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REGIONAL COPPER-NICKEL STUDY

MINNESOTA ENVIRONMENTAL QUALITY BOARD

VOLUME 5, Chapter 2

PUBLIC HEALTH

Volume 5-Chapter 2

PUBLIC HEALTH

Minnesota Environmental Quality Board
Regional Copper-Nickel Study
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2.1 INTRODUCTION AND SUMMARY OF FINDINGS

The effects of a mining industry to the health of workers and nearby communities have undergone many changes in the past century. In the early years mining companies would extract minerals as quickly as possible, in the most profitable manner, and move on when the deposit was exhausted. Little concern was given to safe working conditions, except when they were so unsafe that productivity would suffer. Silicosis was an expected outcome for miners. Development of community health services, such as safe drinking water, hospitals, and even the availability of doctors and nurses, occurred more by chance than by industry efforts. Boom and bust cycles had severe effects on the social fabric and quality of life in mining communities. Air emissions of pollutants adversely affected health in nearby communities.

Although many of these problems still exist, they have been mitigated by a number of factors. Unions have made it possible for workers to obtain safer working conditions and comprehensive medical services. Government intervention has increased accident control efforts and caused a drastic reduction in the incidence of silicosis. Attitudes toward emission of pollutants have changed from whether to control emissions, to how to control emissions. Industry, too, has changed its approach to health because of demands from labor and government, because of its social responsibility, and a desire to smooth out the ups and downs inherent in the minerals industry. New technology has been developed both for increased productivity and to provide a safer, cleaner working environment.

Approximately 330,000 people reside in the seven-county area of northeast Minnesota. This population is split equally among Duluth, the Iron Range com-

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munities, and other areas of the region. Very few people live in the ten miles southeast (downwind) of the Duluth Gabbro Contact. Compared to state residents, northeast Minnesota residents are slightly older; more likely to be rural non-farm residents, less likely to be rural farm or urban residents; have a lower average income; have equal education; are more likely to smoke cigarettes; and have a higher fertility rate.

Mortality rates in northeast Minnesota are higher than the state for infant mortality, all causes of death combined, and each of the twelve leading causes of death. However, the mortality experience of northeast Minnesota is similar to and in some cases better than that of the United States.

Health manpower and facilities are well-distributed with regard to population. Relative to population there are fewer physicians, dentists, and registered nurses in northeast Minnesota than in the state as a whole; however, there are no obvious shortages of these professionals. St. Louis County has one of the best public health departments in the state. Public health services elsewhere in the region are much less comprehensive, which is to be expected considering the size and needs of this population. Compared to federal guidelines, northeast Minnesota has an excess of hospital facilities as measured by the number of licensed beds per 1000 population and bed occupancy rates. Long-term care facilities (convalescent and nursing care units, nursing homes, and boarding care homes) are currently utilized to capacity. Relative to population there are fewer licensed beds for long-term care in northeast Minnesota than the state as a whole, suggesting a possible shortage of these facilities. Northeast Minnesota appears to have the resources to meet federal guidelines for emergency medical services.

Over seventy percent of the population in northeast Minnesota is served by public water and sewer systems. It is estimated that over 20,000 wells and sep-

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tic tanks each are in regular use in this region. Underground sources of drinking water are generally preferable to surface sources because they are less subject to intermittent pollution and fluctuations in quantity. Surface sources are used by Aurora, Ely, Hoyt Lakes, and Winton, which are all close to the Duluth Gabbro Contact, and by Beaver Bay, Duluth, Eveleth, Grand Marais, Silver Bay, and Two Harbors, which are somewhat farther from the Contact. Iron, manganese, and hardness frequently affect the water quality in this region, but have little effect on health. Cleavage fragments closely resembling asbestos fibers have been found in Lake Superior. The significance of this finding with regard to health is uncertain.

Power generation and taconite processing are the major point sources of air pollutants in the region and account for most of the sulfur dioxide and particulate emissions, respectively. Petroleum refineries and paper companies are other major sources of pollutants.

Epidemiological studies of counties with copper and/or nickel development have found evidence of increased mortality in almost all cases. Increased mortality rates occurred most often for respiratory cancers, accidents, and cardiovascular diseases. Although a direct correlation between these results and copper-nickel development in Minnesota may not be possible, these studies suggest that something about existing copper and/or nickel development may be directly or indirectly affecting the health of the nonoccupational population. There is strong evidence that smelter emissions have been responsible for increased absorption of some metals in those living nearby. Those living within 1.6 km of a smelter have been found to have the greatest exposures, but increased exposures have occurred at least out to 6.6 km. Children, particularly those aged 1-4 years, show the greatest increases in absorption of metals.

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Hospitals in northeast Minnesota appear to have excess capacity and could probably accommodate the increased demands on their facilities if copper-nickel development occurs. Health manpower appears to be sufficient for current needs; however, northeast Minnesota has proportionally the same or fewer health care professionals than the state as a whole. Emergency medical services (particularly emergency personnel) are probably the weakest link in the health services system in northeast Minnesota. If sufficient preparations are not made to cope with the expected increased needs created by a new mining industry, victims of accidents and diseases could be much more seriously affected by their conditions than if satisfactory medical care had been available. Over the long run, a shortage of long-term care facilities could occur as the population ages. Public health services appear to have the flexibility to rapidly respond to changing service demands.

Potential impacts on health of most significance, identified as such because appropriate controls have limited or unknown effectiveness are associated with accidents, nickel, particulates/dust, population pressures, and sulfur oxides. These conclusions are heavily dependent on the assumption that extensive "state of the art" controls will be installed or implemented and operated to maximum effectiveness in controlling impacts judged to be less significant. In addition the potential impacts on health were difficult to assess based on available information in five other cases (arsenic, asbestos (mineral fibers), cadmium, lead, and mercury). Biological and environmental monitoring is considered prudent in these cases. These conclusions are summarized in Table 1.

Table 1

Accident rates for a copper-nickel industry in Minnesota would probably be higher than rates for the existing minerals industry in Minnesota because new

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Tab[illegible]1. Potential Impacts on Human Health

LEGEND

S-Impacts for which controls are of unknown or limited effectiveness

M-Biological and environmental monitoring prudent

	Exploration & Construction				Underground Mining				Open-pit Mining				Processing				Smelting & Refining			
	Workers	Families of Workers	General Community	Visitors	Workers	Families of Workers	General Community	Visitors	Workers	Families of Workers	General Community	Visitors	Workers	Families of Workers	General Community	Visitors	Workers	Families of Workers	General Community	Visitors
Accidents	S				S				S				S				S			
Aluminum																				
Arsenic																	M	M	M	
Asbestos (M.fibers)	M				M	M			M	M	M		M	M	M					
Cadmium																		M	M	
Carbon monoxide																				
Cobalt																				
Copper																				
Explosives																				
Iron																				
Lead																		M	M	
Manganese																				
Mercury													M	M	M	M	M	M	M	M
Nickel																	S			
Nitrogen oxides																				
Noise																				
Particulates/dust					S				S				S				S			
Population pressures	S	S	S		S	S	S		S	S	S		S	S	S		S	S	S	
Processing chemicals																				
Silica																				
Sulfur oxides																	S	S	S	
Zinc																				

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and less experienced workers are more likely to be involved in accidents and the more hazardous underground mining techniques which are not currently in use in Minnesota may be used. Complications following accidents may be severe since potential sites for development are generally over 20 miles from existing hospitals and existing personnel are not sufficient to handle more than minor accidents. If a new copper-nickel industry does not make preparations for the treatment of accident victims, complications following accidents may be more severe than necessary.

The risk of cancer presented by nickel dusts in nickel refineries is one of the most significant potential impacts of copper-nickel development. Because the time interval between first exposure to nickel and development of cancer is so long, the effectiveness of existing controls is unknown. Nickel carbonyl ($Ni(CO)_4$) and nickel subsulfide (Ni_3S_2) are the forms of nickel most often implicated as carcinogens; however, other forms ~~are~~ may also be carcinogenic.

In all stages of copper-nickel development except exploration, particulates may cause public health impacts. Chronic respiratory diseases may occur after many years of excessive dust exposure. These diseases, once diagnosed, may be halted but not reversed.

The high level of health enjoyed by modern society is largely due to the complex web of environmental controls used to protect health. A rapidly growing population, which could accompany copper-nickel development, might strain existing controls and be lax in the provision of additional controls. Estimates of population increase show that the populations of Ely and Babbitt could double under some development alternatives. Potential impacts from rapid population growth could well be the most significant impacts on health from copper-nickel development and yet go undetected because of difficulties in measuring and evaluating such impacts.

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Sulfur dioxide and sulfuric acid mist are the forms of sulfur oxides most likely to affect health in the occupational setting, while sulfur dioxide and sulfates are of most concern in the nonoccupational setting. Copper smelters have been one of the largest sources of sulfur oxide emissions in the U.S. Fugitive emissions of sulfur oxides, especially sulfuric acid mist, are difficult and costly to control within the plant. Use of hygiene, secondary collecting hoods, and Hoboken converters, plus reducing the number of converter "blows" should be effective in reducing fugitive emissions, but little operating experience and supporting data are available. Workers exposed to sulfur dioxide have experienced increased rates of chronic respiratory disease at levels as low as 1-2.5 ppm. Highly susceptible populations such as the elderly or chronically ill, may occasionally experience temporary aggravation of respiratory diseases.

In addition to the above groups it would be prudent to monitor possible effects on health due to the following (monitoring proposals are included in a separate document):

Arsenic in concentrate samples is present in very low concentrations compared to those from other U.S. copper smelters. Arsenic, particularly when present in the trivalent form, is a lung and skin carcinogen and causes dermatitis. Children living within four miles of each of eleven U.S. copper smelters studied showed evidence of increased external and systemic exposure to arsenic as measured by hair and urine samples.

Asbestos (mineral fibers) has caused lung cancer, asbestosis, and mesothelioma in workers and mesothelioma in some cases without occupational exposure. There are studies currently in progress to determine if ingestion of mineral fibers may cause gastrointestinal cancer. These diseases take many years to develop following initial exposure to fibers. Hydrous minerals, which are the source of

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mineral fibers in the case of Reserve Mining, are present in copper-nickel ore. Studies of those exposed to mineral fiber emissions (air and water) from Reserve should help clarify the risk of disease due to mineral fibers emitted by a copper-nickel industry.

Cadmium is present in very low concentrations and has been below detection limits in over half the samples. Children living within four miles of nine of eleven U.S. copper smelters showed evidence of increased external exposure to cadmium as measured in hair samples. Cadmium accumulates in the body and may cause chronic cadmium poisoning after years of increased exposures.

Lead levels in concentrate samples (64 ppm) appear to be lower than those in concentrates in most other U.S. copper smelters. Children living near some U.S. copper smelters have shown evidence of increased lead exposure as measured in blood and hair samples. Lead accumulates in the body, and taken in conjunction with other sources of lead in the environment presents a potential hazard of uncertain significance.

Mercury is present in low levels (less than 0.2 ppm) in concentrate samples. An estimated 110 kg/year would be emitted from a smelter and 1150 kg/year would be discharged with tailings for every 100,000 tons of copper plus nickel produced. A public health hazard arises when mercury is bioaccumulated by fish. Fish in some northeast Minnesota lakes already contain mercury at levels exceeding the FDA standards of 0.5 ppm. Although deposition of air-borne mercury is believed to be responsible, a specific source of mercury in the region has not been identified. No information is currently available on the mobility and biological availability of mercury from copper-nickel wastes. Until new information is found concerning the source and fate of mercury in northeast Minnesota lakes, it would be prudent to carefully evaluate and control any new sources of mercury no matter how small.

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2.2 PHILOSOPHY AND METHOD OF APPROACH TO REGIONAL CHARACTERIZATION

2.2.1 Methodology

The goal of the health studies has been to identify and characterize potential impacts on health from copper-nickel development so that, if it occurs, attention can be focused on controlling the most significant potential impacts. It has been assumed that the vast majority of potential impacts from copper-nickel development have been observed in other instances of development; therefore, previously observed impacts have received the most attention in this analysis. Impacts not previously observed may be potentially significant and have also been considered in some cases. In addition, it was attempted to make this a dynamic document by including reference materials and methodologies applicable to further studies of copper-nickel development.

Two methods were used to analyze the potential impacts of copper-nickel development on health. The first was an analysis of specific agents of disease, examining the population groups which may be at risk, and the conditions under which health might be affected. The second, a disease oriented approach, examined the mortality and morbidity experience of regions which already have copper and/or nickel development.

Initially a comprehensive list of potential agents was compiled. Collection of specific information concerning agents placed primary emphasis on identification of impacts on health which had been observed in other instances of copper and/or nickel development. Secondary emphasis was placed on impacts which have been reported for industries other than copper-nickel, but which appeared to be applicable to copper-nickel as well. Supplemental information beyond these bounds was collected, but received less attention. The latter group includes potential impacts which may not have been studied sufficiently, and hence there

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is the possibility that some potentially significant impacts which do not as yet have precedents have been missed.

Mortality and morbidity data were examined to determine the diseases experienced by populations living near mineral industries. In the occupational setting specific agents of disease can usually be identified, but in the general community, identification of agents is much more difficult. Collection of information consisted of studies published in the literature, personal communications with appropriate regional officials and a special mortality study of selected counties in the United States.

Using the background information from these two methods, a three-step analysis process examined the potential impacts of copper-nickel development in northeast Minnesota. In the first step all the possible impacts were prioritized according to copper-nickel development in general. Second, the possible impacts were prioritized according to their applicability to northeast Minnesota. Third, the significance of potential impacts was analyzed in detail based upon the severity of possible effects on health and the ability of pollution control devices to prevent potential impacts.

2.2.2 Discussion of Concepts

2.2.2.1 Agent-Host-Environment Relationships--In order for disease to occur there must be a causative agent and a susceptible host. Disease is also influenced by environmental factors. Therefore, in the study of disease it is important to understand all three factors and the relationships among them. This discussion will focus on non-communicable diseases, the type that is most likely to result from copper-nickel development. These principles were first developed for com-municable diseases and apply to them as well.

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The risk from a particular agent is related to several factors. Toxicity refers to the dose or quantity of agent required for disease to occur. When comparing two agents for toxicity the one that affects health at a lower dose is said to be more toxic. Quantity of agent present is important both in terms of the potential health effects and the severity of those effects. Some agents accumulate in the environment and are concentrated by plants and animals. The mobility of an agent in the environment affects the risk of disease. Agents with high volatility in air or high solubility in water are most likely to come into contact with humans. Persistence, as applied to chemicals, refers to the length of time an agent remains in the environment before it changes to another chemical which may be more or less toxic. Form of the agent refers mainly to compounds of trace elements and is a major determinant of potential impacts on health. For example, trivalent arsenic is much more toxic than pentavalent arsenic and there are different threshold limit values (TLVs--see section 2.2.2.8) for the different forms of arsenic. Physical characteristics of an agent, such as particle size, determine how an agent is transported and how far it penetrates into the respiratory tract.

Characteristics of the host population affect response to various agents and observed disease patterns. Age distribution of the population is of particular concern because the elderly have higher mortality rates than younger age groups. Males and females experience most diseases to different degrees. Different ethnic groups experience diseases in varying degrees both because of genetic differences and different customs. Health status of individuals is also affected by their physiologic state, nutritional status, existing disease, previous disease experience, and stress. Response to equal exposures of the same agent varies among individuals because some are more sensitive and some less sensitive. Aspects of human behavior, such as smoking, occupation, recreation,

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household hygiene, and utilization of medical care also influence the occurrence and severity of disease.

Many environmental factors influence the responses of hosts to various agents and observed disease patterns. Physical factors of the environment such as geology, geography, climate, and meteorology may all influence the dose and duration of exposure an individual receives and the ability of the individual to resist disease. The biologic environment strongly influences the type of economy, occupations, and recreational habits of a population, which in turn influence patterns of disease. Socio-economic factors which influence occurrence of disease include: population distribution, both in terms of density and proximity to industrial activity; housing; education; income; environmental sanitation; availability and adequacy of medical services; and economic development, in terms of industrialization and urbanization of the population.

2.2.2.2 <u>Routes of Pollutant Intake</u>--Pollutants may enter the body by several different routes. Depending upon which intake route occurs, different organs and types of diseases may be expected. Inhalation is the route of pollutant intake of most concern from potential copper-nickel development. Large particles (above 10 um aerodynamic diameter) are filtered out very efficiently by the nose. Particles larger than 5 um are removed by impaction on the surface of the bronchial tree of the lung. Deposition in the alveolae, the deepest portions of the lung, is greatest for particles 1-2 um in diameter. Below 0.5 um, particles behave like gases and deposition in the lung depends on how soluble they are. Respiratory diseases such as emphysema, pulmonary fibrosis, and pulmonary edema may be caused by inhalation of pollutants. Inhaled particulates may reach the gastrointestinal system if they settle out in the upper respiratory tract, are swept up by ciliary action and are then swallowed. Particles may also enter the blood if they diffuse into the capillary system or lymph spaces.

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Direct contact with the skin is the second major route of pollutant intake in the occupational environment. Dermatitis and other skin diseases are the most common adverse effects. In some cases pollutants may be absorbed through the skin and reach other organs.

Ingestion through food and water is the major route of pollutant intake in non-occupational settings. Pollutants may contaminate water, plants, and animals which are subsequently used as food. Ingested pollutants are initially located in the gastrointestinal tract but may be absorbed into the bloodstream and be transported to other body organs.

2.2.2.3 Additive, Synergistic, and Antagonistic Effects--This study has examined the potential effects on health of a number of specific agents. In actuality, however, agents rarely occur alone. Sometimes agents may interact with each other to cause effects greater or less than might be expected by adding the effects of each agent alone. Three major categories of interactions have been defined, when more than one agent is present.

Additive effects occur when agents act independently. The observed effects are the sum of the effects due to each agent individually. This approach is used by the American Conference of Governmental Industrial Hygienists in setting threshold limit values (TLVs) for mixtures of some agents.

Synergistic effects occur when agents interact in such a way that the observed effects are greater than the sum of the effects due to each agent.

Antagonistic effects occur when agents interact in such a way that the observed effects are less than the sum of the effects due to each agent.

