chemicals. For example, root crops (such as carrots, beets and potatoes) can take up arsenic and lead contamination in their roots. Lead is also found in the edible portions of leafy vegetables and herbs, as a result of uptake through the roots or deposition on the plant surfaces (ATSDR 1999a). Ringwood Mines area residents who stated that they fished and hunted the site for subsistence may have been exposed to site-related contaminants. However, no data are available to evaluate this exposure pathway.

Ingestion - Groundwater (Off site Potable Wells)

Although the EMP was discontinued in 1995, on-site groundwater remains contaminated. A number of metals (e.g., antimony, beryllium, lead) were detected above their respective CVs in on-site groundwater monitoring wells and off-site potable wells (see Tables 9 and 10). At present, there is insufficient information regarding groundwater flow and the source of off-site potable well contamination to evaluate this exposure pathway.

A summary of potential exposure pathways identified for the site is presented in Table 11.

Public Health Implications

Once it has been determined that individuals have or are likely to come in contact with site-related contaminants (i.e., a completed exposure pathway), the next step in the public health assessment process is the calculation of site-specific exposure doses. This is called a health guideline comparison which involves looking more closely at site-specific exposure conditions, the estimation of exposure doses, and the evaluation with health guideline comparison values (CVs). Health guideline CVs are based on data drawn from the epidemiologic and toxicologic literature and often include uncertainty or safety factors to ensure that they are amply protective of human health.

Completed human exposure pathways associated with the Ringwood Mines/Landfill site include the incidental ingestion of paint sludge, soils, and sediments, the ingestion of surface water from springs/seeps and brooks, and dermal exposure to sludge, soil, sediment, and surface water. Since there is insufficient information available on the nature and magnitude of potential exposures associated with the inhalation of ambient air, ingestion of biota, and the ingestion of water from off-site potable wells, an evaluation with health guideline CVs could not be conducted.

Non-Cancer Health Effects

To assess non-cancer health effects, ATSDR has developed Minimal Risk Levels (MRLs) for contaminants that are commonly found at hazardous waste sites. An MRL is an estimate of the daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of adverse, non-cancer health effects. MRLs are developed for a route of exposure, i.e., ingestion or inhalation, over a specified time period, e.g., acute (less than 14 days); intermediate (15-364 days); and chronic (365 days or more). MRLs are usually extrapolated doses from observed effect levels in animal toxicological studies or occupational studies, and are adjusted by a series of uncertainty (or safety) factors or through the use of statistical models. In toxicological literature, observed effect levels include:

- no-observed-adverse-effect level (NOAEL); and
- lowest-observed-adverse-effect level (LOAEL).

A NOAEL is the highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or in experimental animals. A LOAEL is the lowest dose of a substance that has been reported to cause harmful (adverse) health effects in people or in experimental animals. In order to provide additional perspective on the potential for adverse health effects, calculated exposure doses may also be compared to the NOAEL or LOAEL. As the exposure dose increases beyond the MRL to the level of the NOAEL and/or LOAEL, the likelihood of adverse health effects increases.

To ensure that MRLs are sufficiently protective, the extrapolated values can be several hundred times lower than the observed effect levels in studies of people or experimental animals. When MRLs for specific contaminants are unavailable, other health based comparison values such as the USEPA's Reference Dose (RfD) are used. The RfD is an estimate of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime of exposure.

Ingestion - Sludge, Soil, and Sediment

Non-cancer health effects associated with the selected COCs (see Tables 3, 4, and 5) were assessed by comparing child and adult exposure doses with health guideline CVs. Contaminant exposure doses were calculated using the following formula:

$$\textit{Exposure Dose (mg/kg/day)} = \frac{C \times IR \times EF}{BW}$$

where, mg/kg/day = milligrams of contaminant per kilogram of body weight per day;

C = concentration of contaminant (mg/kg);
IR = soil ingestion rate (kg/day);
EF = exposure factor representing the site-specific exposure scenario; and,
BW = body weight (kg).

Since available data represent a snapshot in time, it is not possible to definitively determine the level or duration of individual resident exposure. However, given that the potential for exposure persisted with no or limited interruption (i.e., paint sludge remedial actions), it is assumed that the exposure duration is seven years (i.e., 1965 - 1972) for paint sludge (semi-soft sludge) and 40 years (i.e., 1965 - 2005) for soil (including solidified sludge) and sediment. It is further assumed that on average, exposures were intermittent (three days per week, nine months per year). The following assumptions were used to calculate site-specific exposure doses for children and adults:

Exposure Scenario Assumptions[1]					
Media	**Receptor Population**	**Ingestion Rate (mg/day)**	**No. of Days of Exposure Per Year**	**Years Exposed**	**Body Weight (kg)**
Paint Sludge	Child	200	108 days (3 days per week, 9 months per year)	7	16
	Adult	100			70
Soil	Child	200		10 (child)	16
	Adult	100		40 (adult)	70
Sediment	Child	200		10 (child)	16
	Adult	100		40 (adult)	70

[1]USEPA 1991; USEPA 1997; NJDEP 2004; ATSDR 2005

Paint Sludge. Maximum chronic exposure doses calculated for children and adults for bis(2-ethylhexyl)phthalate, arsenic, cadmium, and copper were lower than their corresponding health guideline CV and, therefore, are unlikely to cause adverse non-cancer health effects (see Table 12). The USEPA Region 3 RfD for chronic Aroclor 1248 exposure was unavailable; however, the RfD for Aroclor 1254 is 0.00002 mg/kg/day. Using the sum of Aroclor 1248 and 1254, the estimated exposure dose (i.e., 0.000011 mg/kg/day) was lower than the RfD. As such, non-cancer health effects associated with ingestion of PCBs in paint sludge are not expected.

Calculated child and adult exposure doses for antimony and chromium exceeded their respective health guideline CV (see Table 12). As such, the potential exists for non-cancer adverse health effects; a brief evaluation of the non-cancer health implications is presented below. Although an RfD is unavailable for lead, it has also been evaluated for possible non-cancer adverse health effects.

Antimony - Ingesting large doses of antimony can cause vomiting. Long-term chronic animal studies have also reported liver damage and blood changes (ATSDR 1992). Although information on the toxic effects of chronic oral exposure to antimony is limited, antimony appears to affect heart muscle, the gastrointestinal tract, and the nervous system. The chronic oral RfD for antimony (0.0004 mg/kg/day) is based on reduced longevity, blood glucose, and altered cholesterol levels of a group of male and female rats in an oral bioassay study. A LOAEL of 0.35 mg/kg/day and an uncertainty factor of 1,000 were used to calculate the oral RfD. Based on the maximum concentration of antimony detected in the paint sludge, the exposure dose calculated for children (1.85 mg/kg/day) exceeded the LOAEL whereas the adult exposure dose (0.21 mg/kg/day) was lower than the LOAEL by a factor of 1.7 (see Table 12). Based on the mean concentration of antimony detected in the paint sludge, child and adult exposure doses (0.19 and 0.021 mg/kg/day) were lower than the LOAEL by a factor of 1.8 and 17, respectively. Based on the dose being near the level that showed effect in animal studies, there was a potential for non-cancer adverse health effects in children and adults from incidental ingestion of antimony in paint sludge. No health guideline CVs are available to evaluate potential acute and intermediate duration exposures.