2.2.2.4 Dose-Response Relationships and Thresholds--When an agent is found to affect health, experiments are often undertaken to quantify the response

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(proportion of population affected) to different doses of the agent. Graphs known as dose-response curves are generated from these data. There are two schools of thought concerning these dose-response relationships. Both groups start out with the same information concerning the responses to moderate doses of the agent; the problem arises when responses to low doses are considered.

One group believes that dose-response relationships are linear and there is a threshold below which no effect occurs (Figure 1). This group uses information from high doses and makes a linear extrapolation through lower doses. At lower doses, effects are difficult or impossible to measure. If the threshold concept is correct, once a threshold has been determined, exposures kept below the threshold would not affect health. The linearity of dose-response relationships at low doses and the threshold concept has been disproven in many cases.

Figure 1

The non-threshold school of thought believes that there is a small risk (often difficult to measure) associated with any level of an agent and that the only totally safe level is zero (Figure 1). The non-threshold concept has been used in public policy, most notably in the Delaney clause which bans any level of carcinogens in food. If the dose-response relationship is well understood at low dose levels, non-zero standards can be set based upon an acceptable level of risk.

The form of an agent may profoundly affect the dose-response curve. A more toxic form will shift the curve (Figure 1) to the left, while a less toxic form will shift the curve to the right. The slope of the curve may also vary, depending on the form of the agent. A single agent may be able to cause several different effects, depending on dose. Dose-response curves can be constructed for each effect.

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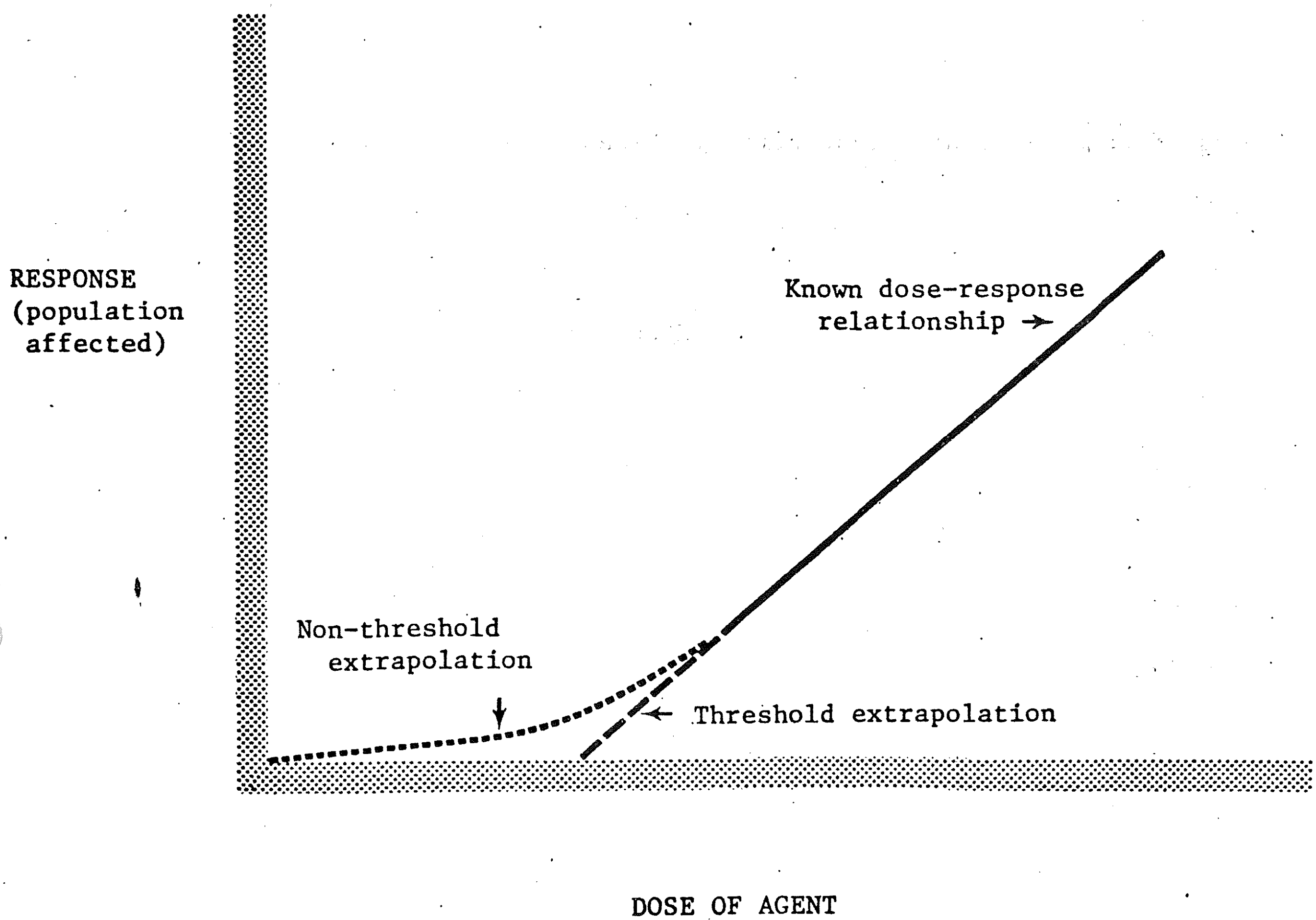
Figure 1. Hypothetical dose-response curve illustrating threshold and non-threshold concepts.



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2.2.2.5 Effects of Exposure to Agents--For the purposes of this discussion an effect of an agent consists of any change which occurs within an individual. An agent may have more than one effect depending on the level of agent present. Such effects may be beneficial, harmful, or have little significance. Figures 2 and 3 illustrate dose-effect curves, which illustrate the different effects observed as the dose of agent varies, for essential and non-essential (to normal functioning of humans) agents, respectively. These two curves are similar, with the exception that for essential agents there is an optimal dose, below which a deficiency disease may occur. Optimal amounts of essential agents may vary depending on the presence of other agents. Beneficial effects occur when the agents are used for necessary body functions and protection against other agents which cause adverse effects. Harmful effects (diseases) occur when the presence of an agent disrupts normal body functions.

Figures 2 & 3

As the quantity of an agent increases, the individual goes through several phases of decreasing health (Figures 2 and 3). First are changes on the molecular level, which are undetectable by current analytical techniques. Next come increased body burdens in hair, blood, and/or urine. At this point effects have been observed; and while these effects may not be detrimental to health, they may be indicators of hazardous conditions. At higher doses of the agent, an individual may experience signs of disease, such as cough or dizziness, but be unaware of the cause of these signs; however, a physician might be able to determine the cause. Next, symptoms of disease are obvious and can be attributed directly to an agent. Finally, disabling disease and, in extreme cases, death occurs.

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Figure 2. Hypothetical dose-effect curve for "essential" agents.

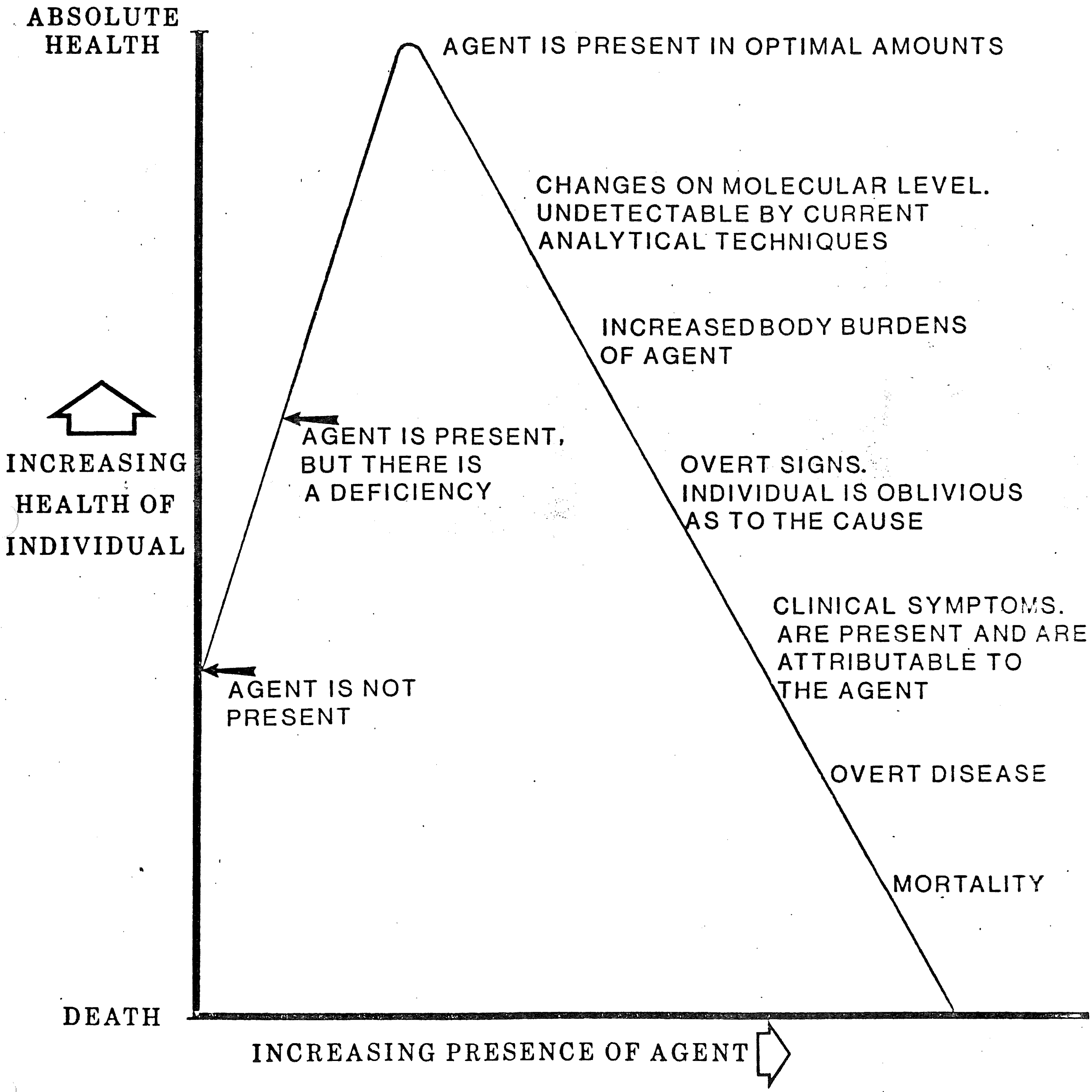

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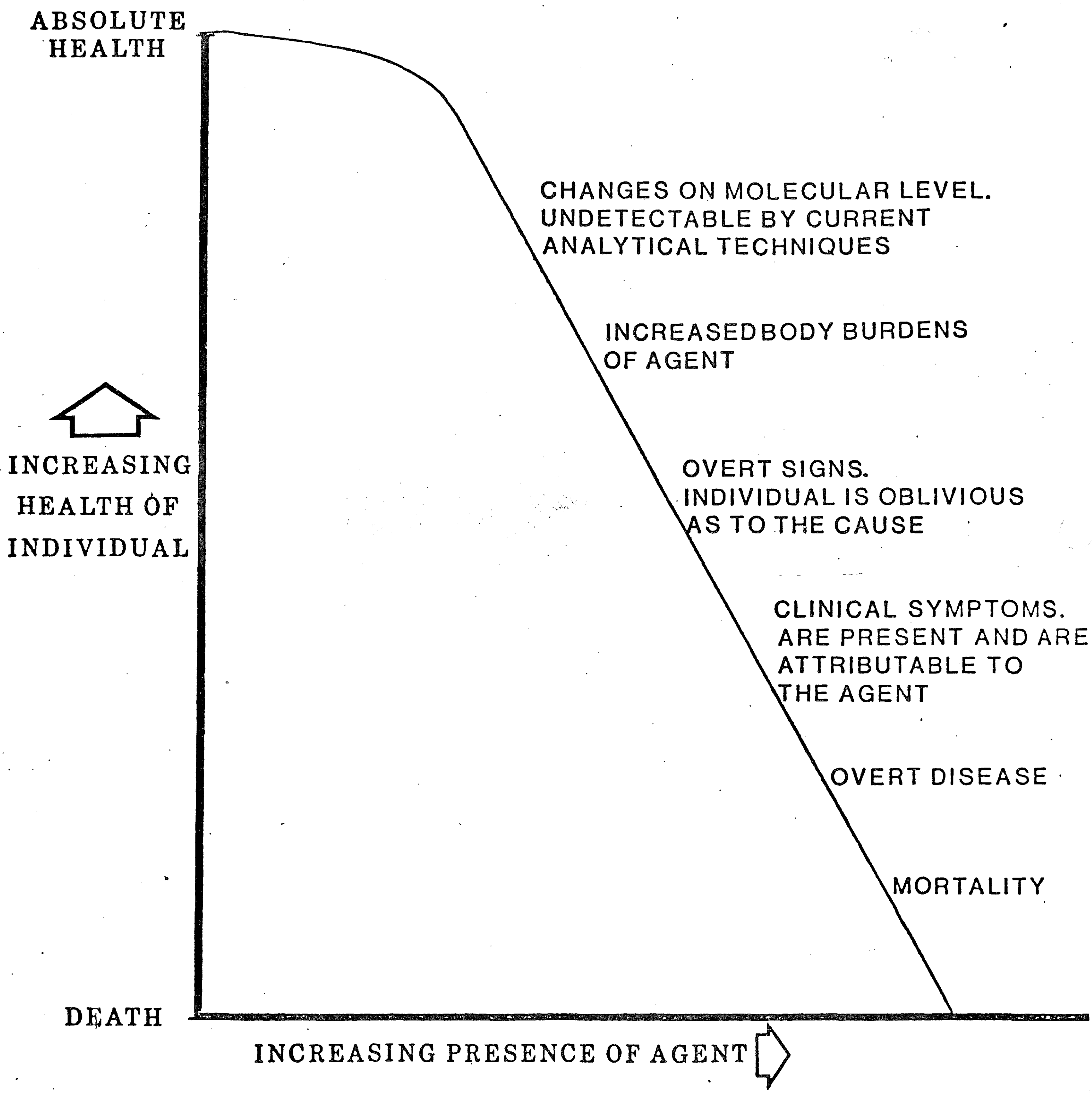
Figure 3. Hypothetical dose-effect curve for "nonessential" agents.



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Keeping Figures 2 and 3 in mind, a major question of this study is concerned with the point at which effects become significant. This is not easy to determine and good arguments can be made for several different points on the graph. In the analyses that follow, any detectable effect will be considered potentially significant. This decision has been made because: 1) any detectable effect is an indicator of increased exposure; 2) a detectable effect may be an indicator of increased risk of disease, either short-term or long-term; and 3) incomplete knowledge of dose-effect relationships leaves open the possibility that disease due to low level exposures to agents may have previously gone undetected.

2.2.2.6 Characteristics of Some Environmentally-Induced Diseases--Some general characteristics of disease categories potentially arising from copper-nickel development are useful in evaluating the severity of potential impacts on health. A discussion of specific diseases observed in other places with copper and/or nickel development appears later (Section 2.6).

Various types of cancer, particularly lung cancer, are one such category. Cancers generally take 20 to 30 years to occur following initial exposure to the agent (Bridbord et al. 1977). Once a cancer is diagnosed the chance that the patient will live another five years is very poor.

Chronic respiratory diseases are a second category. Such diseases may take 5 to 15 years to occur following initial exposure to an agent. Depending upon how far the disease progresses, the individual may be mildly to severely disabled. Removal from the environment causing the disease will usually halt the progression of disease, but rarely will the condition disappear altogether.

Skin diseases, such as dermatoses, are much less severe than the two previously mentioned categories. These diseases may occur after anywhere from a few days

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to a few years of exposure. Although skin diseases are moderately disabling, they can be readily reversed by appropriate treatment.

Congenital malformations (birth defects) vary in severity depending on the specific malformation which occurs. Some malformations may cause little or no permanent disability, while others may cause death at a young age. Exposure to agents during the first three months of pregnancy have the greatest potential for adversely affecting fetal development.

2.2.2.7 Clinical Studies, Epidemiology, and Toxicology--Evaluation of potential impacts on health requires information from several research disciplines. The major disciplines are clinical studies, epidemiology, and toxicology.

Clinical studies refer to experimental studies using humans as subjects. Advantages of these studies include: detailed information can be collected about absorption, metabolism, and excretion of pollutants; doses of pollutants can be measured fairly accurately; different population groups can be studied; cause-effect relationships are more easily ascertained; extrapolation of results to humans is unnecessary; and the information obtained is extremely useful for setting standards. Disadvantages include: exposures occur under artificial conditions; long-term exposures are not feasible; and the ethical problems involved in using humans as subjects (Newill 1974).

Epidemiology is the discipline that studies the relationship of human exposures to agents of disease in real life settings. Epidemiological studies are useful in that: natural exposures are studied; extrapolation of results to humans is unnecessary; the most susceptible groups in the population can be studied; and both long- and short-term exposures can be studied. Difficulties arise in: trying to quantify exposures; the multitude of confounding variables; dose-response relationships are difficult to obtain; and the problem of going from

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associations of agents and diseases to cause and effect relationships (Newill 1974).

Toxicologic studies use many different response systems, such as whole animal, organs, cells, and biochemical systems to study specific effects of agents in detail. Advantages of toxicologic studies are: dose-response information is generally well-defined, although incomplete at low dose levels; studies are performed relatively quickly; cause and effect relationships are more definitively determined; mechanisms of action by agents can be carefully studied. On the negative side: extrapolations from animals to man present problems; studies of delayed effects or chronic cumulative exposures are difficult; and animals are often not appropriate as models for human disease studies (Newill 1974).

Amdur (1977) has summarized the relationships of these three disciplines:

> The toxicologist is in the advantageous position of being able to choose the dose to be studied as well as the appropriate criteria for assessing the response to that dose. The problem comes in extrapolating the effects on other species to probable effects on man. Clinical studies are spared this problem, as man himself is the experimental animal. The dose can be chosen, as in toxicology, but the choice is obviously more limited as are the duration of exposure and the number of subjects used. Epidemiology, to which we presumably must turn for the ultimate answer to the question of the effects of existing pollution on human health, has to struggle in the real world. The problems the epidemiologist faces just in attempting to define the dose...is only one of the epidemiologist's many problems.

2.2.2.8 Standards--Goldsmith (discussed by Corn and Corn 1976) uses the term "standard" in association with a given level and duration of exposure to a spe-

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cified agent. "The standard is based on evidence which presumes predictive validity for the effect that will follow if the standard is exceeded." Documentation linking the given level to an effect on health is implied in the discussion of a standard. If documentation of this link cannot be made the standard lacks predictive validity; the term guide has been suggested for these cases. Corn and Corn (1976) note that "the term standard has deteriorated to refer to any legally promulgated concentration of an environmental agent that must be adhered to, whether predictive validity is present or not."

Given this background, three major types of standards or guides have been used in preparation of the human health studies reports: threshold limit values (TLVs), maximum contaminant levels (MCLs) in drinking water, and air quality standards.

Threshold limit values have been developed and are published annually by the American Conference of Governmental Industrial Hygienists (ACGIH). Although TLVs are often referred to as occupational standards, they are more accurately described as guides, as they are not intended to be used as fine lines between safe and hazardous levels. Threshold limit values assume exposures for a 7- or 8-hour workday and a 40-hour work week, and are designed to protect nearly all workers. Because of variations in individual susceptibility, a small percentage of workers may be affected in some circumstances. Industrial experience and experimental human and animal studies are used to set TLVs (American Conference of Governmental Industrial Hygienists 1977).

Maximum contaminant levels (MCLs) have been developed by the Environmental Protection Agency (EPA) as regulations in accordance with the Safe Drinking Water Act (PL 93-523). Information concerning total environmental exposure of man to specific agents has been used in developing MCLs. Limits have been set

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to minimize the amount of agent coming from drinking water, particularly when other sources such as milk, food, or air are known to represent the major exposures to man. These regulations were designed to be "not so low as to be impracticable nor so high as to encourage pollution of water." A major assumption in developing these limits is that the daily intake of water or water-based fluids is two liters. It is clear that MCLs are not intended as fine lines between safe and unsafe levels; and that under nearly all circumstances human health will not be adversely affected if the standards are met (United States Environmental Protection Agency 1976).

National air quality standards have been developed by the EPA. These standards are based upon air quality criteria--scientifically sound statements about effects which have been caused or inferred to have been caused by various exposures to specific pollutants. Included in these criteria are extrapolations from animal experimentation, clinical studies of persons exposed to pollutants, and epidemiological studies relating pollutants to morbidity and mortality. Primary air quality standards are designed to protect human health, while secondary standards are designed to prevent all other adverse effects of air pollution. States are allowed to set standards more stringent than national standards, but cannot set standards less stringent. Minnesota standards are more stringent than national standards in some cases (see Air Quality Volume 3, Chapter 3). In practice, primary air quality standards have been set slightly below the levels at which adverse effects on human health have been observed. Because air pollutants most commonly aggravate pre-existing disease states, rather than causing new disease, air quality standards do not represent fine lines between safe and unsafe levels, but are levels under which health is extremely unlikely to be impaired (Stern et al. 1973).

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In summary, the "standards" discussed above have been designed to afford the exposed population a high degree of safety from adverse health effects. Because these "standards" often represent educated guesses based upon incomplete knowledge, particularly at low concentrations of an agent, they change from time to time. Increased demands for greater margins of safety have often resulted in more stringent "standards."

2.3 REGIONAL OVERVIEW

To meaningfully evaluate the health status and potential impacts on health from copper-nickel development for the population of northeast Minnesota, an understanding of regional characteristics is necessary. These characteristics include: mortality and morbidity data; population characteristics, such as age, distribution, size, ethnicity, income, education, and others; the health services system in terms of both health professionals and health facilities; sources and characteristics of drinking water; wastewater disposal facilities; and existing and anticipated sources of pollutants. Variations in disease patterns are at least partially explained by these characteristics.

Copper-nickel development would introduce new environmental hazards and might aggravate existing environmental problems. On the other hand, such development would also affect other characteristics of the region, some of which may have a positive effect on health. Therefore, if morbidity and mortality data are not adequately examined, adverse effects on health from copper-nickel development may be obscured by concomitant improvements in health. Although the positive and negative effects of copper-nickel development on these characteristics have not been quantified, knowledge of these characteristics will aid in analysis of potential impacts on health.

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2.3.1 Population Centers and Characteristics

Based on the 1970 census, approximately 330,000 people reside in the seven-county (Aitkin, Carlton, Cook, Itasca, Koochiching, Lake, and St. Louis) area of northeast Minnesota (Regional Copper-Nickel Study 1978s). One-third of this population resides in Duluth; one-third resides on the Iron Range, which stretches from Grand Rapids to Ely; and one-third resides in other areas of the region.

Median age of the population in northeast Minnesota (31 years in 1974) is approximately two years higher than for Minnesota as a whole. Approximately 1.5 percent of the region's population is nonwhite, two-thirds of whom are Native Americans; for the state as a whole, Native Americans comprise one-third of the 1.8 percent nonwhite population. Compared with the state, northeast Minnesota is sparsely populated, with a population density (18.43 persons per square mile in 1974) less than half of the state total. The northeast region has a higher proportion of rural non-farm residents and a lower proportion of rural farm and urban residents than the state as a whole.

Average income for northeast Minnesota is over ten percent below that of the state as measured by per capita income ($2539 in 1970) and median family income ($8774 in 1970). Average education for residents of northeast Minnesota (12.1 years) is very similar to the state as a whole. Compared to the state as a whole, the northeast region has approximately ten percent more smokers, proportionately.

In 1975 there were 4,738 births in northeast Minnesota, giving rise to a crude birth rate of 14.4 live births per 1000 population, which was the same as the state rate, and a fertility rate of 72.2 live births per 1000 women aged 15-44, which was about 10 percent above the state rate. Also in 1975 there were 2,944 marriages and 1,320 divorces in northeast Minnesota.

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2.3.2 Mortality Experience

In 1975 there were 3,393 deaths in northeast Minnesota, giving rise to an age-adjusted mortality rate of 9.2 deaths per 1000 population, which was approximately 10 percent higher than the state rate of 8.3 (Regional Copper-Nickel Study 1978v). A similar relationship existed in 1970. Infant mortality rates for both northeast Minnesota and the state dropped over 20 percent between 1970 and 1975; however, northeast Minnesota had higher rates than the state in both years.

Age-adjusted mortality rates for each of the twelve leading causes of death in 1975 were higher in northeast Minnesota than for the state. There was little difference in 1975 between the overall mortality rates of northeast Minnesota and the United States (Table 2), although northeast Minnesota had higher rates for ten of the twelve causes of death presented. Only one of the top twelve causes of death can be attributed to a communicable disease (influenza and pneumonia).

Table 2

A study of selected chronic diseases for the years 1968-1973 showed that of the eight regions in the state, northeast Minnesota males and females each had the highest mortality rates from heart disease, all cancers (and specifically gastrointestinal and respiratory cancers), bronchitis and emphysema, and suicide. For diabetes males ranked second and females first; while for cirrhosis, males ranked first and females second.

Based on mortality statistics in recent years, the health of the population in northeast Minnesota is similar to that of the entire United States, but compares unfavorably with Minnesota as a whole.

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Table 2. Age-adjusted mortality rates per 100,000 population for selected regions* - 1975.

CAUSE OF DEATH	NORTHEASTERN MINNESOTA**	MINNESOTA	UNITED STATES
Heart Disease	364.0	315.3	350.4
Cancer	178.8	164.3	175.7
Cerebrovascular Disease	102.1	100.8	96.0
Accidental Deaths	59.3	46.2	48.9
Influenza and Pneumonia	31.0	28.8	27.3
Arteriosclerosis	15.5	14.0	14.5
Diabetes	18.5	13.5	17.2
Suicide	19.3	11.4	12.6
Bronchitis, Emphysema, and Asthma	13.2	10.6	12.4
Certain Causes of Perinatal Mortality	11.4	10.3	11.9
Cirrhosis of the Liver	12.7	9.7	14.6
Congenital Anomalies	7.0	6.5	6.0
TOTAL - ALL CAUSES	921.8	832.7	917.5

SOURCE: Minnesota Department of Health (1977c).

*Rates are adjusted to the estimated population for Minnesota in 1975.
**Aitkin, Carlton, Cook, Itasca, Koochiching, Lake, and St. Louis counties.

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2.3.3 Major Existing Sources of Pollutants

Existing point sources of pollutants in northeast Minnesota, including sources in northwest Wisconsin and Canada, emitted approximately 92,000 and 85,000 metric tons per year of particulates and sulfur dioxide respectively, based on data for 1975 and 1976 (see Volume 3, Chapter 3--Air Quality section). Power generation accounted for most of the sulfur dioxide, while taconite processing accounted for most of the particulates. Petroleum refineries and paper companies are other major sources of these pollutants.

2.4 CHARACTERIZATION OF REGION

This section focuses on characteristics of the region that describe or may affect the health status of the population. Most of the information is presented on a county-wide basis for the four counties: Carlton, Cook, Lake, and St. Louis. More detailed information has been presented previously (Volume 5, Chapter 1).

2.4.1 Demographics (related to health)

Some data on demographics and vital statistics, which help to characterize the health of the population are shown in Table 3. These data will be used qualitatively rather than dwelling on specific statistics.

Table 3

St. Louis County contains most of the population in northeast Minnesota. The distribution of this population is highly variable, with the greatest density around Duluth, a relatively high density in the central part of the county and relatively low density elsewhere (Figure 4). Location of the population is very important in determining the size of the population in close proximity to (and

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Table 3. Selected demographics and vital statistics of Carlton, Cook, Lake, and St. Louis counties, 1970-1975.

	CARLTON	COOK	LAKE	ST. LOUIS	MINNESOTA
Population (1975)	28,898	3,489	13,535	218,736	3,923,026
Median Age (1974)	30.1	35.7	28.4	30.9	28.7
Percent Nonwhite (1970)	1.87	3.94	0.76	1.33	1.81
Per Capita Income (1974)(in dollars)	3,761	4,466	4,224	4,243	4,675
Median Education Females 25+ (1970)(in years)	12.1	12.2	12.3	12.3	12.3
Median Education Males 25+ (1970)(in years)	11.4	12.1	12.1	11.3	12.1
Live Births (1975)	396	46	188	3,069	56,463
Fertility Rate* (1975)	70.6	71.7	61.7	70.6	65.1

SOURCES: U.S. Bureau of the Census (1977); Arrowhead Regional Development Commission (1976); Minnesota Department of Health (1977d); Minnesota State Planning Agency (1975).

*Live births per 1000 women age 15-44.

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hence at risk of exposure to pollutants from) a specific site of mineral development. Very few people (less than 500) live in the ten miles southeast (downwind--see Volume 3, Chapter 3-Air Resources) of the Duluth Gabbro Contact.

Figure 4

In general, the population in northeast Minnesota is somewhat older than that of the state, with the exception of Lake County (Table 3). This may be important in that the elderly are less resistant to environmental pollutants. Racial composition is sometimes responsible for differences in mortality rates, because nonwhites as a group have higher mortality rates than whites. The proportion of nonwhites in the region varies from county to county on both sides of the state average. Income and education have both been positively correlated with health status, although it has been questioned which is the cause and which is the effect. Per capita income in all four counties is lower than that of the state, while median education is similar to that of the state for females and similar or less than the state's for males (Table 3).

Birth statistics are presented for possible use in evaluating the significance of potential impacts which might cause congenital malformations. With the exception of Lake County, women in northeast Minnesota have higher (7-8 percent) fertility rates than the state as a whole.

2.4.2 Mortality and Morbidity

Mortality statistics for different age groups are illustrated in Table 4. These data show that most of the counties in northeast Minnesota experienced mortality rates 3-15 percent higher than the state of Minnesota in 1975, both for the total population and specific age groups. Cook County was an exception in 1975. While it may be misleading to base conclusions on the experience of a single

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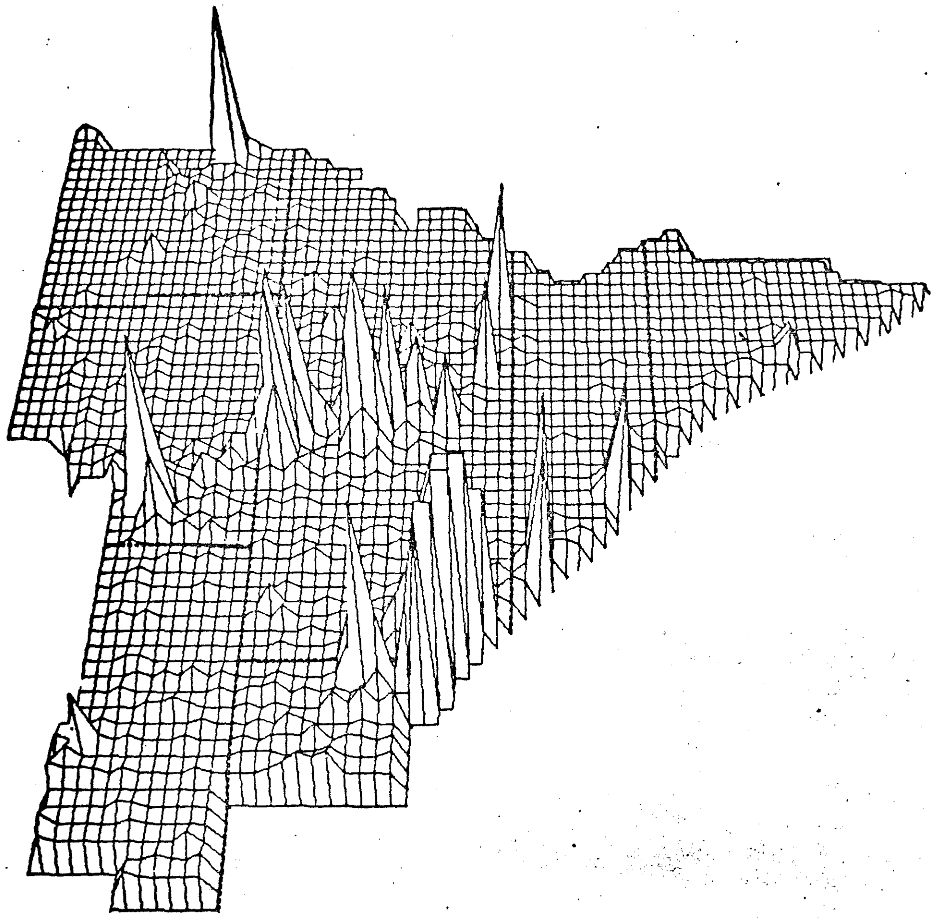
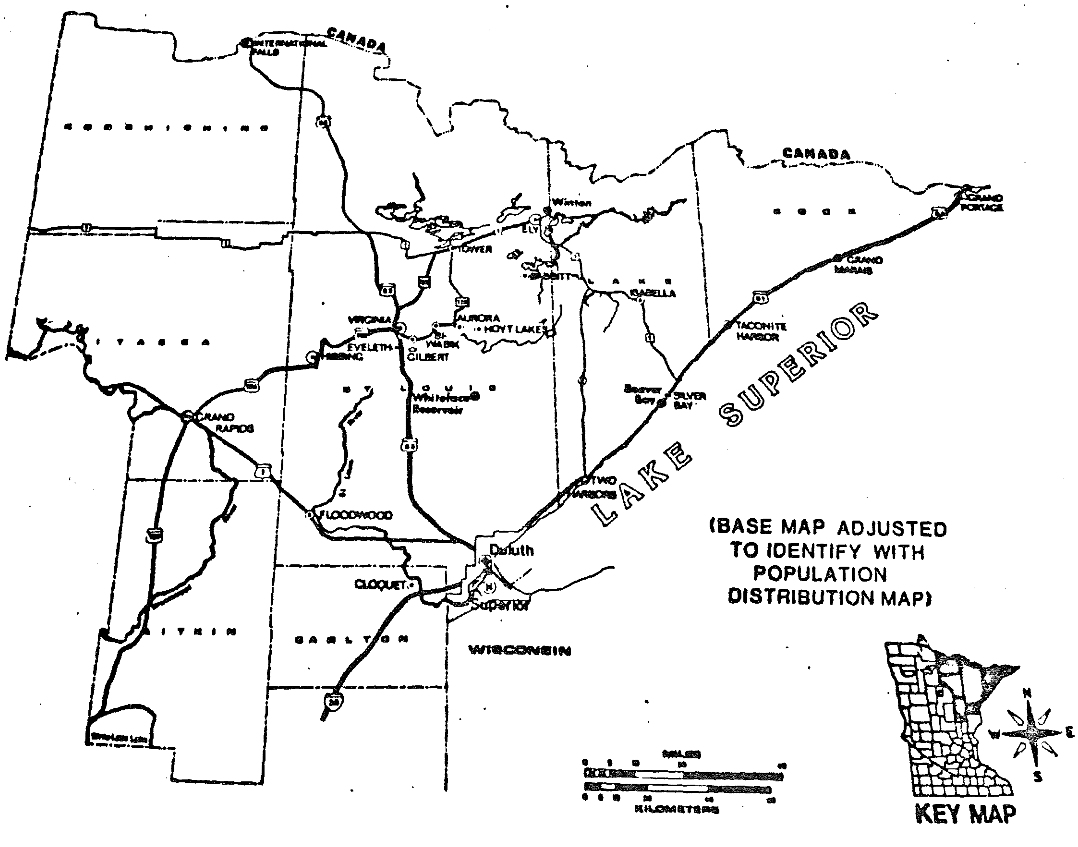
Figure 4. Population distribution 1970





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year, data for other years (such as 1970) support the observation of higher mortality rates in northeast Minnesota, including Cook County.

Table 4

Infant mortality rates for each of the four counties were 10-100 percent higher than the state in both 1975 and 1970 (data not shown), with the exception of Lake and Cook Counties, which had no infant deaths in 1975. These rates were lower in 1975 than 1970 for all four counties and the state as a whole.