Chromium – Chromium may occur in several forms; in nature, chromium (III) is much more common than the more toxic chromium (VI) (USEPA 1994a; NJDEP 1998). Chromium measured in the paint sludge was reported as total chromium. Since the form of chromium in soil is a function of source materials and environmental conditions, to be conservative, the total chromium was assumed to be in the more toxic chromium (VI) form. It should be noted, however, that this assumption may result in an overestimation of exposure dose and potential for health effects.

The chronic oral RfD for chromium (VI) of 0.003 mg/kg/day is based on reduced water consumption in a group of male and female rats (USEPA 2005). An uncertainty factor of 900 and a NOAEL (i.e., the dose that showed no effect in animal studies) of 2.5 mg/kg/day were used to calculate the oral RfD. Based on the maximum and mean concentration of chromium detected in the paint sludge, the child exposure doses (i.e., 0.009 mg/kg/day and 0.0066 mg/kg/day) were 277 and 378 times lower than the NOAEL, respectively (see Table 12). Based on the fact that RfD is based on NOAEL and all chromium detected was assumed to be in the chromium (VI) form, non-cancer adverse health effects for exposures by ingestion to chromium detected in sludge is low.

Lead - The maximum and mean lead concentration detected in paint sludge was 310,000 mg/kg and 64,880 mg/kg, respectively (see Table 12). The maximum concentration was about 775 times higher than the RDCSCC (400 mg/kg). No MRL or RfD is available for lead (ATSDR 1999a). Health effects associated with lead exposure, particularly changes in children's neurobehavioral development, may occur at blood lead levels so low as to be essentially without a threshold (i.e., no NOAEL or LOAEL is available). Accumulation of lead in the body can cause damage to the nervous and gastrointestinal systems, kidneys, and red blood cells. Children, infants, and fetuses are the most sensitive populations to lead exposures. Lead may cause learning difficulties and stunted growth, and may endanger fetal development.

Lead exposures associated with the intermittent recreational use of paint sludge contaminated areas at the Ringwood Mines Landfill site were evaluated using the USEPA's integrated exposure uptake biokinetic (IEUBK) model (USEPA 1994b). The IEUBK model estimates a plausible distribution of blood lead levels centered on the geometric mean blood lead levels from available exposure information. Blood lead levels are indicators of recent exposure, and are also the most widely used index of internal lead body burdens associated with potential health effects. The model also calculates the probability (or P_{10}) that children's blood lead levels will exceed a level of concern. Health effects of concern have been determined to be associated with childhood blood lead levels at 10 micrograms of lead per deciliter of blood (or μg/dL) or less (USEPA 1986, 1990; CDC 1991). In using the IUEBK model, the USEPA recommends that the lead concentration in site soil does not result in a 5% probability of exceeding a blood lead concentration of 10 μg/dL (USEPA 1994c). The average lead level in paint sludge (64,880 mg/kg; see Table 12) was used as an input value to calculate expected children's blood lead levels due to incidental ingestion of paint sludge during the time frame of 1965 - 1972. The assumptions for the recreational exposure scenario for children aged six to 84 months are as follows:

1. Children were exposed to paint sludge containing lead each time the site was visited. The site visit frequency was three days per week over nine months of the year; exposure during the remaining days of the week was at the residence.
2. Model default values were used for all other variables (USEPA 2002) including residential soil and dust.

The predicted geometric mean blood lead levels and the probability of blood lead levels exceeding 10 µg/dL (P_{10}) for children are shown in the following table:

Exposure Scenario		
Age (months)	Three Site Visits Per Week[1]	
	Blood Lead Level[2] (µg/dL)	P_{10} (%)[3]
6 -12	52	99.97
12 - 24	59	99.99
24 - 36	57	99.98
36 - 48	56	99.98
48 - 60	50	99.97
60 - 72	45	99.93
72 - 84	41	99.88

[1]background soil lead concentration = 200 ppm; weighted paint sludge lead concentration (64,880 ppm x 3/7) + (200 ppm x 4/7) = 27,920 ppm (USEPA 2003a); [2]Geometric mean lead levels in blood; [3]probability of blood lead level > 10 µg/dL

For the incidental paint sludge ingestion exposure scenario, the model predicted that the blood lead levels for children ages 6 - 84 months were four to six times higher than the level of concern (10 µg/dL). In addition, the probabilities of blood lead levels exceeding 10 µg/dL for children ages 6 - 84 months was near 100 percent. Therefore, for children exposed to paint sludge contaminated areas at the Ringwood Mines/Landfill site in the period 1965 - 1972, the predicted blood lead levels could have been extremely high. An adult blood lead model estimated a geometric mean blood lead level of 42 µg/dL (USEPA 2003b).

It is important to note that the IEUBK model should not be relied upon to accurately predict blood lead levels above 30 µg/dL since the model was not empirically validated. Additionally, the model should not be used for exposure periods of less than three months, or in which a higher exposure occurs less than once per week or varies irregularly.

<u>Soil</u>. Since several paint sludge contaminated areas remain and are currently being delineated and remediated, exposure to soil contaminants was assumed to be 40 years (1965 - 2005). The maximum chronic exposure dose calculated for children and adult for benzene, arsenic, and thallium are lower than their corresponding health

guideline CVs, and, therefore, are unlikely to cause non-cancer adverse health effects (see Table 13).

Benzo[a]pyrene - Benzo[a]pyrene, was also detected in the soil. Benzo[a]pyrene is one of a group of compounds called polycyclic aromatic hydrocarbons (PAHs). PAHs are formed as a result of incomplete combustion of organic materials. Many industrial products contain PAHs, including coal tar, roofing tar, and creosote. Additionally, the burning of rubber tires can generate PAHs. No acute or chronic MRL have been derived for Benzo[a]pyrene because no adequate human or animal dose-response data are available that identify threshold levels for appropriate non-cancer health effects. However, intermediate duration oral MRLs of 0.4 mg/kg/day have been derived for fluoranthene and fluorene; both were based on LOAELs of 125 mg/kg/day for increased relative liver weight in male mice (ATSDR 1999b). Based on the maximum concentration of Benzo[a]pyrene detected in soil, the estimated child and adult dose of 7.23 $x10^{-7}$ and 8.27 $x10^{-8}$ mg/kg/day, respectively are several orders of magnitude lower than the most conservative MRL of 0.4 mg/kg/day for any of the PAHs (see Table 13). Therefore, it is unlikely that non-cancer adverse health effects would occur in children or adults. This determination takes into account that PAHs have similar physical, chemical, and toxicological characteristics.