Cancers are of interest because more than half of all cancers are caused by environmental factors. Overall, Carlton, Cook, Lake, and St. Louis ranked 9th, 18th, 3rd, and 1st for cancer mortality rates among Minnesota's 87 counties, respectively, in 1968-1973 (data not shown). Mortality rates for males and females for all cancers and the subcategories of digestive and respiratory cancers for the years 1968-1973 are shown in Table 5. Males in Carlton and St. Louis counties had very high mortality rates for all cancers, digestive cancers, and respiratory cancers; while males in Cook and Lake counties had very low mortality rates for these causes, with the exception of digestive cancers in Cook County. Females in Cook and Lake counties had very high cancer mortality rates for all cancers and digestive cancers; while in Carlton and St. Louis counties females had mortality rates for these two causes moderately higher than the state. Respiratory cancer mortality rates for females average about one-fourth those of males and are fairly close to the state rates for the four counties under discussion. These cancer mortality rates are also shown for Duluth. With one minor exception, Duluth males and females had higher mortality rates than comparable rates for St. Louis County for all three categories of cancer. Other categories of cancer (not shown) for which northeast Minnesota counties had mortality rates among the highest 10 percent (top 8 counties) during 1968-1973 were

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Table 4. Adjusted mortality rates per 1000 population for selected regions of Minnesota* (1975).

	MINNESOTA	CARLTON	COOK	LAKE	ST. LOUIS	DULUTH
Total Deaths	32,686	285	33	104	2,300	1,154
Age- and Sex-Adjusted Death Rate	8.3	9.6	7.0	8.6	9.5	10.6
Sex-Adjusted Rates for Specific Age Groups:						
Under 5 years	3.3	5.0	-	-	4.0	4.5
5-14 years	0.3	0.6	-	0.4	0.7	0.7
15-24 years	1.1	1.4	1.6	1.6	1.2	1.0
25-44 years	1.3	1.4	1.3	1.3	2.0	1.6
45-64 years	8.2	8.6	6.7	7.5	10.5	10.9
65 and over	52.5	60.5	44.7	57.6	56.1	66.3

SOURCE: Minnesota Department of Health (1977d).

*Rates are adjusted to the estimated population for Minnesota in 1975.

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urinary cancers (Lake County males and females), genital cancers (Cook County females), lymphomas (Cook and Lake County females), and leukemia (Carlton County males).

Table 5

Similar data for other chronic diseases are shown in Table 6. Carlton, Cook, and St. Louis County males and females experienced heart disease mortality rates higher than those of the state during 1968-1973; Lake County males and females had lower mortality rates. Both males and females in all four counties (with the exception of Cook County females) had mortality rates due to bronchitis and emphysema (two chronic respiratory diseases) higher than those of the state. Males in Lake and St. Louis counties, and females in Carlton, Cook, and St. Louis counties had cirrhosis mortality rates higher, and in some cases much higher, than those of the state. Cook County males had a relatively low mortality rate, and no deaths due to cirrhosis were recorded for Lake County females during 1968-1973. Mortality rates due to accidents were higher than those of the state for males in all four counties; however, among the 87 Minnesota counties, Lake and St. Louis ranked in the lower half; females in Cook County had an extremely high accident mortality rate, while Carlton and Lake County females were below the state average. With one exception, Duluth males and females had higher mortality rates for these four causes of death (Table 6) than did St. Louis County. Other categories of chronic diseases (not shown), for which northeast Minnesota counties had mortality rates among the highest 10 percent during 1968-1973 were diabetes (Cook County females), suicide (Cook and Lake County males, and Carlton and St. Louis County females), and homicide and other violent deaths (Cook County males).

Table 6

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Table 5. Average annual age-adjusted mortality rates per 1000 population for selected cancers* (1968-1973).

	MALES						FEMALES					
REGION	ALL CANCERS		DIGESTIVE		RESPIRATORY		ALL CANCERS		DIGESTIVE		RESPIRATORY	
Carlton	2.0	(4)**	.65	(7)	.54	(6)	1.5	(34)	.51	(24)	.10	(33)
Cook	1.2	(86)	.64	(8)	.21	(83)	2.1	(1)	.67	(3)	.09	(41)
Lake	1.6	(59)	.42	(78)	.32	(64)	2.0	(2)	.72	(2)	.12	(16)
St. Louis	2.1	(2)	.67	(5)	.56	(1)	1.6	(17)	.54	(13)	.13	(8)
Duluth	2.4		.71		.65		1.7		.56		.13	
Minnesota	1.8		.55		.43		1.5		.45		.10	

SOURCE: Minnesota Department of Health (1977a).

*Adjusted to the 1970 Minnesota population.
**Numbers in parentheses are the rank among the 87 counties of Minnesota.

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Table 6. Average annual age-adjusted mortality rates per 1000 population for selected causes of death* (1968-1973).

	MALES				FEMALES			
REGION	HEART DISEASE	BRONCHITIS & EMPHYSEMA	CIRRHOSIS	ACCIDENTS	HEART DISEASE	BRONCHITIS & EMPHYSEMA	CIRRHOSIS	ACCIDENTS
Carlton	4.5 (8)**	.30 (9)	.13 (23)	1.3 (20)	2.5(29)	.06 (3)	.11 (4)	.27 (77)
Cook	4.0(25)	.23 (25)	.07 (67)	1.5 (7)	3.5 (3)	0 -	.35 (1)	1.3 (1)
Lake	3.5(63)	.54 (1)	.17 (9)	.97 (57)	2.0(72)	.11 (2)	0 -	.23 (83)
St. Louis	4.4(11)	.26 (20)	.20 (2)	.95 (61)	3.0(10)	.04 (33)	.09 (7)	.38 (53)
Duluth	4.9	.27	.27	.91	3.2	.05	.11	.42
Minnesota	3.8	.21	.13	.80	2.4	.04	.7	.34

SOURCE: Minnesota Department of Health (1977a).

*Adjusted to the 1970 Minnesota population.
**Numbers in parentheses are the rank among the 87 counties of Minnesota.

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Morbidity studies, which examine everyone who contracts a disease including those who die from it, are generally believed to be more meaningful indicators of health status than mortality studies. Because of the Reserve Mining controversy, some cancer morbidity studies have recently been conducted in northeast Minnesota. Incidence rates for gastrointestinal and lung cancers were collected for Duluth, Two Harbors, Silver Bay, and Beaver Bay for the three-year periods 1969-1971 and 1972-1974, and were compared to rates for Minneapolis and St. Paul. During these six years there appeared to be little difference in morbidity rates between Duluth and either St. Paul or Minneapolis. For Two Harbors, Silver Bay, and Beaver Bay morbidity rates appeared to be similar or less than those of Duluth (Sigurdson et al. 1977).

2.4.3 Health Services System

Northeast Minnesota has a well-defined health services system. Duluth has the greatest number of health professionals and the widest variety of services and facilities in the area. Other cities, particularly Virginia and some of the other Iron Range communities, have a wide variety of health services available, although not as comprehensive as Duluth. Beyond Duluth and the Iron Range a basic level of service appears to be available in central locations throughout northeast Minnesota.

2.4.4 Health Manpower

There are approximately 350 active physicians in Carlton, Cook, Lake, and St. Louis counties. Approximately two-thirds of these physicians are in Duluth (Regional Copper-Nickel Study 1978u). Another 12 percent practice in Virginia; and the remainder are well-distributed among 18 other communities, mostly in St. Louis County. Relative to population, St. Louis County has the most physicians of any of the four counties; however, even St. Louis County has fewer physicians

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per thousand population than the state as a whole. Physician distribution in northeast Minnesota is consistent with national trends which show relatively more physicians in large metropolitan counties and relatively fewer in rural counties. Approximately half of these physicians are specialists certified as "Diplomates" by national specialty boards. The distribution of specialists throughout northeast Minnesota is similar to the distribution of all physicians. The greatest variety of specialty fields is found in Duluth, while there is a smaller variety of specialty fields in Virginia, and even less elsewhere.

Dentists number approximately 200 in the four counties of northeast Minnesota. Fifty percent of these are in Duluth, 12 percent in Virginia, and the remainder well-distributed throughout the region. St. Louis County has more dentists per 1000 population than the state, while the other three counties have fewer.

Over 1200 registered nurses are active in northeast Minnesota. Approximately 85 percent of these are in St. Louis County. Relative to population, St. Louis County has the most registered nurses; however, all four counties have relatively fewer nurses than the state average.

Public health services are well-developed in northeast Minnesota. The St. Louis County Health Department provides services as comprehensive as those anywhere in the state, including programs in Health Education, Public Health Nursing, and Environmental Health. Services in St. Louis County are decentralized in that major offices are located in Virginia and Duluth, and branch offices in Cook, Ely, Hibbing, and Meadowlands. This decentralization gives St. Louis County the flexibility to rapidly respond to the changing needs of its population. Public health services in the other three counties are not nearly as comprehensive as those in St. Louis County, which is to be expected considering the size and needs of their respective populations. The recently

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implemented Community Health Services Act has spurred development of public health services and requires an annual review of needs and services.

2.4.5 Health Facilities

Fourteen hospitals are located in the four counties of northeast Minnesota and are geographically well-distributed throughout the region (Figure 5)(Regional Copper-Nickel Study 1978t). These hospitals had 1711 licensed beds in 1976, ranging from 14 to 546 beds at individual hospitals. Most of these beds (1060) were in Duluth hospitals. Bed occupancy levels averaged slightly under 64 percent in 1976, well below the target of 80 percent set by the Department of Health, Education and Welfare. In that year the number of beds per 1000 population ranged from 2.7 in Lake County to 7.0 in St. Louis County, compared to 4.9 for the state and 4.0 recommended by the Department of Health, Education, and Welfare. Also in 1976, the hospitals performed over 47,000 operations and handled almost 80,000 emergency department visits; over 80 percent of both were in St. Louis County. Both the quantity and range of services provided by hospitals tend to increase with the size of the municipality in which the hospital is located.

Figure 5

Long-term care facilities with complete services consist of convalescent and nursing care units, and nursing homes. The distinction between the two is that convalescent and nursing care units have a physical link with a hospital while nursing homes do not. Twenty-three long-term care facilities with complete services had almost 2400 licensed beds in 1976 in the four county area; of these, St. Louis County had over 80 percent. Bed occupancy rates for the region averaged about 97 percent in 1976. Total beds per 1000 population aged 65 and

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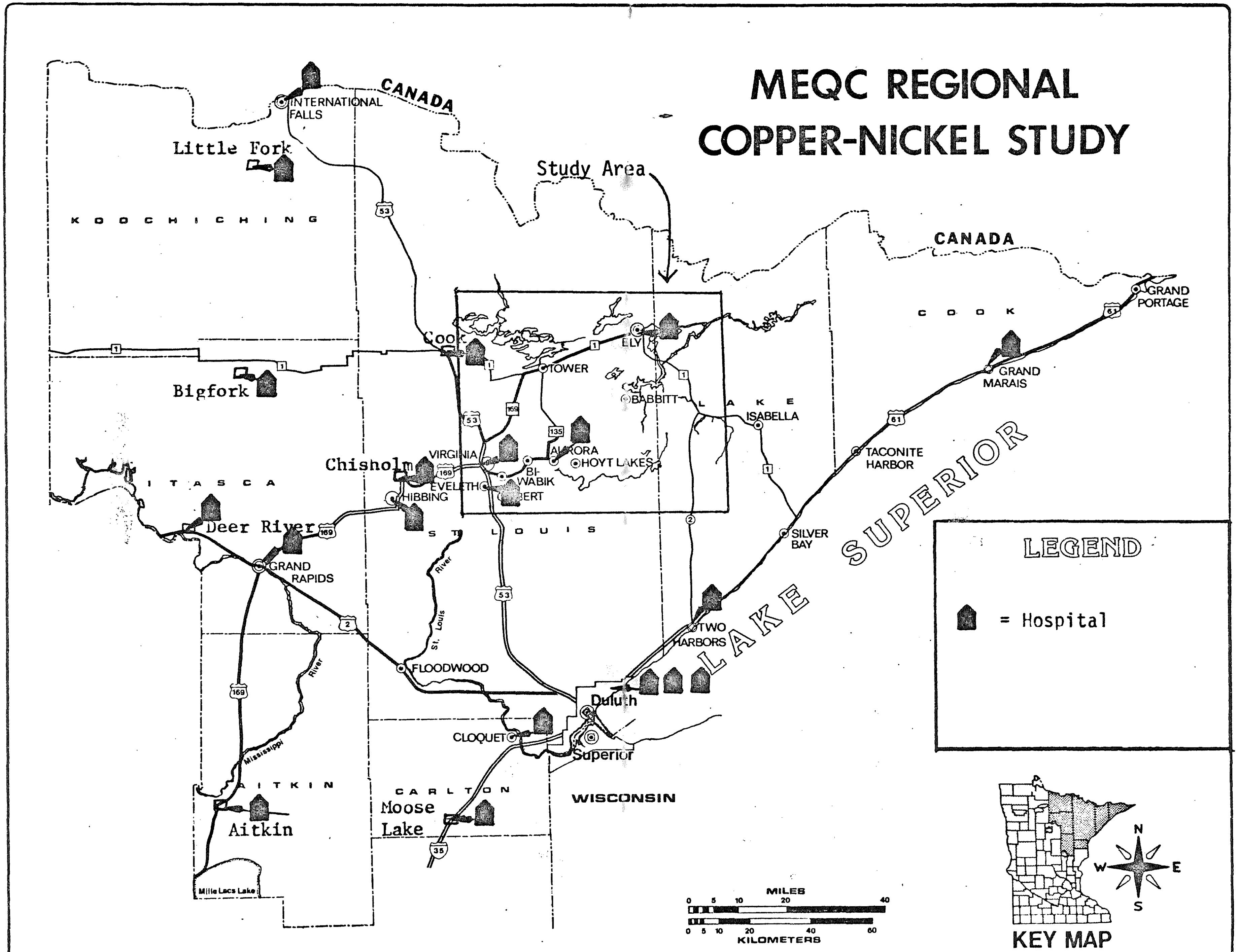
Figure 5 Hospitals in Northeastern Minnesota



SOURCE: Minnesota Department of Health (1977) over, ranged from 37 (Lake County) to 90 (Cook County) compared with an average of 90 for all of Minnesota.

Long-term care facilities with partial services consist of boarding care homes and supervised living facilities. Boarding care homes provide room, board, and some other services, but do not provide skilled nursing care. Supervised living facilities provide services similar to boarding care homes, but while boarding care homes serve the aged or infirm, supervised living facilities provide care for the mentally retarded, chemically dependent, adult mentally ill, or physically handicapped. In 1976 there were five boarding care homes in northeast Minnesota with 249 licensed beds averaging 95 percent occupancy. Boarding care beds per 1000 population age 65 and over ranged from none (Cook County) to 29.6 (Lake County) compared to the state average of 16.9. St. Louis County was well below the state average with 5.8 boarding care beds per 1000 population aged 65 and over. In 1976 there were 21 supervised living facilities in northeast Minnesota, all but two of them located in St. Louis County. These facilities had 262 licensed beds.

Ambulance services can be divided into three categories of providers: the private sector, some hospitals, and municipalities through police and fire departments. Two federal guidelines issued by the Department of Health, Education, and Welfare apply to emergency medical services: 1) at least 95 percent of the calls for emergency medical assistance should be answered within 10 minutes in urban areas and 30 minutes in rural areas; and 2) there should be at least one emergency department (not necessarily a hospital) within 60 minutes of travel from the emergency scene for at least 95 percent of the cases. Northeast Minnesota appears to have the resources to meet these two guidelines, although hard data are not available.

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2.4.6 Water Supply and Wastewater Disposal

Sources of drinking water can be divided into two major categories: surface and underground (Regional Copper-Nickel Study 1978w). Underground sources are generally preferable to surface water sources because they are less subject to intermittent pollution and fluctuations in quantity. In northeast Minnesota the sources of municipal water supplies may be divided into five groups: groundwater (drilled wells); surface water; combined--groundwater and surface water; combined--drilled wells and mine shaft; and those which obtain water from a nearby municipal water system (Figure 6).

Figure 6

Most of the municipal water supplies in the region use groundwater sources. However, surface water sources are used by several municipalities, including Aurora, Ely, Hoyt Lakes, and Winton, which are all in close proximity to the Duluth Gabbro Contact, and Beaver Bay, Duluth, Eveleth, Grand Marais, Silver Bay, and Two Harbors, which are somewhat farther from the Contact. Iron, manganese, and hardness frequently affect the quality of the water in this region; however, these do not affect health and can be removed by common treatment methods. Cleavage fragments closely resembling asbestos fibers have been found in Lake Superior. The significance of this finding with regard to health is uncertain (see Volume 3, Chapter 4-Water Resources).

The proportion of the population served by municipal supplies ranges from 38 percent in Cook County to 77 percent in St. Louis County. Approximately 28 percent of the people in this four-county region have individual systems. Assuming that there is one well for every three persons not served by a municipal supply, it is estimated that this region has over 24,000 wells in regular use. In addi-

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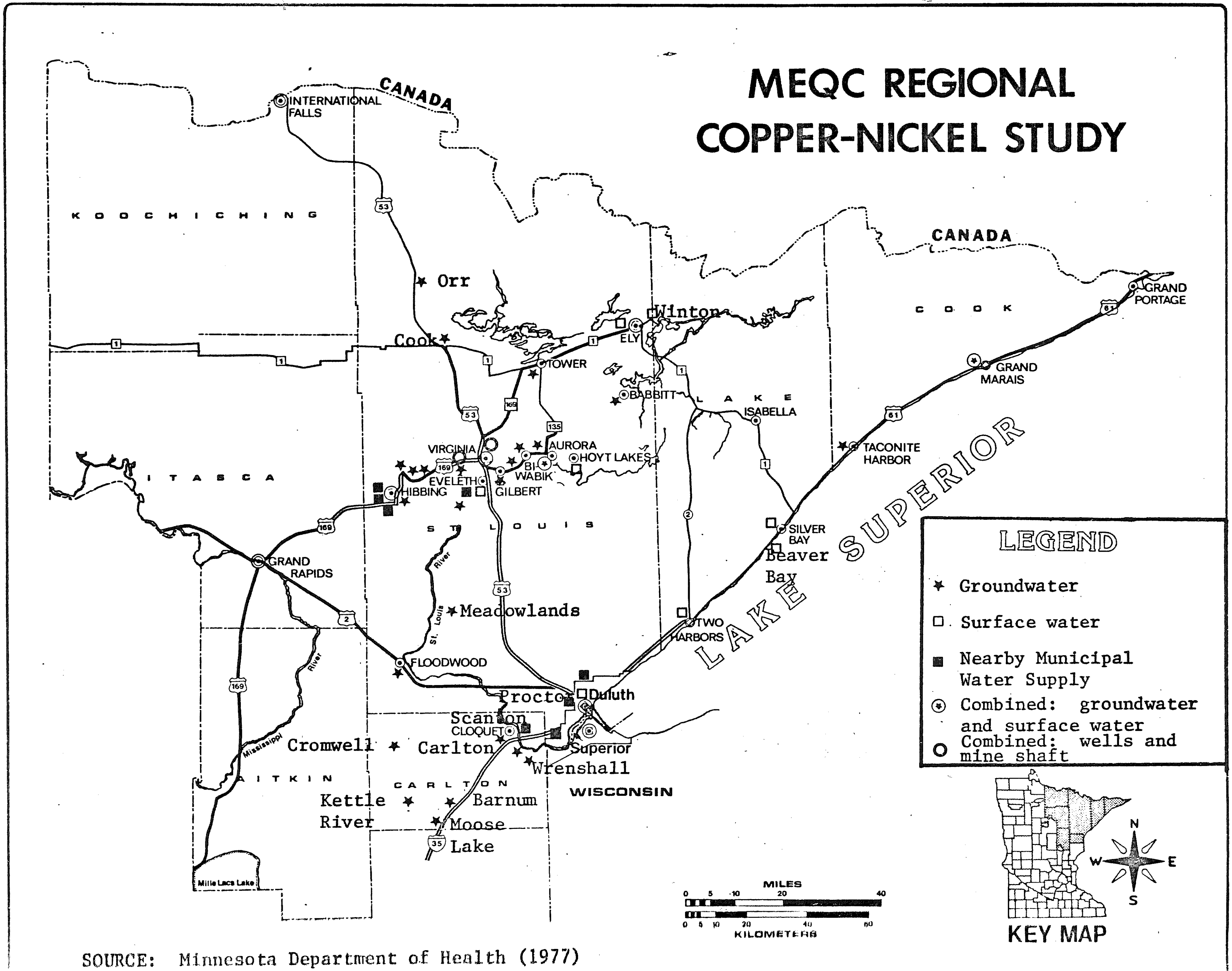
Figure 6 Source of Public Water Supplies in Northeast Minnesota



SOURCE: Minnesota Department of Health (1977)

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tion, many seasonal residences in the region are also served by wells; however, the number of wells and the size of the population in this category are not known. During the drought of 1976, over 1,700 private wells went dry. Availability of adequate quantity of water is discussed elsewhere (see Volume 5-Socio-Economic and Volume 3, Chapter 4-Water).

Municipal sewage treatment plants are generally located in the same communities that have municipal water supplies. The proportion of the population served by municipal systems ranges from 38 percent in Cook County to 78 percent in St. Louis County. Approximately 26 percent of the population in the four-county region are served by individual (or on-site) systems. Assuming there is one individual system (septic tank, cesspool, or privy) for every three persons not served by a municipal system, it is estimated there are over 22,000 individual systems in use. Again, this figure does not include seasonal residents, whose numbers would greatly increase the estimated number of individual systems. No unusual problem areas, in terms of effects on health, currently exist.

2.5 PHILOSOPHY OF APPROACH TO IMPACT ASSESSMENT

Copper and/or nickel mining, processing, and smelting has occurred in many places throughout the world. Considerable evidence exists that such development has either directly or indirectly affected the health of both occupational and nonoccupational groups in the past and up to the present. Although many changes have taken place over the years to mitigate the adverse effects of copper-nickel development, many potential hazards still exist.

Potential impacts on human health have been analyzed according to the diagram shown in Figure &. Collection of information emphasized an understanding of agent-host-environment relationships which might occur with copper-nickel development. Other information inputs include studies of the mortality experience

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of other areas with copper or nickel development and studies presented in other sections of this document.

Figure 7

The impact assessment is divided into three major sections. The first discusses mortality experience of nonoccupational groups exposed to copper and/or nickel development. The second describes potential impacts on the health services system. The final section presents a detailed analysis of potential impacts, as defined by agents of disease, the population affected, and conditions under which such impacts may occur, and will focus attention on the most significant potential impacts on health.

2.6 NONOCCUPATIONAL MORBIDITY AND MORTALITY--PREVIOUS EXPERIENCE

Sudbury County in Ontario, Canada, contains the largest copper-nickel development in the world. A study of mortality rates for the years 1964-1968 found that Sudbury County had the worst mortality experience for both males and females, aged 35-74, of the 55 counties in Ontario (El-Shaarawi 1976). Selected causes of diseases were examined (Table 7). For males, cardiovascular diseases, accidents, poisonings, and violence were the major contributors to high mortality rates; smaller contributions were made by neoplasms and cerebrovascular diseases. Females showed less variation from the Ontario mortality rates, but experienced higher mortality rates from cardiovascular diseases, neoplasms, and respiratory diseases. In addition, the counties surrounding Sudbury also experienced some of the highest mortality rates in Ontario. The purpose of this study was to examine regional differences in mortality rates. Factors responsible for these differences, as suggested by the authors, may include genetic factors and environmental factors such as cigarette smoking, softened drinking

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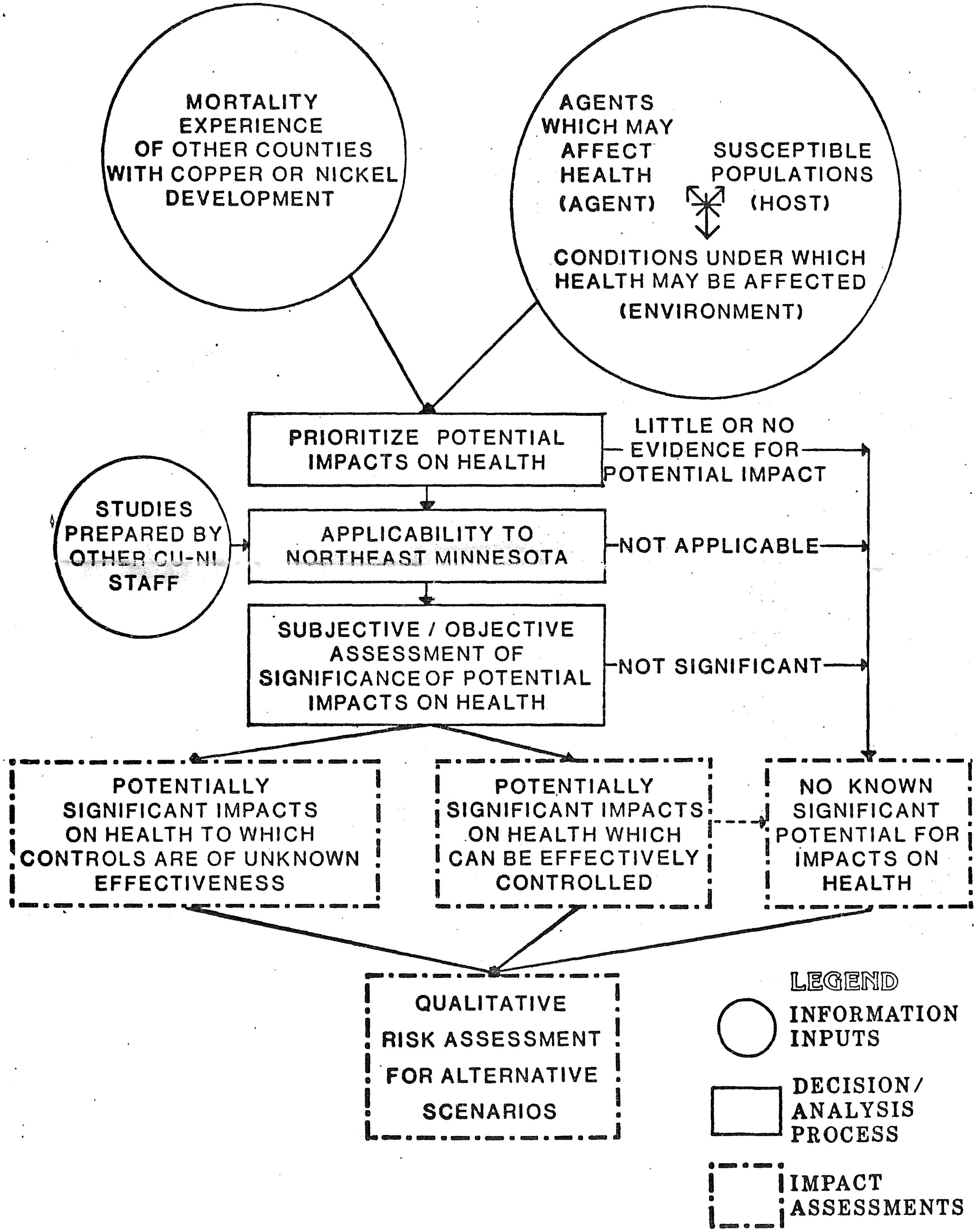
Figure 7.

FLOW DIAGRAM FOR ASSESSING POTENTIAL EFFECTS OF COPPER-NICKEL DEVELOPMENT ON HUMAN HEALTH



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water, climatic parameters, and, more generally, various physical and socioeconomic parameters.

Table 7

A large copper industry exists in Montana with mines located in Silver Bow County and a smelter in Deer Lodge County. These two counties are adjacent to each other. Mortality rates for these two counties have been compared to Montana as a whole (Table 8). Highly significant excesses occurred in Silver Bow County for circulatory diseases and cancer of the respiratory system, and to a lesser extent, for respiratory diseases, and asthma, emphysema, and bronchitis. Differences between Deer Lodge County and Montana, were not as striking as in the case of Silver Bow; however, similar trends were noted with the exception that mortality rates from circulatory diseases for those 65 years and older in Deer Lodge County were lower than state rates.

Table 8

A preliminary study of the mortality experience of seven U.S. counties exposed to copper or nickel mining and/or smelting compared to nonexposed counties in the same states was recently conducted for the years 1969-1973 (Regional Copper-Nickel Study 1978q). The exposed counties were: Yavapai, Arizona (open pit copper mine); Lyon, Nevada (open pit copper mine); White Pine, Nevada (open pit copper mine and smelter); Grant, New Mexico (open pit copper mine and smelter); Hidalgo, New Mexico (underground copper mine); Douglas, Oregon (open pit nickel mine and smelter); and Polk, Tennessee (underground copper mine and smelter). Exposed counties were selected only if: copper or nickel mining and/or smelting was the principal industry in the county; more than 50 workers were employed by the industry; and the county did not have an urban population

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Table 7. Statistical significance of differences of mortality rates (1964-1968) between Ontario Province and Sudbury County.*

	AGE GROUP	LEVEL OF SIGNIFICANCE Males	Females
		(in percent)	
All Causes (001-795, E800-E999)**	35-44	1	5
	45-54	1	5
	55-64	1	N.S.
	65-74	1	1
Cardiovascular Diseases (400-468)	35-44	N.S.	N.S.
	45-54	5	1
	55-64	1	N.S.
	65-74	1	1
Neoplasms (140-239)	35-44	N.S.	10
	45-54	1	N.S.
	55-64	N.S.	N.S.
	65-74	N.S.	N.S.
Cerebrovascular Diseases (330-334)	35-44	N.S.	N.S.
	45-54	N.S.	N.S.
	55-64	1	N.S.
	65-74	N.S.	N.S.
Accidents, Poisonings, and Violence (E800-E999)	35-44	1	N.S.
	45-54	5	N.S.
	55-64	1	N.S.
	65-74	1	N.S.
Diseases of the Respiratory System (240, 241, 470-527)	35-44	N.S.	N.S.
	45-54	N.S.	10
	55-64	N.S.	N.S.
	65-74	N.S.	N.S.

SOURCE: El-Shaarawi et al. 1976.

*In all cases of statistical significance, Sudbury County mortality rates are higher than Ontario.
**1955 I.C.D. Code

N.S. = Not significant.

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Table 8. Statistical significance of differences of mortality rates (1969-1973) between Montana State and Deer Lodge or Silver Bow Counties.

	AGE GROUP	DEER LODGE Males	DEER LODGE Females	DEER LODGE Both	SILVER BOW Males	SILVER BOW Females	SILVER BOW Both
		(in percent)			(in percent)		
Respiratory Diseases (460-519)*	All	1.0	+	1.0	0.1	1.0	0.1
	40-64	+	N.D.	1.0	0.1	+	0.1
	65 & Over	+	+	+	0.1	+	1.0
Asthma, Emphysema, and Bronchitis (490-493)	All	+	N.D.	1.0	0.1	N.D.	1.0
	40-64	N.D.	N.D.	+	1.0	N.D.	1.0
	65 & Over	+	N.D.	+	+	N.D.	+
Pneumonia (480-486)	All	+	N.D.	+	+	0.1	0.1
	40-64	N.D.	N.D.	N.D.	N.D.	N.D.	+
	65 & Over	-	N.D.	-	+	+	+
Cancer of the Respiratory System (160-163)	All	0.1	N.D.	0.1	0.1	0.1	0.1
	40-64	1.0	N.D.	1.0	1.0	1.0	0.1
	65 & Over	1.0	N.D.	+	1.0	1.0	1.0
Circulatory Diseases (390-458)	All	0.1	+	0.1	0.1	0.1	0.1
	40-64	0.1	+	0.1	0.1	0.1	0.1
	65 & Over	-0.1	-	-0.1	0.1	0.1	0.1
Cerebrovascular Diseases (430-438)	All	+	+	+	+	+	1.0
	40-64	1.0	0.1	0.1	+	+	+
	65 & Over	-	-	-	+	-	-

SOURCE: Haddow, D., Montana Department of Health and Environmental Sciences, Personal Communication 1976.

*I.C.D. Numbers (8th Revision)

Legend: N.D. = No data (less than 10 deaths)
+ = County higher than the state but not significant
- = County lower than the state but not significant
X% = County significantly higher than the state at X level of significance
-X% = County significantly lower than the state at X level of significance

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larger than 50,000. Age-adjusted mortality rates for each pair of exposed and nonexposed counties were compared (Table 9). For all causes of death, six of the seven comparisons showed higher mortality rates for the exposed counties, irrespective of whether males, females, or both sexes combined were considered. Specific categories in which most of the exposed counties had higher mortality rates than the nonexposed counties were accidents and all cancers. Douglas County, Oregon, is of special interest because it has the only nickel mine and smelter in the U.S. and because nickel can cause lung cancer. Mortality rates from lung cancer in Douglas County were higher than in the nonexposed counties for both males and females; and the rates for females were twice as high in Douglas as compared to the nonexposed counties.

Table 9

One study indicated that average mortality rates from lung cancer for white males and females in the United States in 1950-1959 were significantly increased in 36 counties with copper, lead, or zinc smelting and refining industries as compared to other U.S. counties (Blot and Fraumeni 1975). Counties with fewer than 0.1 percent of the population working in the industry were excluded. Industrial sources of inorganic arsenic were suggested as the most likely explanation for the excess lung cancer observed; however, the authors noted that other industrial agents may contribute to the hazard.

Children exposed to heavy metals emitted from nearby ore smelters have been studied. A copper smelter in Tacoma, which produces commercial arsenic trioxide as a byproduct, was conservatively estimated in 1973 to emit from its main smelter stack 580 tons/year of particulates, of which 200 tons and 130 tons were arsenic and lead, respectively (Milham and Strong 1974). Fugitive emissions were not mentioned. Third- and fourth-grade children from two schools, 0.3 and

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Table 9. Summary of comparisons of mortality rates between exposed counties and nonexposed comparison counties.

	BOTH SEXES	MALES	FEMALES
All Causes	6/7*	6/7	6/7
All Cancers	5/7	5/7	5/7
Digestive Cancer	2/7	3/7	4/7
Respiratory Cancer	4/7	4/7	5/7
Urinary Cancer	4/7	4/7	3/7
Respiratory Diseases	3/5	3/5	1/5
Accidents	5/5	5/5	4/5

*x/y x = number of times exposed county had higher rate than nonexposed county.
y = total number of comparisons.

Note: These comparisons do not include Fannin County, Georgia.

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12.8 km from the smelter stack, respectively, were studied for lead and arsenic absorption. No differences were observed in blood lead levels, but arsenic in hair and urine were considerably elevated in the children living close to the smelter. Additional studies found urinary arsenic levels (0.3-0.02 ppm) and vacuum-cleaner dust samples (1300-70 ppm) to decline with distance from the smelter stack extending 4 km downwind. Urinary arsenic levels in six of the children living near the smelter and followed over a five-week period were found to fluctuate according to wind direction, suggesting inhalation was the most likely route of exposure. Younger children consistently had higher levels of urinary arsenic than older children or adults. Although children inhale more air per unit body mass than do adults, the authors did not believe this was enough to account for differences in urinary arsenic levels. Ambient air levels or arsenic were not reported.

A study of a lead, copper, and zinc smelter handling over 800,000 metric tons of ore concentrates per year in El Paso also examined heavy metal absorption in children (Landrigan et al. 1975). Over the three-year period 1969-1971, an estimated 1012 metric tons of lead, 508 metric tons of zinc, 11 metric tons of cadmium, and one metric ton of arsenic were emitted from the smelter stacks. Fugitive emissions were not mentioned. Air concentrations of all four metals were highest immediately adjacent to the smelter boundary and decreased rapidly with distance, reaching background levels at 4 to 5 km. Particles below 2.0 um in diameter constituted 42 percent of the particle mass at one site 0.25 km from the smelter. Dustfall samples of these metals were greatest at the smelter boundary and decreased with distance. Lead levels in soil also showed an inverse relationship with distance, but remained above background as far as 10 km. Zinc, cadmium, and arsenic showed similar distribution patterns. A random sample of children aged 1-19 years found elevated blood lead levels in 52.7 per-

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cent of those living within 1.6 km and 9.8 percent of those 1.6 to 6.6 km from the smelter. Blood lead levels varied inversely with age, with the 1-4 year-olds having the highest prevalence of blood lead levels. The authors attributed increased lead exposure to levels in dust and air. Lead in soil was believed to be relatively immobile and less accessible for absorption.