Lead - The maximum concentration of lead detected in non-residential site soils (1,300 mg/kg) was about three times higher than the RDCSCC, however, the mean concentration (129.6 mg/kg) was lower than the RDCSCC. Health effects associated with lead exposures were presented earlier in this section.

<u>Residential Soil.</u> Lead contamination above the RDCSCC was detected in residential properties located on the Ringwood Mines/Landfill site.

Lead - The maximum and mean concentrations of lead detected in Residence 1 (3,857 and 634 mg/kg) exceeded the RDCSCC. As discussed earlier, the IEUBK model may be used to evaluate the residential soil exposure pathway. The assumptions for the residential exposure scenario for children ages 6 - 84 months are:

- Children were exposed to residential lead contaminated soil and dust, and,
- Model default values were used for all other variables.

The predicted geometric mean blood lead levels and the probability of blood lead levels exceeding 10 µg/dL (P_{10}) for children are shown below:

Age (months)	Exposure Scenario			
	Maximum Lead Concentration (3,857 mg/kg)		Mean Lead Concentration (634 mg/kg)	
	Blood Lead Level[1] (µg/dL)	P_{10} (%)[2]	Blood Lead Level (µg/dL)	P_{10} (%)
6 -12	24	97	7.5	28
12 - 24	27	98	8.6	38
24 - 36	26	98	8.1	33
36 - 48	26	98	7.7	29
48 - 60	23	96	6.4	18
60 - 72	20	93	5.5	10
72 - 84	18	89	4.9	6

[1]Geometric Mean lead levels in blood; [2]probability of blood lead level > 10 µg/dL

For residential exposures to maximum lead soil concentration detected in Residence 1, the model predicted that the blood lead levels for the ages 6 - 84 months were considerably elevated above 10 µg/dL. In addition, the probabilities of blood lead levels exceeding 10 µg/dL for children ages 6 - 84 months was from 89 to 97 percent. For residential exposures to mean concentration, the predicted blood lead levels for the ages 6 - 84 months were below 10 µg/dL. However, the probabilities of blood lead levels exceeding 10 µg/dL for children ages 6 - 84 months was from 6 to 38 percent.

Sediment. The maximum chronic exposure dose calculated for children and adult for arsenic and thallium are lower than the corresponding health guideline CVs (see Table 14), and, therefore, are unlikely to cause non-cancer adverse health effects.

Benzo[a]pyrene - Benzo[a]pyrene was also detected in sediment. As discussed earlier, no acute or chronic MRL have been derived for Benzo[a]pyrene; however, intermediate duration oral MRLs of 0.4 mg/kg/day have been derived for fluoranthene and for fluorene (ATSDR 1995). Based on the maximum concentration of Benzo[a]pyrene detected in sediment, the estimated child and adult dose of 2.45×10^{-6} and 2.08×10^{-7} mg/kg/day, respectively are several orders of magnitude lower than the most conservative MRL of 0.4 mg/kg/day for any of the PAHs (see Table 14). Therefore, it is unlikely that non-cancer adverse health effects would occur in children or adults.

Ingestion - Surface Water (Brooks, Springs/Seeps)

The evaluation of potential non-cancer health effects for the selected COCs (see Table 6 and 7) in surface water is accomplished by estimating the amount or dose of those contaminants that an adult or child might have ingested on a daily basis. The contaminant exposure dose is calculated using the following formula:

$$\textit{Exposure Dose (mg/kg/day)} = \frac{C \times IR}{BW}$$

where, mg/kg/day = milligrams of contaminant per kilogram of body weight per day;
C = concentration of contaminant in water (milligrams per liter or mg/L);
IR = ingestion rate (liters per day or L/day); and,
BW = body weight (kg)

Based on the historical information, it was assumed that Ringwood Mines/Landfill area residents were exposed to surface water contaminants for approximately 20 years (i.e., from 1965 to mid 1980s). The following assumptions were used to estimate the site-specific exposure doses for children and adult.

Exposure Scenario Assumptions				
Water Source	**Exposed Population**	**Ingestion Rate (L/day)**	**Years Exposed**	**Body Weight (kg)**
Surface	Child	1	10 (child) 20 (adult)	16
	Adult	2		70

Based on the maximum concentrations of benzene and 1,2-dichloropropane detected, exposure doses calculated for children and adults were lower than their corresponding health guideline CV and are unlikely to cause adverse non-cancer health effects (see Table 15). Based on the maximum (40 μg/L) and mean (16.56 μg/L) arsenic concentrations detected, exposure doses for children and adults were higher than the corresponding health guideline CV (see Table 15). Although health guideline CVs are unavailable for mercury and lead, non-cancer adverse health effects are discussed below.

Arsenic - Arsenic is a naturally occurring element widely distributed in the earth's crust. The MRL for arsenic is set at a level meant to protect against non-cancer health effects, specifically dermal lesions (ATSDR 2000). Chronic exposure to low levels of inorganic arsenic can cause a darkening of the skin and the appearance of small "corns" or "warts" on the palms, soles, and torso. Skin contact with inorganic arsenic may cause redness and swelling. Organic arsenic compounds are less toxic than inorganic arsenic compounds.

Based on the maximum concentration of arsenic detected in surface water, the chronic exposure dose calculated for children and adults (i.e., 0.0025 mg/kg/day and 0.0011 mg/kg/day) exceeded the ATSDR MRL of 0.0003 mg/kg/day (see Table 15). The calculated child and adult exposure doses are about 3.1 and 1.4 times higher than the NOAEL (i.e., 0.0008 mg/kg/day), respectively. Additionally, based on the mean concentration of arsenic detected (the more likely exposure scenario), the calculated chronic exposure dose for child was about 1.25 times higher than the NOAEL. As such, there is a potential for non-cancer adverse health effects from exposures to arsenic in surface water in the period 1965 - 1985 when the water was used for potable purposes.

Mercury - Thirty percent (6/20) of the samples collected from seeps were contaminated with mercury in the Ringwood Mines/Landfill site. Since a chronic oral MRL and RfD are unavailable for mercury, the calculated exposure dose for children and adults could not be compared to a health guideline CV (see Table 15). However, an intermediate oral MRL for mercury is available (0.002 mg/kg/day) and is based on increased kidney weight of rats exposed to mercuric chloride once every five days for twenty-six weeks (ATSDR 1999c). An uncertainty factor of 100 and a NOAEL of 0.23 mg/kg/day were used to calculate the MRL. Maximum exposure doses calculated for children and adults (i.e., 0.00083 mg/kg/day and 0.00025 mg/kg/day) were about 277 and 920 times lower than the oral intermediate NOAEL, respectively. It should also be noted that the oral RfD for mercuric chloride ($HgCl_2$) and methylmercury (CH_3Hg) are 0.0003 mg/kg/day and 0.0001 mg/kg/day, respectively (USEPA 2005). As such, although the exposure to mercury may have continued for about 20 years, the likelihood of non-cancer adverse health effects in area residents is considered low.

Lead - Both the maximum and the mean concentration of lead detected in the surface water exceeded the New Jersey action level (see Table 7). As discussed earlier, the IEUBK model may be used to evaluate the surface water ingestion pathway. The assumptions for the residential exposure scenario for children ages 6 - 84 months are:

- Children were exposed to lead through potable water, and,
- Model default values were used for all other variables.

The predicted geometric mean blood lead levels and the probability of blood lead levels exceeding 10 µg/dL (P_{10}) for children are shown in the following table:

Age (months)	Exposure Scenario			
	Maximum concentration = 120 µg/L		Mean concentration = 105 µg/L	
	Blood Lead Level[1] (µg/dL)	P_{10} (%)[2]	Blood Lead Level (µg/dL)	P_{10} (%)
6 -12	8.4	36	7.9	30
12 – 24	11.8	64	11	58
24 – 36	11.7	63	10.8	57
36 – 48	11.5	62	10.6	55
48 – 60	11	59	10.1	51
60 – 72	10.7	58	9.8	48
72 – 84	10.1	52	9.3	44

[1]Geometric Mean lead levels in blood; [2]probability of blood lead level > 10 µg/dL

For ingestion exposures to maximum lead concentration detected in surface water, the predicted blood lead levels in children for ages 6 - 84 months were from 8.4 to 11.8 µg/dL. In addition, the probabilities of blood lead levels exceeding 10 µg/dL for children ages 6 - 84 months was from 36 to 64 percent. For ingestion exposures to mean lead concentration detected in surface water, the predicted blood lead levels for children ages 6 - 84 months were between 7.9 and 10.8 µg/dL. However, the probabilities of blood lead levels exceeding 10 µg/dL for children ages 6 - 84 months was between 30 and 58 percent for the period 1965 - 1985 when the water was used for potable purposes.

Cancer Health Effects

The site-specific lifetime excess cancer risk (LECR) indicates the cancer potential of contaminants. LECR estimates are usually expressed in terms of excess cancer cases in an exposed population in addition to the background rate of cancer. For perspective, the lifetime risk of being diagnosed with cancer in the United States is 46 per 100 individuals for males, and 38 per 100 for females; the lifetime risk of being diagnosed with any of several common types of cancer ranges approximately between 1 in 100 and 10 in 100 (SEER 2005). Typically, health guideline CVs developed for carcinogens are based on a lifetime risk of one excess cancer case per 1,000,000 individuals. ATSDR considers estimated cancer risks of less than one additional cancer case among one million persons exposed as insignificant or no increased risk (expressed exponentially as 10^{-6}).

According to the United States Department of Health and Human Services (USDHHS), the cancer class of contaminants detected at a site is as follows:

1 = Known human carcinogen
2 = Reasonably anticipated to be a carcinogen
3 = Not classified

Ingestion - Sludge, Soil and Sediment

The cancer class of the COCs detected in the sludge, soil and sediment are given in Tables 16, 17, and 18. The tables show that bis(2-ethylhexyl)phthalate, PCBs, arsenic, cadmium, chromium in the paint sludge, benzene, benzo[a]pyrene, arsenic in the surface soil, and benzo[a]pyrene, arsenic in the sediment have the potential to cause cancer among exposed populations.

Estimated cancer exposure doses were calculated using the following formula:

$$\textit{Cancer Exposure Dose (mg/kg/day)} = \frac{C \times IR \times EF}{BW} \times \frac{ED}{AT}$$

where C = concentration of contaminant in soil (mg/kg);
IR = soil ingestion rate (kg/day);
EF = exposure factor representing the site-specific exposure scenario;
ED = exposure duration (year);
BW = body weight (kg); and,
AT = averaging time (year).

The assumptions used to calculate site-specific exposure doses were the same as described previously for non-cancer health effects. The LECR for adults was calculated by multiplying the cancer exposure dose by the cancer slope factor (CSF). The CSF is defined as the slope of the dose-response curve obtained from animal and/or human cancer studies and is expressed as the inverse of the daily exposure dose, i.e., $(mg/kg/day)^{-1}$.

Paint Sludge. Of the COCs identified in the paint sludge, arsenic is classified as a known human carcinogen, and bis(2-ethylhexyl)phthalate and Aroclors 1248 and 1254 are classified as reasonably anticipated to be carcinogens among exposed populations (see Table 16). Carcinogenicity information of chromium by oral exposure in humans is inadequate. Limited epidemiologic studies have indicated that exposure to cadmium in food or drinking water is not carcinogenic.

Based on the maximum concentration of arsenic detected in paint sludge, the LECR calculated was one in 1,000,000 to the exposed population (see Table 16). At the mean arsenic concentration (4.33 mg/kg), the more likely exposure scenario, the LECR was three in 10,000,000 to the exposed population. Overall, the LECRs associated with the contaminants indicated five in 100,000,000 to one in 1,000,000 based on the maximum and the mean concentrations, respectively.

Surface Soil. Of the COCs identified in the surface soil, benzene and arsenic are classified as known human carcinogens and benzo(a)pyrene is classified as reasonably anticipated to be a carcinogen among exposed populations (see Table 17). At the maximum concentration of contaminants in the surface soil, the LECR calculated was seven in 1,000,000 to the exposed population for arsenic (see Table 17). At the mean arsenic concentration (2.03 mg/kg), the more likely exposure scenario, the LECR was one in 1,000,000 to the exposed population.

The LECR calculated for other carcinogens (benzene, benzo[a]pyrene) were below one in 1,000,000 to the exposed population.

Sediment. Of the COCs identified in the sediment, arsenic is classified as a known human carcinogen and benzo[a]pyrene is classified as reasonably anticipated to be a carcinogen among exposed populations (see Table 18). Based on the maximum concentration of arsenic (31.4 mg/kg) detected in the sediment, the calculated LECR was one in 100,000 to the exposed population. Based on the mean concentration (9.13 mg/kg) of arsenic detected in the sediment (i.e., the more likely exposure scenario), the LECR was four in 1,000,000 to the exposed population. The LECR calculated for benzo[a]pyrene was one in 1,000,000 to the exposed population.