2.7 IMPACTS ON THE HEALTH SERVICES SYSTEM

Northeast Minnesota has no obvious shortages of health professionals or facilities (Regional Copper-Nickel Study 1978 f,g). Numbers of physicians, dentists, and nurses in this region are less than or equal to the numbers for the state when adjusted for population size. Although clusters occur in Duluth, Virginia, and along the Iron Range, health professionals are well-distributed with regard to population throughout the region. Public health services are well-developed and have the flexibility to rapidly respond to the changing needs of the population, particularly in St. Louis County. Health care facilities, especially hospitals, are well distributed with regard to population throughout the region. Hospitals appear to have excess capacity as reflected by bed occupancy levels and licensed beds per 1000 population. Facilities for long-term care (convalescent and nursing care units, nursing homes, and boarding care homes) are filled close to capacity and the number of beds per 1000 population 65 and over is 20 percent less than the state average. Emergency medical services resources in this region appear to be sufficient to meet the federal guidelines as discussed above (Section 2.4.5).

The key point in assessing adequacy of health manpower and facilities is not the quantity present, but whether the sick and injured have ready access to satisfactory medical care. If satisfactory medical care is not readily accessible, victims of accidents or disease may be much more seriously affected by their conditions than if satisfactory medical care had been available. Satisfactory medical care appears to be readily available in northeast Minnesota at this time. A rapid population increase could strain health care services in certain parts of the region, particularly if it occurs in some of the smaller communities on the eastern end of the Iron Range. Although hospitals have excess capacity in terms of licensed beds, excess health manpower is not present.

Availability of adequate emergency medical services is probably the weakest link of the health services system in northeast Minnesota, especially emergency facilities for workers. A significant increase in the number of workers, as would occur with copper-nickel development, could place a severe burden on existing emergency facilities from time to time since the minerals industry, especially underground mining, has high accident rates. Potential copper-nickel mine locations are relatively isolated compared to existing taconite mines. If the mining companies do not provide emergency facilities and manpower at the plant, expansion of existing facilities and increased personnel will be necessary to be adequately prepared for emergencies.

A possible secondary impact, which might occur well after development commences, concerns long-term care facilities. In northeast Minnesota, these facilities are currently used to capacity. Over the short-term, a population influx due to copper-nickel development would be minimal because new workers and their families would be much younger than 65 years old. Delayed effects of a population influx might show up some time in the future as this new population ages.

Shortages of health care professionals in areas of rapid growth would probably not be very serious problems except on a temporary basis. Public health services appear to have the flexibility to rapidly respond to changing service demands.

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2.8 EVALUATION PROCESS FOR POTENTIAL IMPACTS ON HUMAN HEALTH

A three-step process has been used to focus attention on the potential impacts most likely to affect health: 1) prioritization of impacts on health potentially arising from copper-nickel development in general; 2) applicability of these potential impacts to northeast Minnesota specifically; and 3) assessment of the significance of these potential impacts.

2.8.1 General Prioritization of Potential Impacts-Step 1

Initial priorities for potential impacts on health from copper and/or nickel development in general were determined according to the criteria presented in Table 10. Potential impacts rated as priority one or two will undergo further evaluation as outlined by the three-step process discussed above. Potential impacts rated as priority three or four will not be further analyzed unless new information becomes available suggesting that these categories should be placed in priority one or two.

Table 10

Categories, initially identified as potential impacts of most concern, as defined by agent-host-environment relationships, are illustrated in Table 11, with an indication of their priority ratings. Agents consist of metals and other environmental hazards. Hosts, or susceptible populations, are divided into four groups: workers, families of workers, the general community, and visitors (visitors consisting of tourists, seasonal residents, and other transients). Environment is used to refer to the five discrete stages of copper-nickel development: exploration, underground mining, open-pit mining, processing, and smelting and refining. Other agents considered in less detail

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Table 10. Criteria--Step 1 (General prioritization of potential impacts).

Priority One--Categories for which effects on health, ranging from mortality to overt signs and symptoms of disease, have been observed in other places which have had copper and/or nickel development.

Priority Two--Categories which satisfy at least one of the following requirements:

- increased body burdens of agents (although not, as yet, associated with disease) in areas of copper and/or nickel development.
- effects on health, ranging from increased body burdens of agents to mortality, which have been observed in situations other than copper and/or nickel development, and which may apply to copper-nickel development.
- potentially hazardous chemicals used by workers to process ores and concentrates

Priority Three--Categories for which effects on health may occur under certain circumstances. Based on current knowledge there is little or no evidence whether or not such circumstances might occur with copper-nickel development.

Priority Four--Categories which satisfy at least one of the following:

- effects on health might occur under certain circumstances which are unlikely to apply to copper-nickel development based on current knowledge
- the category is not applicable to copper-nickel development

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are illustrated in Table 12 with their priority ratings. The reasoning used in applying the criteria (Table 10) to arrive at the priority ratings can be found in a separate document (Regional Copper-Nickel Study, 1978c).

Tables 11 & 12

2.8.2 Applicability of Potential Impacts to Northeast Minnesota--Step 2

Potential impacts on health rated as priority one or two from the Step 1 analysis are summarized in Table 13. Criteria to determine whether these impacts should be reclassified to a lower level, based upon the applicability to northeast Minnesota, are presented in Table 14.

Tables 13 & 14

2.8.2.1 Reclassifications to Priority Three--As shown in Table 14, categories of potential impacts on health will be reclassified to priority three if either of two conditions exist. The first condition is that the agent has not been detected in ore, concentrate, or tailings depending on the stage of copper-nickel development under discussion. Agents potentially affected by this condition include: arsenic, asbestos, cadmium, iron, lead, mercury, nickel, silica, and zinc. Analyses of ore, concentrate, and tailings (Table 15) show that each of these agents except asbestos have been detected in samples of each type of material. Cleavage fragments very similar to asbestos fibers have been identified in tailings produced in pilot studies of ore processing. Therefore, the potential impacts of these agents are possibly applicable to copper-nickel development in northeast Minnesota.

Table 15

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TABLE II PRIORITIZATION OF POTENTIAL IMPACTS ON PUBLIC HEALTH

LEGEND

- Priority one (dense cross-hatch with grid)
- Priority two (cross-hatch)
- Priority three (single diagonal hatch)
- Priority four (blank)

	Exploration and Construction				Underground Mining				Open-pit Mining				Processing				Smelting and Refining			
	Workers	Families of Workers	General Community	Visitors	Workers	Families of Workers	General Community	Visitors	Workers	Families of Workers	General Community	Visitors	Workers	Families of Workers	General Community	Visitors	Workers	Families of Workers	General Community	Visitors
Accidents	1	3	3	3	1	3	3	3	1	3	3	3	1	3	3	3	1	3	3	3
Aluminum					3								3							
Arsenic					2	3	3		3	3	3		3	3	3		1	1	1	
Asbestos	2				2	2	3	3	2	2	2	3	2	2	2	3				
Cadmium													3	3	3	3	3	2	2	3
Carbon monoxide					1															
Cobalt																	3	3	3	
Copper					3	3	3		3	3	3		3	3	3		3	3	3	
Explosives					1				1	3	3	3								
Iron					2				3				2				2	3	3	
Lead													3	3	3		3	2	2	
Manganese													3				3			
Mercury					3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2
Nickel	2				2	3	3		2	2	2		2	3	3		1	3	3	
Nitrogen oxides					2												3	3	3	
Noise	1	3	3	3	1				1	3	3	3	1	3	3	3	1			
Particulates/dust	2				1	2			1	2	2	3	1	2	2	3	1	1	1	3
Population pressures	2	2	2		2	2	2		2	2	2		2	2	2		2	2	2	
Processing chemicals													2	3	3	3	2	3	3	3
Silica					1				1				1				3			
Sulfur oxides																	1	1	1	3
Zinc													2				3			

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TABLE 12 PRIORITIZATION OF OTHER POTENTIAL IMPACTS ON PUBLIC HEALTH

	PRIORITY		PRIORITY
Acid Mist	see sulfur oxides	Phosphorus	
Barium		Potassium	
Beryllium		Scandium	
Boron		Selenium	
Calcium		Silver	
Cerium		Sodium	
Chlorides		Strontium	
Chromium		Tellurium	
Coal	Priority three (hatched)	Thorium	
Fluorides	Priority three (hatched)	Titanium	
Gadolinium		Vanadium	
Gallium		Ytterbium	
Magnesium		Yttrium	
Molybdenum		Zirconium	
Osmium	Priority three (hatched)		

LEGEND

Priority one — Priority two — Priority three — Priority four

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TABLE 13 POTENTIAL IMPACTS ON PUBLIC HEALTH UNDERGOING FURTHER ANALYSIS

LEGEND
- Priority one
- Priority two

	Exploration and Construction				Underground Mining				Open-pit Mining				Processing				Smelting and Refining			
	Workers	Families of Workers	General Community	Visitors	Workers	Families of Workers	General Community	Visitors	Workers	Families of Workers	General Community	Visitors	Workers	Families of Workers	General Community	Visitors	Workers	Families of Workers	General Community	Visitors
Accidents	Priority one				Priority one				Priority one				Priority one				Priority one			
Aluminum																				
Arsenic					Priority two												Priority one	Priority one	Priority one	
Asbestos	Priority two				Priority two	Priority two			Priority two	Priority two	Priority two		Priority two	Priority two	Priority two					
Cadmium																		Priority two	Priority two	
Carbon monoxide					Priority one															
Cobalt																				
Copper																				
Explosives					Priority one				Priority one											
Iron					Priority two								Priority two				Priority two			
Lead																		Priority two	Priority two	
Manganese																				
Mercury													Priority two	Priority two	Priority two	Priority two				
Nickel	Priority two				Priority two				Priority two	Priority two	Priority two		Priority two				Priority one			
Nitrogen oxides					Priority two															
Noise	Priority one				Priority one				Priority one				Priority one				Priority one			
Particulates/dust	Priority two				Priority one	Priority two			Priority one	Priority two	Priority two		Priority one	Priority two	Priority two		Priority one	Priority one	Priority one	
Population pressures					Priority two	Priority two	Priority two		Priority two	Priority two	Priority two		Priority two	Priority two	Priority two		Priority two	Priority two	Priority two	
Processing chemicals													Priority two				Priority two			
Silica					Priority one				Priority one				Priority one							
Sulfur oxides																	Priority one	Priority one	Priority one	
Zinc													Priority two							

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Table 14. Criteria--Step 2 (applicability to northeast Minnesota).

Categories will be reclassified to priority three if either of the following conditions exist:

- agents which have not been detected in the ore, tailings, or concentrate depending on the stage of copper-nickel development under discussion (based upon samples analyzed for the Regional Copper-Nickel Study)
- agents which are not used or produced using current technology

Categories will be reclassified to priority four in the development scenarios if the stage of copper-nickel development (exploration, underground mining, open-pit mining, processing, or smelting and refining) is not included in the scenario.

All other categories will retain the same classification as identified in Step 1.

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Table 15. Average concentrations in disseminated samples from the Duluth Gabbro (ppm).

ELEMENT	SYMBOL	FEED (Ore)	TAILINGS	CONCENTRATE
Aluminum	Al	92,100	90,500	17,100
Arsenic	As	10*	2	31
Barium	Ba	704.3	1,056	122.4
Beryllium	Be	0.54	0.74	0.06
Boron	B	571.2	1,120	293
Cadmium	Cd	10*	6	40
Calcium	Ca	55,300	55,300	10,800
Chromium	Cr	300	300	400
Cobalt	Co	120	80	1,320
Copper	Cu	5,450	520	145,800
Iron (oxide)	Fe	86,900	87,200	23,900
Iron (sulfide)	Fe	12,490	2,530	304,240
Lead	Pb	5.3	2.2	64
Magnesium	Mg	45,400	43,600	14,600
Manganese	Mn	1,200	1,100	300
Mercury	Hg	0.08	0.06	0.177
Molybdenum	Mo	1.6	2.4	28.5
Nickel	Ni	1,250	420	26,180
Oxygen	O	428,500	441,800	117,100
Phosphorus	P	300	400	100
Potassium	K	3,500	3,300	800
Selenium	Se	4*	4*	4*
Silicon	Si	222,900	236,500	68,500
Silver	Ag	2.7	1.3	36.2
Sodium	Na	21,800	21,900	3,700
Strontium	Sr	277.7	272	47.4
Sulfur	S	11,290	2,340	262,350
Tellurium	Te	3.3*	3.3*	3.3*
Thorium	Th	4.3	3.5	2.8
Titanium	Ti	9,200	9,400	900
Vanadium	V	166.2	160.4	80.8
Zinc	Zn	139	109.1	1,134.4
Zirconium	Zr	96.1	95.2	24.3

SOURCE: Stevenson, Regional Copper-Nickel Study, 5/30/78.

*Detection limit.

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The second condition, that the agents are not used or produced using current technology, may apply to carbon monoxide, explosives, nitrogen oxides, noise, processing chemicals, and sulfur oxides.

Although proposed plans for copper-nickel development in northeast Minnesota incorporate newer technology which will mitigate some of these impacts observed previously, these potential impacts will not be entirely eliminated. In the event of any technological changes, these agents should be reanalyzed for applicability to northeast Minnesota.

Although these two conditions have not narrowed down the list of potential impacts on health, some of the information collected will be useful in assessing the significance of potential impacts. These criteria were prepared for ongoing use in the analysis of potential impacts from copper-nickel development. As technology and development methods change and new ore bodies are found, some of these criteria may apply to future evaluations of potential impacts on health.

2.8.2.2 Reclassifications to Priority Four--Copper-nickel development has been divided into five discrete stages: 1) exploration and construction; 2) underground mining; 3) open-pit mining; 4) processing; and 5) smelting and refining. If all five stages are not included in proposed development plans, then some of the potential impacts identified in Table 13 will be reclassified to priority four. If, for example, a development plan included all stages except open-pit mining, then all the potential impacts identified under open-pit mining in Table 13 (5 priority one categories and 11 priority two categories) cease to be potential impacts as far as this plan would be concerned.

2.8.3 Significance of Potential Impacts on Health--Step 3

Potential impacts on health classified as priority one or two in the first two steps are now examined in greater detail according to Figure 8. As illustrated

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in Table 13 there are 85 different "instances" (29 priority one and 56 priority two) of agent-host-environment relationships which have potential for affecting health. These 85 "instances" have been combined to form 9 priority one agent groups, with one of these (particulates/dust) subdivided into occupational and nonoccupational categories, and 12 priority two agent groups to give a total of 22 groups for a more detailed analysis of significance.

Figure 8

For each of the 22 groups there is a separate analysis of the agent, susceptible population (host), and environment. Levels of metals found in samples of ore, concentrate, and tailings from the Duluth Gabbro are shown Table 15. A less comprehensive table (Table 16) of metal levels in the concentrates of other U.S. copper smelters is used for comparison when data are available. Estimates of metal emissions from a smelter are shown in Table 17. Estimates of the number of workers involved in models of each stage of copper-nickel development are presented in Table 18. Following each discussion of agent-host-environment factors is an impact assessment, which discusses how these factors may combine to: 1) cause effects in humans; and 2) affect the severity of these effects in humans. Following the impact assessment is a general discussion of controls--including both possible control strategies and effectiveness of the same or similar controls in other settings. Finally, the significance of each potential impact is discussed.

Tables 16, 17, 18

Generally, potential impacts are considered to have little significance if the agent-host-environment relationships necessary for the occurrence of effects on health are unlikely to exist or if the expected controls have been proven effec-

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Figure 8. Factors used to analyze significance of potential impacts.

POTENTIAL IMPACT

AGENT FACTORS

1. Characteristics of agent: toxicity, persistence, accumulation, synergism.
2. Quantity of agent.
3. Sources of agent besides Cu-Ni.
4. Mode of transmission.
5. Form(s) of agent which are most likely to cause impact.

HOST FACTORS

1. Population group affected: age, sex, etc.
2. Size of population at risk.
3. Smoking habits.

ENVIRONMENTAL FACTORS

1. Applicability of previous observations to N.E. Minnesota.
2. Length of exposure.
3. Will standards be exceeded?
4. Stage(s) of Cu-Ni development in which potential impact may occur.
5. Proximity of industrial activity to population centers.

IMPACT ASSESSMENT (QUALITATIVE)

1. Severity of effects, type of disease.
2. Ability to treat disease once it is detected.
3. Ability to monitor for effects on health.
4. Time between exposure and manifestation of disease.

DISCUSSION OF CONTROLS

1. Possible controls.
2. Effectiveness of controls.

QUALITATIVE RISK ASSESSMENT

1. Discussion of how above factors may affect probability or severity of disease.
2. Put risks in perspective (compare with standards).

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Table 16. Definition of ranges of element concentrations in Cu and Zn smelter ore concentrations.

	RANGE OF ELEMENT CONCENTRATION IN ORE CONCENTRATES (All entries are in ppm unless otherwise noted)		
Element	Low (L)	Medium (M)	High (H)
As	200	200 - 999	1000
Hg	1	1 - 9.9	10
Cd	100	100 - 999	1000
Pb	1000	1000 - 9999	1%
Ni	20	20 - 99	100
Mn	100	100 - 999	1000
Zn	1%	1% - 29.9%	30%
Sb	100	100 - 999	1000
Se	5	5 - 99	100

SOURCE: PEDCo. Environmental (1976).

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Table 17. Model* for the constituents in the stack particulate emmissions from a flash smelter facility processing 100,000 MPTY of Cu+Ni metal.

CONSTITUENT	MTPY
Cu	263.5
Ni	50.45
S(particulate)	496.63
As	17.44
Cd	1.84
Co	2.53
Be	0.02
Pb	9.8
Hg	0.07
Zn	23.82
Fe	581.67
Sb	0.003
Cl	0.39
F	0.02
S_iO_2	638.51
Al_2O_3	101.83
MgO	57.48
CaO	100.18
other**	39
Total (particulates)	2385
SO_2 (gaseous)	11284

*The model assumes the particulates will have the same composition as the smelter feed. Normal operating conditions are assumed, with an acid plant meeting minimum new source performance standards. No scrubbers are used.

**Includes oxides of Na, K, Ti, P, Mn, Cr, and Fe.

(See Technical Assessment....Vol. II., Chapter IV.)

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Table 18. Estimated numbers of workers.