In summary, excess cancer risk from ingestion of paint sludge, surface soil, and sediment is estimated to be very low when compared to background cancer risk (see Figure 7).

<u>Lead in paint sludge and surface soil.</u> Although lead has not been classified as a carcinogen by the USDHHS[9], the carcinogenicity of inorganic lead and lead compounds have been evaluated by the USEPA (USEPA 1986, 1989). The USEPA has determined that data from human studies are inadequate for evaluating the carcinogenicity of lead, but there is sufficient data from animal studies which demonstrate that lead induces renal tumors in experimental animals. In addition, there are some animal studies which have shown evidence of tumor induction at other sites (i.e., cerebral gliomas; testicular, adrenal, prostate, pituitary, and thyroid tumors). A cancer slope factor has not been derived for inorganic lead or lead compounds, so no estimation of LECR can be made for lead exposure.

Ingestion - Surface Water (seeps/springs, brooks)

The ingestion cancer exposure doses were calculated using the following formula:

$$\text{Cancer Exposure Dose (mg/kg/day)} = \frac{C \times IR}{BW} \times \frac{ED}{AT}$$

where, C = concentration of contaminant in water (mg/L)
IR = contact rate (L/day)
ED = exposure duration (years)
BW = body weight (kg)
AT = averaging time (years)

LECRs were calculated by multiplying the cancer exposure dose with the CSF. The USDHHS cancer class for the contaminants of concern in the surface water and springs is presented in Table 19.

<u>Surface Water.</u> Of the COCs identified in the surface water, benzene and arsenic are classified as known human carcinogens among exposed populations (see Table 19). Based on the maximum and mean concentrations of benzene detected in surface water, the calculated LECRs are nine and seven in 10,000,000, respectively. Based on the maximum concentration of arsenic detected in the surface water, the calculated LECR was five in 10,000 to the exposed population (see Table 19). Based on the mean concentration (16.56 μg/L), i.e., the more likely exposure scenario, the calculated LECR for arsenic was two in 10,000 to the exposed population (see Figure 7).

Assessment of Joint Toxic Action of Chemical Mixtures

In the Ringwood Mines/Landfill site, residents may have been exposed to a number of contaminants detected in paint sludge, soil, sediment and surface water. Exposure to multiple chemicals with similar toxicological characteristics may increase

[9]Lead and Lead Compounds are listed in the Eleventh Edition of the Report on Carcinogens as ‘‘reasonably anticipated to be human carcinogens’’ (NTP 2006)

their public health impact. The severity of the impact depends on the particular chemicals being ingested, pharmacokinetics, and toxicity in children and adults.

To assess the risk for non-cancer adverse health effects of chemical mixtures, the hazard indexes (HI) and the ratio of exposure dose to NOAEL for the contaminants was calculated (see Appendix E for details). The results indicated that potential exists for additive or interactive effects of chemical mixtures from exposures to paint sludge and surface water, particularly for neurological effects associated with co-exposure to lead and arsenic (ATSDR 2004; ATSDR 2005).

Child Health Considerations

The NJDHSS and ATSDR recognize that the unique vulnerabilities of infants and children demand special emphasis in communities faced with contamination in their environment. Children are at greater risk than adults from certain types of exposures to hazardous substances. Their lower body weight and higher intake rate results in a greater dose of hazardous substance per unit of body weight. The developing body systems of children can sustain permanent damage if toxic exposures occur during critical growth stages. Most important, children depend completely on adults for risk identification and management decisions, housing decisions, and access to medical care.

The NJDHSS and ATSDR evaluated the potential risk for children residing in the Ringwood Mines area who were exposed to site contaminants. Exposures at the site (based on lead and antimony contamination of paint sludge, arsenic contamination of surface water, and lead contamination of soil and surface water) were found to have the potential to cause non-cancer adverse health effects in children. LECRs associated with the ingestion of paint sludge, surface soil, and sediment was estimated to be very low when compared to background cancer risk. Based on the maximum and mean concentrations of arsenic detected in surface water, the calculated LECRs were estimated to be approximately five and two excess cancer cases per 10,000 individuals (including exposure as children), respectively.

Health Outcome Data

Community members have raised health concerns they feel are related to exposures associated with site contamination. Those health concerns include cancer (ovarian, cervical, leukemia, breast, lung, Ewing sarcoma, colon), respiratory disease (asthma, emphysema), reproductive and developmental effects (female reproductive disorders, miscarriages, birth defects, learning disabilities, behavioral problems), neurological disorders, heart disease, skin rashes, eye irritation, anemia, and diabetes. With the exception of cancers and birth defects, these conditions are not reportable, and documentation on the frequency of each of these conditions over time is not available in any community in New Jersey. Cancer has been a reportable disease since late 1978 and has been evaluated for this public health assessment. Birth defect data are available, but because of the small size of the population and the rarity of the outcomes, these data have not been reviewed for this public health assessment.

Because of the potential for exposure to lead in contaminated site media, data on childhood blood lead tests were evaluated for the community. Information from the NJDHSS' Childhood Lead Poisoning Surveillance System is summarized below.

Childhood Lead Exposure

Since lead is an important contaminant associated with the paint sludge at the Ringwood Mines/Landfill site, the NJDHSS evaluated data on childhood blood lead levels. Blood lead is an excellent indicator of exposure to lead. Current state regulations, in accordance with federal Centers for Disease Control and Prevention (CDC) guidelines, require health care providers to do a blood lead test on all one and two year old children. This is the age at which lead poisoning is most damaging to the developing nervous system. State regulation requires all clinical laboratories to report the results of all blood lead tests to the NJDHSS. Prior to July 1999, only blood lead tests above 20 micrograms per deciliter (µg/dL) were reportable. While the current CDC blood lead guideline is 10 µg/dL, all blood-lead test data are reportable to the NJDHSS' Childhood Lead Poisoning Prevention Surveillance System.

Data from the Childhood Lead Poisoning Prevention Surveillance System was reviewed for the period July 1999 through October 2005 for Ringwood Borough. For the purpose of this discussion, children with multiple tests were assigned their highest blood lead level. A total of 909 Ringwood children were tested during this period.

The NJDHSS defined a "Focus Area" comprising the population in the Ringwood Mines area, to better understand the potential for exposure due to this site. The Focus Area includes children living on the following streets: Peters Mine Road, Cannon Mine Road, Horseshoe Bend Road, Van Dunk Lane, Milligan Drive, Petzold Avenue, Sloatsburg Road, Farm Road, Industrial Parkway, Boro Parkway, Chicken House Road, Manor Road, Margaret King Avenue, and Cable House Road. Of the 909 Ringwood children tested for blood lead between July 1999 and October 2005, 45 lived in the Focus Area, 861 lived in non-Focus Area locations in Ringwood, and three had insufficient address information to determine residential location.

For the non-Focus Area, seven children had a blood lead level of 10 µg/dL or higher. The rate of elevated blood lead level was 8 children per 1,000 tested. The range of blood lead levels was 1 to 26 µg/dL with a geometric average of 2.5 µg/dL (95% confidence interval: 2.4 to 2.6 µg/dL). The average age at time of the test for non-Focus Area children was 28 months, with a range of less than one month to 198 months.

For the Focus Area, two children had a blood lead level of 10 µg/dL or higher. The rate of elevated blood lead level was 44 children per 1,000 tested. The range of blood lead levels was 1 to 28 µg/dL with a geometric average of 3.7 µg/dL (95% confidence interval: 3.0 to 4.4 µg/dL). The geometric average blood lead level was statistically significantly higher in the Focus Area children than the non-Focus Area children. The average age at time of the test for Focus Area children was 30 months, with a range of two to 113 months.

In Figure 8, childhood blood lead levels were categorized into 14 2-µg/dL intervals by Area, and displayed as a percentage for each category. While most children had a blood lead level below the 10 µg/dL level, there appears to be a slight shift to the right (higher levels) in the distribution of blood lead levels in the Focus Area children. This shift in the distribution of blood lead levels in Focus Area children could be an artifact due to the relatively small sample size, or it could indicate that these children had slightly more exposure to lead in the environment than non-Focus Area children.

The Ringwood Health Department has followed up on the two children in the Focus Area whose blood lead levels exceeded 10 µg/dL. The elevated blood lead level for one child was attributed to potential exposure to lead in paint sludge, while for the other child the likely cause of elevated blood lead was lead paint during home renovation (S. Wogish, Ringwood Borough Health Department, personal communication, 2003).

The occurrence of a child with an elevated blood lead level associated with potential exposures to contaminated soils is consistent with lead model estimates (based on limited data available for Residence 1) for average lead levels in residential soils.

Cancer Incidence

The NJDHSS and ATSDR evaluated cancer incidence in the population living near the Ringwood Mines/Landfill site (see Appendix F for a detailed report). Total cancer incidence and 13 specific cancer types were evaluated. The specific cancers types were selected because they represent cancer groupings that may be more sensitive to the effects of environmental exposure, in general. The New Jersey State Cancer Registry, a population-based cancer incidence registry covering the entire state, was used for the ascertainment of cancer cases. The study period for this investigation was January 1, 1979 through December 31, 2002. Standardized incidence ratios (SIRs) were used for the quantitative analysis of cancer incidence. The SIR compares the observed number of cases to an expected number of cases based on average state rates. Males and females, all races combined, were evaluated separately. Cancer data was evaluated for all of Ringwood and for the area of town closest to the site. As with the analysis of blood lead levels, this area is called the Focus Area for this discussion (see Appendix F Figure 1).

For Ringwood Borough as a whole, neither all cancers combined nor any of the 13 specific cancer types were elevated compared to the state. For the Focus Area, lung cancer in males was significantly higher than expected (SIR=2.8). Lung cancer in Focus Area females was slightly lower than expected (SIR=0.9). No other specific cancer types analyzed were significantly higher than expected, that is, differences from expected are within the range of variation due to chance.

Cancer is a group of more than 100 different diseases (i.e., cancer types and subtypes); each cancer type has its own set of risk factors. The multifactorial nature of cancer etiology, where a given disease may have more than one cause, complicates the evaluation of potential risk factors and specific disease outcomes. Known or probable human carcinogens were found in completed human exposure pathways at the Ringwood Mines/Landfill site. Arsenic has been identified as a possible risk factor for certain cancer types, including lung cancer (ATSDR 2000). PAHs are considered a probable human carcinogen based on animal experiments and may increase the risk of developing cancer, especially lung and skin cancers (American Cancer Society 2004 and ATSDR 1995).

While there are multiple risk factors for lung cancer, tobacco smoking is considered the most important risk factor, estimated to account for more than 85% of all lung cancer cases (National Cancer Institute, 1996). Other known risk factors for lung cancer include indoor exposure to radon and environmental tobacco smoke, occupational exposure to asbestos and other cancer-causing agents in the workplace (including radioactive ores; chemicals such as arsenic, vinyl chloride, nickel, chromates, coal products, mustard gas, and chloromethyl ethers; fuels such as gasoline; and diesel exhaust), and exposure to air pollution (American Cancer Society, 2004).

The overall cancer incidence (all cancers combined) was not elevated in the Focus Area. Lung cancer in males was significantly higher than expected while lung cancer in females was slightly lower than expected in the Focus Area. Since smoking histories are not available in the NJSCR, it is unknown what influence this important risk factor may have played. Given that lung cancer incidence in females is lower than expected, the current analysis provides little evidence that the rate of cancer incidence in the Focus Area population is due to potential exposure to Ringwood Mines contamination.

Evaluation of Other Community Health Concerns

In addition to cancers, the community has raised other health concerns they feel are related to exposures associated with site contamination: respiratory diseases (asthma, emphysema), reproductive effects (female reproductive disorders, miscarriages, birth defects), developmental effects (learning disabilities, behavioral problems), neurological disorders, heart disease, skin rashes and eye irritation, anemia, and diabetes. Community members have also expressed concerns about early mortality.

This is a diverse list of diseases and conditions, each of which may be caused by multiple non-environmental and environmental factors. There is no systematically collected surveillance data for these diseases (except for birth defects) in New Jersey, so an analysis of data cannot be conducted. As such, these community health concerns will be discussed in relation to the known or suspected toxicologic characteristics of the chemicals in completed exposure pathways that had the potential to cause non-cancer adverse health effects. The evaluation is based on the health effects reported in ATSDR's Toxicological Profiles for lead, antimony and arsenic. (Detailed discussions of general toxicologic characteristics of these chemicals are found in Appendix D.)

Although a quantitative assessment of exposure to chromium by dermal exposure was not conducted, chromium will be included in this discussion.

Lead. Lead exposure may affect many body organs and systems, causing effects in the gastrointestinal tract, hematopoietic system (blood making organs), cardiovascular system (blood pressure), central and peripheral nervous systems, kidneys, immune system, and reproductive system. Based on the exposure dose estimates for the Ringwood Mines/Landfill site discussed earlier, the highest estimated exposures would have occurred through the ingestion of paint sludge around the time of dumping. Lead in soils, particularly in residential areas, has also been a significant contributor to lead exposure; removal of paint sludge has decreased the potential for this exposure over the years.

Lead exposures are generally expressed in terms of concentration of blood lead. The concentration of blood lead reflects mainly the exposure history of the previous few months and does not necessarily reflect the cumulative exposure to lead over longer periods of time. Depending on the length of exposure, lead may accumulate in bone.