OPERATION	SIZE OF OPERATION (mtpy)	OPERATING MANPOWER FULL PRODUCTION	CONSTRUCTION MANPOWER PEAK
Exploration	---	20	---
Underground Mine	5.35×10^6	674	180
Processing		183	750
Open Pit Mine	11.33×10^6	546	180
Processing		308	960
Underground Mine	12.35×10^6	1555	280
Processing		302	990
Underground & Open Pit Combination Mine	16.68×10^6	1220	360
Processing		379	1150
Open Pit Mine	20.00×10^6	964	318
Processing		414	1250
Smelting	100,000	435	1250
Refining	(Cu + Ni metal)	186	

See Volume 2, Chapter 5 for further information.

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tive in other places. Potential impacts which are likely to occur and for which controls are of limited or unknown effectiveness are considered to have the greatest significance.

2.9 HEALTH IMPACTS OF PRIORITY ONE GROUPS

Potential impacts on health were classified as priority one in steps one and two if effects on health had been observed in other instances of copper or nickel development. Of the 29 potential impacts classified as priority one, 12 occur during smelting and refining, while only 2 occur during exploration and construction (Table 13). Examination of the 29 priority one potential impacts by population group affected shows that 23 are applicable to workers.

2.9.1 Accidents

2.9.1.1 Potential Impact--Accidents may cause injuries and/or deaths in workers in all stages of copper-nickel development.

2.9.1.2 Analysis of Agent--The agent for accidents may be thought of as physical force. Sources of physical force include equipment, machinery, falling rock, jagged or slippery surfaces, fires, gas explosions, and electricity, plus other less common sources. Potential for accidents presents a constant hazard to workers.

2.9.1.3 Analysis of Susceptible Population--Workers in all five stages of development would be potentially affected. For a large development, several thousand workers would be at risk of accidents. Initially many of these would be inexperienced. New, less-experienced employees account for a disproportionately large number of accidents.

2.9.1.4 Analysis of Environment--All stages of copper-nickel development present the potential for accidents. Location of the ore deposits has a profound

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effect on the potential for accidents in a mine. Underground mining is the most hazardous, with accident frequency statistics three times those of the other four stages. Accident statistics for the other stages of development are similar to or slightly higher than the average of 8-10 disabling injuries per million manhours worked for all U.S. industries studied by the National Safety Council. When injuries do occur in open-pit mining, they tend to be much more severe than other industries as evidenced by the fact that injury severity rates in surface mines are over three times the average of 650 days lost per million man-hours worked for all U.S. industries combined. Accident rates for the copper industry are similar to those for the minerals industry as a whole. Congress passed the Metal and Nonmetallic Mine Safety Act (PL 89-577) in an attempt to reduce these accident statistics. The taconite mining industry in Minnesota, which includes only open-pit mines, has had accident frequency rates well below comparable rates for the U.S. as a whole. (In 1975 accident frequency rates for surface mines and mills in Minnesota were one-half and one-fourth, respectively, of the rates observed for the entire U.S.--U.S. Department of the Interior, 1975). New technology generally produces a safer environment for the worker. Potential development sites included in this study for copper-nickel development are generally over 20 miles from existing hospitals, and existing hospitals may not have sufficient personnel to cope with an accident involving more than a few victims.

2.9.1.5 Impact Assessment--Effects of accidents may range from cuts and bruises to disabling injuries and death. In Minnesota an average of two mining-related deaths have occurred annually over the past five years out of an average of over 14,000 full-time workers in surface mines and mills. Unlike chronic diseases such as cancer and respiratory disease, effects of accidents are readily apparent. The victims of many injuries recover without permanent disability.

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Injury statistics have shown large fluctuations in recent years. Based upon 1976 data for the copper industry (Regional Copper-Nickel Study, 1978a): for every 500 underground miners, there would be 44 disabling injuries, 1335 days lost and 0.22 fatalities per year; for every 500 surface miners, there would be 10 disabling injuries, 873 days lost and 0.15 fatalities per year; and for every 500 mill workers, there would be 13 disabling injuries, 701 days lost and 0.12 fatalities per year.

Because new and less-experienced employees are the group of workers most likely to be involved in mining accidents, and because of the possibility for underground mining, accident frequency rates for a new copper-nickel industry may be expected to be higher than those for the present mining operations in Minnesota, which have experienced workers and open-pit mines. Complications may arise if prompt treatment is not readily available. An adequate supply of personnel trained in the handling of trauma, combined with an adequate transportation system for victims, can reduce both the number and severity of complications.

2.9.1.6 Discussion of Controls--Studies have shown that most accidents can be prevented (Regional Copper-Nickel Study, 1978a). Preventive measures require action by both management, to create a safe working environment, and workers, to avoid unnecessary risks. Controls have centered on two major areas. The first has been through regulations, such as those for equipment design and use, promulgated by the Mining Enforcement and Safety Administration, (now the Mine Safety and Health Administration, MSHA) to assure adequate safeguards against accidents. The other major thrust has been accident safety programs which educate and encourage employees to practice safe working habits. There is some evidence that both types of controls have reduced accident rates; however, accidents are a constant hazard and will never be completely eliminated from the mining environment.

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2.9.1.7 Qualitative Risk Assessment--Accidents are an ever present potential hazard of copper-nickel development. Federal standards for safety are currently in force and all mining companies have accident safety programs. Competition for workers with the taconite industry and Minnesota's history of relatively low accident rates will provide strong pressures on a new copper-nickel industry to provide working conditions of comparable safety. Another positive factor would be that a new industry would probably utilize new technology which usually means a less hazardous work environment. New technology often requires more skills from workers, making it in the interests of management to protect them.

On the negative side is the fundamental conflict between management's desire for high productivity and the time and cost of safety practices. Workers may sometimes be at fault, too, if they are willing to take more pay for more dangerous jobs and refuse to demand a safer worker environment because it might mean lower pay.

A strong safety program, including facilities and skilled personnel sufficient for handling the victims of accidents, can reduce the numbers of accidents and the severity of subsequent complications.

Taking all these factors into account, accident rates in Minnesota would be expected to increase with copper-nickel development, even assuming the industry has a strong safety program, for the following reasons: 1) it is likely that some of the mining would be underground, which is much more hazardous than open-pit mining; and 2) newer and less experienced workers account for a high proportion of accidents. The positive factors discussed above will certainly influence accident rates, while the negative factors discussed above are less likely to occur due to increased regulation of the industry and union demands for a safe working environment. However, it is unlikely that accidents will be completely controlled.

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2.9.2 Arsenic

2.9.2.1 Potential Impact--Arsenic emitted from smelting and refining may cause lung cancer in workers and dermatitis in workers, their families, and the general community.

2.9.2.2 Analysis of Agent--Trivalent arsenic, particularly arsenic trioxide (As_2O_3) is generally considered to be the most toxic form of arsenic (Regional Copper-Nickel Study 1978d). Pentavalent arsenic may apparently be ingested in relatively large quantities without an effect on health. Effects of inhalation of arsenic compounds may be different than those from ingestion; thus, the National Institute of Occupational Safety and Health (NIOSH) has recommended an occupational standard for exposures to all forms of inorganic arsenic of 2 ug/m^3. Lung cancer has been observed in workers exposed to arsenic compounds other than arsenic trioxide. Dermatitis has been observed in workers exposed to a wide variety of arsenic compounds and in a mining community in which large quantities of inorganic arsenic settled out in the dust from smelter emissions. Bench scale concentrate samples from the Duluth Gabbro have averaged 31 ppm by weight arsenic. This value is less than one-sixth the cut-off value for the low range in copper and zinc concentrates (Table 16) from other locations in the U.S.; however, large fluctuations in the arsenic levels of such concentrates are known to occur (Radian 1978).

2.9.2.3 Analysis of Susceptible Population--Workers at greatest risk of lung cancer from arsenic, based on previous experience, are smelter workers. Those at risk of dermatitis include the smelter workers, plus their families, and the general community in close proximity to the smelter. Smelter workers who smoke would have an even greater risk of lung cancer.

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2.9.2.4 <u>Analysis of Environment</u>--Previous experience in areas of copper development has shown arsenic from smelting and refining to affect the health of workers exposed to arsenic in the plants, and their families and the general community exposed to arsenic from smelter emissions. Children living within four miles of a copper smelter showed evidence of exposure to arsenic as measured by hair and/or urine samples in all of eleven U.S. smelters studied (Baker et al. 1977). These results suggest that in addition to the fact that the health of the non-working population has been affected by arsenic from smelter emissions when the arsenic content of the concentrate has been relatively high (over one percent by weight), there is also evidence of increased environmental exposures to arsenic wherever there is a copper smelter. Conversely, the health of copper smelter workers has been reportedly affected only in cases where the arsenic levels in the concentrate have been relatively high (workers at copper smelters with lower levels of arsenic in the concentrate have not been studied). The average ambient air concentration of arsenic in northeast Minnesota is 4 ng/m^3 (Regional Copper-Nickel Study 1978p), a level that is below those reported from other areas of the United States and the world (U.S. Environmental Protection Agency, 1976).

2.9.2.5 <u>Impact Assessment</u>--Two types of disease have been observed in areas with copper smelters--lung cancer and dermatitis. Lung cancer is a severe disease and one in which the vast majority of the victims die soon after diagnosis regardless of treatment efforts. Dermatitis is generally a mild disease, one which causes temporary disability at worst and usually can be treated easily. Neither disease occurs immediately upon exposure to arsenic; however, the time between exposure and manifestation of disease is usually measured in years for lung cancer and days or weeks for dermatitis. In light of the study (Baker et al. 1977) showing that children age 1-5 living within four miles of

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copper smelters showed evidence of increased exposure to arsenic, regardless of the arsenic concentration in the concentrate, potential effects on health from arsenic must be considered if copper-nickel development occurs in Minnesota. Monitoring of human exposure by examining arsenic levels in hair and urine will indicate if increased external exposure to arsenic has occurred, but has not, as yet, been related to disease in humans. Because arsenic is a carcinogen, it would be prudent to consider any increased exposure to arsenic with caution.

2.9.2.6 Discussion of Controls--For workers, controls consist of ventilation and pre-vention of fugutive emissions within the plant. Dust emission controls on the smelter can effectively be used to protect the general community. Controls used with a smelter in Minnesota are expected to be more effective than controls on existing copper smelters, because newer technology employs more efficient methods and because regulations affecting new installations are more restictive than regulations affecting existing installations. Because of the long period between arsenic exposure and development of lung cancer it is difficult to assess the effectiveness of controls as it pertains to public health response to lower exposure levels.

2.9.2.7 Qualitative Risk Assessment--It appears probable that people living near a smelter will experience increased exposure to arsenic, since that has been the case at every other U.S. copper smelter which has been studied (eleven have been studied). The Regional Copper-Nickel Study estimates that ambient air levels of arsenic could reach a 24-hour average of 85 ng/m^3 two km from the smelter under worst case conditions. This compares to the proposed TLV (NIOSH) of 2 ug/m^3 and is over two orders of magnitude below the ACGIH intended change of 50 ug/m^3 (see Volume 3, Chapter 3-Air Quality). On the other hand, the arsenic levels in concentrates from Minnesota appear to be lower than concentrates from all other copper smelters for which data are available (n=9).

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Also serving to limit the potential impacts would be the fact that a new smelter would be expected to have better controls at the start than existing smelters. Taking all these factors into account it seems unlikely that arsenic would have any significant effect on workers, their families, or the general community. However, biological sampling of hair and urine combined with environmental and emission monitoring would be prudent.

2.9.3 Carbon Monoxide

2.9.3.1 Potential Impact--Carbon monoxide poisoning of underground miners.

2.9.3.2 Analysis of Agent--Carbon monoxide is a byproduct of combustion when a sufficient supply of oxygen is not available to produce carbon dioxide. Two major sources of carbon monoxide in underground mining are diesel-powered equipment and explosives. Fires may also produce carbon monoxide. Carbon monoxide is odorless and colorless.

2.9.3.3 Analysis of Susceptible Population--Those most susceptible workers are underground miners.

2.9.3.4 Analysis of Environment--Carbon monoxide is most likely to build up to unsafe levels in poorly-ventilated, enclosed areas. Underground mining is the only stage of development in which these conditions may exist to any great extent.

2.9.3.5 Impact Assessment--Because it is odorless, carbon monoxide poisoning is potentially very dangerous. Areas with poor air circulation, where carbon monoxide is most likely to occur, are usually also the places where there are few workers. Under these circumstances, if a worker was overcome by carbon monoxide, by the time he was discovered the consequences could be very severe. Personality changes in underground miners have been observed following severe cases of carbon monoxide poisoning. (Regional Copper-Nickel Study 1978e).

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2.9.3.6 Controls--There are two basic types of controls for carbon monoxide: engineering controls and personal protection devices. Engineering controls consist of methods such as adequate ventilation and use of electric powered equipment instead of diesel. Ventilation can be quite effective in preventing buildup of carbon monoxide; however, underground mines often have many areas where air circulation may be poor, regardless of the ventilation system. Replacement of diesel powered equipment by electric is most effective in areas of poor air circulation, but is also desirable throughout an underground mine. Underground mine models, prepared by the Regional Copper-Nickel Study, project an approximate mix of 50 percent diesel and 50 percent electric powered equipment.

Personal protective devices currently in use are intended to provide temporary relief to the worker and cannot legally be used to control carbon monoxide exposure except on a temporary basis. Each worker is required by the Mine Safety and Health Administration (MSHA) to have one of these devices in his possession at all times when underground.

2.9.3.7 Qualitative Risk Assessment--Carbon monoxide has long been recognized as a potential hazard of underground mining. As long as there are sources of carbon monoxide, potential for carbon monoxide poisoning will be present. The several different types of controls currently in use can effectively control carbon monoxide and are expected to limit this potential hazard.

2.9.4 Explosives

2.9.4.1 Potential Impacts--Explosives may cause injury, and sometimes death in workers. Potential impacts from the carbon monoxide and nitrogen oxides which are released during explosions are discussed elsewhere.

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2.9.4.2 Analysis of Agent--The agent in this case would be physical force from explosives. This force may be extremely powerful and acts very rapidly. It is expected that ammonium nitrate-fuel oil (ANFO) explosives would be used.

2.9.4.3 Analysis of Susceptible Population--This potential impact applies to the workers in underground and open-pit mining.

2.9.4.4 Analysis of Environment--Explosives are used only during the mining stages of copper-nickel development in both underground and open-pit mines. Ammonium nitrate-fuel oil explosives, although not free of risk, are unlikely to detonate accidently (Regional Copper-Nickel Study 1978b). Explosives may loosen rock or weaken structural supports, effects which may not be readily apparent, but which may be a source of accidents at a later time.

2.9.4.5 Impact Assessment--Effects on health from explosives are readily apparent. Every year a few deaths are attributed to explosives. Injuries are far more common with effects ranging from minor cuts to severe disability.

2.9.4.6 Controls--Adequate precautions for clearing the explosion area and proper handling of explosives should prevent hazards. Any injury that occurs from explosives could probably have been prevented.

2.9.4.7 Qualitative Risk Analysis--The explosives expected to be used with copper-nickel development are no more hazardous than explosives used elsewhere in the mining industry. With proper operating procedures accidents due to explosives should be virtually eliminated. Potential hazards to health from the use of explosives are not expected to be significant.

2.9.5 Nickel

2.9.5.1 Potential Impacts--Lung cancer, nasal cancer, and dermatitis in nickel refinery workers.

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2.9.5.2 Analysis of Agent--Nickel carbonyl [$Ni(CO)_4$] and nickel subsulfide (Ni_3S_2) are the forms of nickel most often implicated as carcinogens; however, other forms may also be carcinogenic (Regional Copper-Nickel Study 1976). Lung and nasal cancers are caused by inhalation of dusts containing nickel in sufficiently high concentrations. Dermatitis may be caused by direct contact with nickel or objects containing nickel. Heat and sweating enhance development of dermatitis.

2.9.5.3 Analysis of Susceptible Population--Women appear to be more sensitive to nickel than men, in terms of contracting dermatitis. Smokers may have an even greater risk of lung cancer in an environment containing nickel dusts.

2.9.5.4 Analysis of Environment--No single stage of refining has been implicated as the only area of risk for cancer. At one time lung and nasal cancers were believed to occur only at refineries using the nickel carbonyl (Mond) process; however, these cancers also have been observed at other nickel refineries. The current TLV for nickel is 1 mg/m^3. NIOSH has recommended that this be lowered to 0.015 mg/m^3. Dusty areas of the refinery are considered to be much more hazardous than dust free areas.

2.9.5.5 Impact Assessment--Dermatitis is far more common than lung or nasal cancer in nickel refineries. Time between first exposure and observation of dermatitis is generally on the order of days or weeks. Dermatitis is readily treatable and is usually not disabling unless treatment is delayed.

Lung and nasal cancer are usually fatal shortly after diagnosis. Neither can be treated with much success. At a Port Colbourne, Ontario, nickel refinery the time between date of first employment and death or diagnosis of cancer ranged from 17 to 49 years for nasal cancer (36 cases) and 15 to 51 years for lung cancer (90 cases)(NOISH, 1977). Because of the long interval between first

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exposure and development of cancer, adverse effects may not show up for decades making it extremely difficult to determine if hazardous conditions exist.

2.9.5.6 Controls--Nickel levels in the air may be controlled by ventilation or dust suppressive measures. Because safe levels of exposure to nickel have yet to be adequately determined and the time interval between first exposure and development of cancer is so long, effectiveness of such controls for reducing risk to health are currently unknown.

2.9.5.7 Qualitative Risk Assessment--The carcinogenic risk presented by nickel dusts is one of the most significant potential human health impacts of copper-nickel development. Lung and nasal cancers have been observed in workers from all parts of refineries. Although the numbers of workers at risk may be relatively small (186 workers employed in a model refinery-Table 18), these cancers are usually fatal. Furthermore, such cancers have a long induction period, making prevention impossible by the time the first cases are diagnosed. Dermatitis is a relatively mild disease and may be expected to have little significance except as an annoyance. Conditions in a new refinery may be expected to be less hazardous than in existing refineries; however, this does not mean a new nickel refinery will be free of hazardous conditions.

2.9.6 Noise

2.9.6.1 Potential Impact--Hearing loss from excessive noise exposure.

2.9.6.2 Analysis of Agent--The agent is the physical force of energy which causes sound (Regional Copper-Nickel Study 1978). Although there is always some noise around us, hearing loss appears to be caused only by noise greater than 80 decibels. Exposures to excess noise are cumulative. Sources of noise in the mining industry which are particularly loud include drills, fans, and heavy equipment (see Volume 3, Chapter 5-Noise).