Based on presumed exposure scenarios, the child and adult blood lead level associated with ingestion of lead in paint sludge were calculated using the IEUBK and adult lead models, respectively. For adults, mean blood lead levels were estimated to reach 40 µg/dL, and for children, mean blood lead levels exceeded this level. Blood lead data are not available to determine whether the levels in children or adults reached these modeled levels in the past, in the population living near the Ringwood Mines/Landfill site. Based on the maximum and mean soil lead levels detected in residential soils, the model predicted a mean blood level up to 27 µg/dL and up to 8.6 µg/dL for children, respectively. As discussed above, additional lead exposure may have occurred during the time that surface water was used as a drinking water source.

It should be noted that the mean current blood lead level among children aged 1 - 5 years in the U.S. is approximately 2 µg/dL (CDC 2005). However, general population exposures were considerably higher in the past due to the use of tetraethyl lead in gasoline. For example, in the late-1970s, the geometric mean blood lead levels in children (1 - 5 years) in the US were 15 µg/dL (ATSDR 1999a).

For children, blood lead levels exceeding 30 µg/dL may result in delayed nerve conduction velocity. Levels above 40 µg/dL may cause depressions in hemoglobin levels, and levels above 60 µg/dL may result in gastrointestinal disturbances such as colic. Blood lead levels in children above 70 µg/dL may result in serious effects on brain function (encephalopathy). Lower levels of blood lead in children may also increase the risk of certain health effects. Blood lead levels above approximately 15 µg/dL may depress Vitamin D levels and affect red blood cell production. Even levels of 10 µg/dL or below may be associated with delays or impairments in neurodevelopment, delayed sexual maturation, and inhibition of enzymes involved in the synthesis of hemoglobin, a component of red blood cells. There is also some indication that lead exposure may heighten immune response and increase the risk of asthmatic reactions. In adults, high levels of lead exposure (>30 to 40 µg/dL) may result in kidney effects, neurological and neurobehavioral effects, reduced fertility, altered thyroid hormones, and depressed hemoglobin.

Health effects of exposure to lead include several of the diseases and conditions of concern to the community. This is especially true of past exposures to paint sludge, but also to a lesser but still important degree, of exposure to lead in residential soils.

Antimony. No information is available regarding the chronic toxicity of antimony in humans. From experimental animal studies, target body systems and organs for long-term exposure to antimony are the blood (hematological disorders) and liver (mild hepatotoxicity) (ATSDR, 1990). In rats, long-term exposure to potassium antimony tartrate in the drinking water resulted in decreased lifespan. The LOAEL of 0.35 mg/kg/day from this study was used to calculate the chronic oral RfD of 0.0004 mg/kg/day. Mean exposure doses of antimony from ingestion of paint sludge (children, 0.19 mg/kg/day; adults 0.021 mg/kg/day) were estimated to exceed the chronic oral RfD, and were near the LOAEL. The same study showed an increase in serum cholesterol and a decrease in fasting glucose levels for rats receiving a lifetime exposure to potassium antimony tartrate (746 mg/kg/day) in drinking water. However, the biological significance of these findings in rats or humans is not certain. Since the estimated mean exposure doses from ingestion of antimony in paint sludge approached the LOAEL, it is possible that exposures to antimony in paint sludge caused an adverse health impact. However, it is not clear whether any of the health outcomes of concern to the community might be related to antimony exposure.

Arsenic. Ingestion of water from springs/seeps and brook may have resulted in long-term mean exposure to arsenic exposure doses of approximately 0.001 mg/kg/day in children and 0.0005 mg/kg in adults.

The effect of long-term oral exposure to inorganic arsenic compounds is associated with development of skin lesions. These lesions may appear at chronic exposure doses ranging from 0.002 to 0.02 mg/kg/day. Studies of chronic oral exposure to arsenic at levels ranging from 0.0004 to 0.01 mg/kg/day have not reported dermal effects. The mechanism(s) by which inorganic arsenic causes dermal effects is not well-understood.

Numerous studies of acute, high-dose exposures have reported nausea, vomiting, diarrhea, and abdominal pain, although specific dose levels associated with the onset of these symptoms have not been identified. Chronic oral exposures have been reported to result in irritant effects on gastrointestinal tissues at levels as low as 0.01 mg/kg/day. For both acute and chronic exposures, the gastrointestinal effects generally diminish or resolve with cessation of exposure.

Ingestion exposure to high levels of inorganic arsenic may result in the development of peripheral neuropathy. Reports of neurological effects at lower arsenic levels (0.004–0.006 mg/kg/day) have been inconsistent, with some human studies reporting fatigue, headache, depression, dizziness, insomnia, nightmare, and numbness while other studies reported no neurological effects.

Relatively little information is available on effects due to direct dermal contact with inorganic arsenic compounds, but several studies indicate the chief effect is local irritation and dermatitis, with little risk of other adverse effects.

Mean arsenic exposure doses in the Ringwood Mines/Landfill area are lower than levels of arsenic exposure associated with non-cancer health effects. Therefore, it seems unlikely that exposure to arsenic is related to health outcomes of concern to the community.

<u>Chromium.</u> Chromium was detected in paint sludge at a mean concentration of 1,640 mg/kg, as total chromium. However, the proportion of chromium (VI), the more potent form, is not known. At soil concentrations exceeding 270 mg/kg, exposure to hexavalent chromium may cause allergic contact dermatitis. Therefore, it is possible that "skin rashes" reported to be of concern by the community may be related to past exposure to chromium in paint sludge.

<u>Summary of Other Community Health Concerns in Relation to Site Contaminants.</u> Respiratory diseases mentioned by the community include asthma and emphysema. While emphysema is unlikely to be related to exposure to site-related contaminants, there is some evidence that lead exposure may increase asthmatic episodes. However, there are numerous other, common triggers of asthma, and any linkage to potential site exposures would have to be determined on an individual basis. Diabetes is also unlikely to be related to site-related contaminants.

Community concerns also included reproductive and developmental effects, neurological disorders, cardiovascular disease, and anemia. Studies have shown that these health effects may be associated with exposure to lead at varying levels of chronic or acute exposure. However, all of these health outcomes may be caused by many other non-environmental (e.g., behavioral) and environmental risk factors.

Skin lesions and neurological disorders may also be associated with exposure to arsenic. However, the estimated levels of ingestion exposure to arsenic in the past do not appear to be sufficiently high to have resulted in these effects. It is possible that skin rashes reported to be of concern by the community may be related to past dermal exposure to chromium in paint sludge.

Conclusions

Disposal of paint sludge and other waste materials at the Ringwood Mines/Landfill site during the late 1960s and early 1970s resulted in the contamination of soil, sediment, and ground and surface water. Although remedial actions were taken in 1987/1988 and the site was deleted from the NPL in 1994, paint sludge and associated soil contamination is still being found, including at on-site residential properties. At the present time, additional site characterization and remedial actions are being implemented to address the paint sludge and soil contamination.

In the past, there were completed exposure pathways to area residents via the ingestion of contaminated surface water and the incidental ingestion of contaminated paint sludge, soil, and sediment. Contaminants of concern identified for the site were Aroclors, bis(2-ethylhexyl)phthalate, antimony, arsenic, cadmium, chromium, copper and lead in paint sludge, benzene, benzo[a]pyrene, arsenic, lead and thallium in soil, benzo[a]pyrene, arsenic and thallium in sediment, benzene, 1,2-dichloropropane, arsenic, lead and mercury in surface water, and benzene, methylene chloride, bis(2-ethylhexyl)phthalate, pentachlorophenol, arsenic, cadmium, lead and thallium in groundwater. In addition, tetrachloroethene, antimony, beryllium, lead and silver detected in off-site potable wells and lead detected in residential soils exceeded their respective environmental guideline CVs.

Exposures associated with lead and antimony contamination detected in paint sludge, arsenic contamination detected in surface water, and lead contamination detected in soil and surface water were found to have the potential to cause non-cancer adverse health effects in children and adults. Potential health hazard due to additive or interactive effects of chemical mixtures may be greater than estimated by the endpoint-specific hazard index, particularly for neurological effects associated with co-exposure to lead and arsenic. Lifetime excess cancer risks associated with the ingestion of paint sludge, surface soil, and sediment were estimated to be very low when compared to background cancer risk. Based on the maximum and mean concentrations of arsenic detected in surface water, the calculated lifetime excess cancer risks were estimated to be approximately five and two excess cancer cases per 10,000 individuals, respectively.

Paint sludge is the likely source of lead and antimony at the site. Arsenic, however, may be naturally occurring in the area. Lead was detected in on-site residential soils at concentrations of health concern to children. Based on health risks posed by exposures to lead and antimony, the site posed a ***Public Health Hazard***[10] in the past. Since there may be on-going exposure from paint sludge and soil at levels of health concern, the site currently poses a ***Public Health Hazard***.

Ringwood Mines area residents and others may have been exposed to contaminated ambient air, biota, and off-site groundwater. These exposures constitute an ***Indeterminate Public Health Hazard*** as no data or insufficient data are available for evaluation.

Childhood blood lead data available from the NJDHSS Child and Adolescent Health Program were evaluated for the Ringwood Mines/Landfill area site. Data available since 1999 showed a higher proportion of children with elevated blood lead levels (>10 μg/dL) and a slightly higher average childhood blood lead level in the area closest to the Ringwood Mines/Landfill area in comparison to the rest of Ringwood

[10]A complete summary of ATSDR conclusion categories are provided in Appendix G.

Borough. Although there are multiple sources of lead in a child's environment (such as peeling lead-based paint in homes), lead containing paint sludge may have contributed to these differences in blood lead levels.

An analysis of cancer incidence in the Ringwood Mines/Landfill area was conducted. In the period 1979 - 2002, overall cancer incidence was not elevated. However, lung cancer incidence was statistically elevated in males in the area closest to the Ringwood Mines/Landfill site. It is not known whether past exposure pathways are related to this observation. Information on smoking history, the most important risk factor for lung cancer, was not available. Since lung cancer incidence was not elevated in females, there is little evidence that cancer incidence has been affected by Ringwood Mines/Landfill site contamination.

Other health concerns that residents believe are related to exposures to the Ringwood Mines/Landfill site contamination include respiratory diseases, reproductive and developmental effects, neurological disorders, heart disease, skin rashes and eye irritation, anemia, and diabetes. Many of the community's concerns are consistent with health effects of lead and arsenic exposures reported in the scientific literature; however, these health outcomes may also be caused by other environmental and non-environmental risk factors.

Recommendations

1. Efforts by the USEPA and NJDEP to fully characterize, delineate and remediate the paint sludge contamination of environmental media and residential properties should be completed as soon as feasible. Special consideration should be given to children's play areas and residential gardens.

2. The USEPA should delineate groundwater contamination and consider reinstituting an Environmental Monitoring Plan, particularly for off-site potable wells and other potential exposure points.

3. The USEPA or the NJDEP should characterize the potential contamination of local biota, particularly game consumed by Ringwood Mines/Landfill area residents.

4. The USEPA should further characterize the site to determine the background contribution to the concentration of arsenic and other COCs.

5. Because of the potential for exposure to metals from the paint sludge and contaminated soils, an exposure investigation of the population living on the Ringwood Mines/Landfill site should be conducted. This investigation should include biological testing of adults and children for current exposure to lead, antimony, and arsenic. Such testing should be undertaken at a time of year when the potential for exposure is highest, and it should be made clear that biological

testing for these metals would not be indicative of past exposure levels. The exposure investigation should also include concurrent testing of environmental media such as indoor dust and soils close to homes.

Public Health Action Plan

The purpose of a PHAP is to ensure that this public health assessment not only identifies public health hazards, but also 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 follow up on this plan to ensure that it is implemented. The public health actions to be implemented by the NJDHSS and the ATSDR are as follows:

Actions Undertaken

1. The NJDHSS and ATSDR have prepared this public health assessment in response to a petition from legal counsel representing the community.

2. The NJDHSS and ATSDR have participated in public availability sessions and meetings with local residents. ATSDR and NJDHSS met with the community to inform area residents of the preliminary results of the public health assessment and to obtain pertinent exposure-related information.

Actions Planned

1. Copies of this Public Health Assessment will be provided to concerned residents in the vicinity of the site via direct mail, the township library and the Internet.

2. Public meetings will be scheduled with area residents to discuss the findings of this report and to address any community concerns.

3. As remedial investigation data (from the residential properties) become available, the NJDHSS and ATSDR will evaluate the public health implications of contaminants detected and provide assistance to residents in reducing exposures to chemicals.

4. As a member of the New Jersey Environmental Justice Task Force, the NJDHSS will work with NJDEP and other state agencies to develop an appropriate Action Plan in cooperation with the community.

5. The NJDHSS and ATSDR will begin planning for implementation of an Exposure Investigation to determine the extent of exposure to heavy metals from environmental media contaminated by paint sludge. Plans should be developed in conjunction with community members, and may follow a phased approach as outlined in the January 2005 Environmental Health Initiative (RNAA 2005). As a

first step, the NJDHSS and ATSDR have begun outlining available biological monitoring tests, meanings and limitations of such tests, and laboratory capabilities for testing, and will provide this information to the community. The NJDHSS and ATSDR will also work with the USEPA and NJDEP to coordinate potential environmental testing that would be conducted in association with biological monitoring.

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