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2.9.6.3 Analysis of Susceptible Population--Almost all workers may be exposed to potentially hazardous levels of noise. There is no evidence that humans can adapt to higher levels of noise without experiencing some hearing loss.

2.9.6.4 Analysis of Environment--Noise is a well-known problem in all stages of the mining industry and will continue to be into the foreseeable future. Noise in underground mines is generally louder than in open-pit mines or mills.

2.9.6.5 Impact Assessment--Hearing loss is not a fatal disease. It can, however, cause severe disability. Once detected it usually cannot be reversed. Tests for hearing acuity are fairly easy to administer, so that early indications of hearing loss can be observed and steps can be taken to prevent additional hearing loss. Loss of hearing, when it occurs, usually develops over a period of years of excessive noise exposure.

2.9.6.6 Controls--Noise may be controlled through the use of quieter machines and procedures. Mufflers or other noise control devices may be applied to equipment. Isolation procedures used to seal off areas of high noise levels may be used to reduce the size of the exposed population. Combinations of these controls are present in most noise control programs. When hearing acuity is regularly monitored in conjunction with noise control efforts most noise related impacts can be eliminated.

2.9.6.7 Qualitative Risk Assessment--Noise-induced hearing loss will be a potential impact of copper-nickel development. It is not an impact which is unique to the mining industry, but occurs in a wide variety of occupational settings. Adequate noise control programs are effective in preventing hearing loss and have been used with success. If adequate attention is not given to controlling noise exposure, workers will probably experience impairment of hearing more frequently than the average population.

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2.9.7 Particulates/Dust

This category is divided into two sections: occupational and non-occupational impacts.

2.9.7.1 Potential Impact--Particulates/dust causing respiratory diseases in workers.

2.9.7.2 Analysis of Agent--In the occupational setting particulates/dust are not usually measured per se (Regional Copper-Nickel Study 1977a). Instead individual components of the dusts, such as silica, asbestos fibers, or in the case of the copper industry, arsenic are monitored. Clearance of particulates from the alveolae is slowest of all the areas of the lung. Maximum deposition of particulates in the alveolae occurs when particulates are 1-2 micrometers in size. Respirable particulates may be intrinsically toxic, interfere with clearance of other particulates from the lung, or act as carriers of other toxic agents.

2.9.7.3 Analysis of Susceptible Population--Workers involved in underground mining, open-pit mining, processing, and smelting and refining would be at risk. Smokers may have an even greater risk of respiratory diseases in a dusty environment.

2.9.7.4 Analysis of Environment--In all stages of copper-nickel development except exploration, particulates present potential public health impacts. Exposures from exploration activities are considered to be too limited to be of significance in this report. Areas of poor ventilation are the most hazardous.

2.9.7.5 Impact Assessment--Chronic respiratory diseases, such as the pneumoconioses, bronchitis, emphysema, and decreased respiratory function are the most common results of excessive dust exposure. In severe cases these may result in death, but more commonly they are disabling to various degrees. These diseases take many years to develop and are usually not totally reversible once detected. Those with chronic respiratory diseases are generally more sensitive to air pollution and more severely affected by infectious diseases, such as influenza, than the general population.

2.9.7.6 Controls--Occupational standards exist for mineral dusts containing silica, silicates, and coal, and a number of nuisance particulates. Standards for silica or asbestos are restrictive enough that other dusts are well-controlled at the same time. Engineering controls include ventilation, the use of wet processes, and isolation of dusty areas. These controls can be highly effective when properly employed.

2.9.7.7 Qualitative Risk Assessment--Improved dust control efforts over the past several decades have markedly reduced deaths from some occupationally related respiratory diseases. However, chronic respiratory diseases continue to be observed, with effects ranging from decreased lung function to disabling bronchitis and emphysema. Because these diseases take many years to develop, monitoring can be difficult to perform adequately. If miners smoke more than the general population, as evidence suggests may be the case, their chances of contracting chronic respiratory diseases is probably greater than the smoking population in general because of the interactions between smoking and dusts. In spite of improved dust control programs the potential impact of dust exposure remains significant.

2.9.7.8 Potential Impact--Particulates/dust causing respiratory disease in families of workers and the general community.

2.9.7.9 Analysis of Agent--In most air pollution studies examining health effects on the general community the composition of the particulates is not

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determined. Particles in the range of 1-2 micrometers are of most concern in terms of deposition in the lung. Respirable particles may be inherently toxic, interfere with clearance of other particulates from the lung, or act as carriers of other toxic materials. Effects of smoking and exposure to particulates may be additive or synergistic.

2.9.7.10 Analysis of Susceptible Population--Segments of the population of greatest concern are the spouses of workers, children, infants, the elderly, and the chronically ill. Some of these groups (infants, elderly, and chronically ill) have less resistance to particulate air pollution. Spouses may be exposed to high levels of dust if the workers bring home their dusty clothes. Children are of concern because of their greater degree of mouth breathing (the nose is a very effective filter) and the possibility that early childhood respiratory illness predisposes them to respiratory disease as an adult.

2.9.7.11 Analysis of Environment--Smelter emissions of particulates and fugitive dust from tailings basins are of most concern. Proximity of residences to the smelter would in large part determine the potential risk. Background levels of particulates in the study area are approximately 11 ug/m^3 as an annual average (see Volume 3, Chapter 3-Air Resources).

2.9.7.12 Impact Assessment--Chronic respiratory diseases such as bronchitis, emphysema, and decreased respiratory function may result from excessive dust exposure. For those chronically ill, elevated levels of dust may aggravate their conditions. Development of chronic respiratory disease occurs gradually over a period of years. Aggravation of existing disease may occur soon after exposure to high levels of dust. In most cases these diseases are not totally reversible. There is also evidence that particulates may increase the rate of acute respiratory disease.

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2.9.7.13 Controls--Controls consist of preventing dust emissions from the smelter. There are several different ways of doing this and the technology has been welldeveloped in recent years (see Volume 2 and Volume 3, Chapter 3).

2.9.7.14 Qualitative Risk Assessment--The two major factors in determining the significance of potential impacts of particulate emissions are the emission characteristics and proximity of residences. In a recent study, children living near each of eleven copper smelters in the U.S. showed evidence of increased external exposure to arsenic. Because arsenic is only one component of particulates, this finding suggests the probability that increased exposure to particulates was also occurring for these children, and hence the community in general. Best estimates of the particulate threshold for adverse effects of short-term exposures (days) are 70 ug/m^3 with SO_2 levels of 180-250 ug/m^3 for aggravation of asthma, and 80-100 ug/m^3 with SO_2 levels above 365 ug/m^3 for aggravation of cardiopulmonary symptoms in the elderly; for long-term exposures (years) the best estimates of particulate thresholds for increased prevalence of chronic bronchitis in adults, acute lower respiratory disease in children, and decreased lung function in children are all close to 100 ug/m^3 with SO_2 levels of 95 ug/m^3 as an annual average (based upon the CHESS studies). The Regional Copper-Nickel Study estimates that ambient air levels of particulates could reach a 24-hour average of 170 ug/m^3 (compared to the 24-hour ambient air standard of 260 ug/m^3) 0.25 km and 27 ug/m^3 at 10 km from the smelter under worst case conditions (see Air Quality Section). If the National Primary Air Quality Standard of 75 ug/m^3, as an annual geometric average, is not exceeded, the effects of particulates on the non-occupational population will probably be of limited significance. Existing regulations for new sources of particulates are designed to prevent particulates from exceeding the National Primary Air Quality Standards.

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2.9.8 SILICA

2.9.8.1 Potential Impact--Silicosis in those working in underground mines, open-pit mines, or processing plants.

2.9.8.2 Analysis of Agent--Silicosis is caused by "free silica" a term applied to silicon dioxide compounds which do not contain cations (as opposed to silicates which do contain cations)(Regional Copper-Nickel Study 1978n). Particles smaller than five micrometers are of most concern. Exposures appear to be cumulative.

2.9.8.3 Analysis of Susceptible Population--Populations at risk consist of workers in underground mines, open-pit mines, and processing plants.

2.9.8.4 Analysis of Environment--As noted above, the stages of copper-nickel development in which silica dust could pose a hazard are underground mining, open-pit mining, and processing. Enclosed, poorly-ventilated areas would present the greatest potential hazards, making underground mining the area with the most potential for impacting health.

2.9.8.5 Impact Assessment--In extremely dusty conditions, such as frequently occurred in metal mines earlier in this century, silicosis may develop within a few years. Silicosis can be very severe, leading to death, or if detected in its earlier stages and the victim is removed from exposure to silica, the disease may be only mildly disabling. Periodic monitoring through the use of pulmonary function tests and chest x-rays can detect silicosis in its early stages. Damage to the lung is usually permanent and treatment is not very effective.

2.9.8.6 Controls--Controls consist of reducing dust exposure. Ventilation, use of wet processes, and isolation of dusty areas are the most common controls. In

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the past forty years dust control efforts have been vastly improved and the incidence of silicosis has dropped dramatically.

2.9.8.7 Qualitative Risk Assessment--Silicosis was once widespread in the mining industry. Today, however, effective control techniques are well-known and in use. If silica dust is effectively controlled, and this appears probable, silicosis should not occur in any of the workers.

2.9.9 Sulfur Oxides

2.9.9.1 Potential Impact--Respiratory diseases in workers, their families, and the general community due to sulfur oxides from smelting and refining.

2.9.9.2 Analysis of Agent--Sulfur oxides encompass a number of compounds including sulfur dioxides, sulfuric acid, sulfates, and sulfites (Regional Copper-Nickel Study 1977a). In the occupational setting, sulfur dioxide and sulfuric acid mist are the forms most likely to affect health. Sulfur dioxide and sulfates are the forms of most concern in the non-occupational setting. Because sulfur oxides interfere with clearance of particulates from the respiratory tract, mixtures of sulfur oxides and particulates may act synergistically. Maximum deposition of particulate sulfates in the alveolae occurs when the particles are 1-2 micrometers in size. The effects of sulfates vary depending on the cations associated with the sulfate molecule. Inhalation of sulfur oxides, especially through the mouth, is the route of intake of most concern. Sulfuric acid mist may cause skin irritations and burns in the occupational setting. Existing major sources of sulfur oxides in the region include power plants and the taconite industry (see Volume 3, Chapter 3-Air).

2.9.9.3 Analysis of Susceptible Populations--Workers are exposed to sulfur oxides only during smelting and refining. In the non-occupational setting children,

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infants, the elderly, and the chronically ill would be most susceptible to sulfur oxides.

2.9.9.4 Analysis of Environment--Sulfur oxides are produced only during the smelting and refining stages, including the sulfuric acid plant if that is part of the control system. Meteorological conditions play an important role in determining which forms of sulfur oxides may be present, the concentrations present, and the particle size. Proximity of residences to the smelter would in large part determine the potential risk.

2.9.9.5 Impact Assessment--Sulfur oxides act as respiratory irritants, reduce lung function, cause chronic respiratory diseases such as bronchitis and emphysema, and aggravate cardiopulmonary conditions in the chronically ill. A recent study (cited in Regional Copper-Nickel Study, 1977a) has demonstrated decreased lung function and increased respiratory symptoms in workers exposed to sulfur dioxide at levels of 1.0-2.5 ppm, which are below the occupational standard of 5 ppm. Sulfuric acid mist may cause tooth erosion. Some authors have suggested that respiratory disease in children may predispose them to chronic respiratory diseases as adults. Chronic respiratory diseases are generally not reversible and disable the victims to varying degrees depending on the severity of disease. Ventilatory function is fairly easy to monitor. However, since respiratory diseases usually develop over a period of years, small changes in ventilatory function observed in periodic screening may not be judged significant until clinical disease is actually present.

2.9.9.6 Controls--For workers controls consist of ventilation and isolation of areas with high sulfur oxide levels. In the non-occupational setting, smelter emissions may be controlled using scrubbers and methods which recover sulfur, such as an acid plant. Copper smelters have been one of the largest sources of sulfur oxide emissions in the U.S. Effectiveness of the controls depends on the desire of management, which in turn may be affected by the market for sulfur byproducts and government regulation, and on the ability of the employees to operate controls at optimum effectiveness. Sulfur oxide controls can be costly, but adequate attention to detail in the design of the system in the first place can reduce the problem considerably. Waste gases from flash smelters contain higher concentrations of sulfur oxides than smelters now in operation in the U.S.--a fact which makes control more economically feasible.

2.9.9.7 Qualitative Risk Assessment--Sulfur oxides have been a significant public health problem near established U.S. copper smelters. However, none of these smelters are flash smelters and control of sulfur oxide emissions has not been rigorously enforced until the last few years. Sulfur oxides, particularly sulfuric acid mist is expected to continue as a respiratory irritant to workers due to the difficulties of controlling fugitive emissions within the plant.

Smelter emissions are expected to be better controlled than has occurred in the past due to improved initial design and improved technology (see Volume 3-Technical Assessment and Volume 3, Chapter 2-Air Resources). The Regional Copper-Nickel Study estimates that under worst case conditions (but with controls) the 24 hour sulfur dioxide level could reach 110 ug/m^3 at 0.25 km and 50 ug/m^3 at 10 km from the smelter. These levels compare to the state standard of 260 ug/m^3 (see Volume 3, Chapter 3-Air Resources). However, controls do not work 100 percent of the time and meteorological conditions may occasionally occur such that the chronically ill experience aggravation of their diseases, if such a population resides close enough to the smelter.

2.10 PRIORITY TWO GROUPS

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Potential impacts on health were classified as priority two in steps one and two if effects on health had been observed in instances other than copper or nickel development, but which appear applicable to such development. Of the 56 potential impacts classified as priority two, sixteen occur during processing, while only three occur during exploration and construction (Table 13). Examination of the 56 priority two potential impacts by population group affected shows that 23 are applicable to workers and only one is applicable to visitors.

2.10.1 Arsenic

2.10.1.1 Potential Impact--Lung cancer and dermatitis in underground miners.

2.10.1.2 Analysis of Agent--Arsenic trioxide is the form of arsenic of most concern (Regional Copper-Nickel Study 1978d). There have been reports of people eating other forms of arsenic (believed to be naturally occurring elemental arsenic, As_4) without adverse effects. Therefore, the form in which arsenic occurs is quite important. In a report of lung cancer and dermatitis in underground (gold) miners (Osburn 1969), arsenic levels in the ore were characterized as high. Because arsenic has been shown to be a lung carcinogen, the National Institute of Occupational Safety and Health has recommended a workroom standard of 2 ug/m^3 for inorganic arsenic.

2.10.1.3 Analysis of Susceptible Population--Underground miners are the population at risk. Those who smoke may have an even greater risk of lung cancer.

2.10.1.4 Analysis of Environment--Arsenic is a common constituent of copper ores. At the present time it appears that arsenic levels in ore samples in northeast Minnesota are relatively low (compare Tables 15 and 16). Inhalation of arsenic compounds in dusty areas, possibly combined with smoking, was believed to be responsible for the lung cancer observed in the underground gold mine. Dermatitis may occur from exposure to high levels of arsenic in the dust.

2.10.1.5 Impact Assessment--These diseases have been discussed before in the priority one section on arsenic (2.9.2). Lung cancer is a severe disease, usually fatal shortly after diagnosis and taking many years to develop following initial exposure to arsenic. Dermatitis is usually a mild condition and easily treated.

2.10.1.6 Controls--Dust control by ventilation, use of wet processes, and isolation of dusty areas are most commonly employed. For workers daily baths after work and daily changes of work clothes may be used to prevent dermatitis. These controls can be very effective depending upon how rigorously they are applied.

2.10.1.7 Qualitative Risk Assessment--Arsenic levels were characterized as high at the mine evaluated by one report on arsenic-induced diseases in underground miners. In light of the low levels of arsenic detected in the ore and the probability of dust control efforts for other agents such as silica, the potential impact of arsenic on the health of underground miners does not appear to be very significant. Any effects from arsenic would probably first appear in smelter workers, if at all. If monitoring of smelter workers shows any effects of arsenic, it would be prudent to monitor underground miners.

2.10.2 Asbestos

Asbestos is used as a collective mineralogical term encompassing the asbestiform varieties of various silicate minerals and is applied to a commercial product obtained by mining primarily asbestiform minerals (Campbell, et al. 1977). Five minerals fit this definition: chrysotile (a member of the serpentine group), and the asbestiform varieties of actinolite-tremolite, anthophyllite, cummingtonite-grunerite, and riebeckite (memebers of the amphibole group). Chrysotile always occurs in the asbestiform habit; however, amphiboles usually occur in non-asbestiform habits, with the exception of riebeckite, which usually

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occurs in the asbestiform habit as crocidolite. Asbestiform minerals occur as fibers, which display some resemblances to organic fibers in terms of circular cross section, flexibility, silky surface luster, and other characteristics. Cleavage fragments produced from crushing and processing non-asbestiform minerals do not satisfy this definition of fibers and should be considered "fiber-like." When asbestiform and non-asbestiform minerals are subjected to crushing and processing, the resulting fragments have minor differences in morphology and physical properties that are very difficult to distinguish under a transmission electron microscope. For this reason, when the transmission electron microscope is used, fragments with an aspect (length to width) ratio of 3:1 or greater are reported as fibers, even though many of these fragments may not meet the definition of a fiber. In this document the term "mineral fiber" will refer to both asbestos fibers and cleavage fragments of non-asbestiform minerals (Regional Copper-Nickel Study 1978r).

2.10.2.1 Potential Impacts--Asbestosis, lung cancer, and mesothelioma in workers, and mesothelioma in families of workers and the general population due to inhalation of fibers; potential for gastrointestinal cancer due to ingestion of fibers in drinking water.

2.10.2.2 Analysis of Agent--Cleavage fragments are generated by processing nonasbestiform amphibole minerals in the ore body. The current workroom standard is two fibers (length-to-width ratio at least 3) greater than five micrometers in length per cubic centimeter; however, the Occupational Safety and Health Administration (OSHA) has proposed lower standards (0.5 fibers/cm^3). Maximal deposition of particulates in the alveolae occurs in the range of 1-2 micrometers. Studies of asbestos suggest that longer fibers and thinner fibers are in general more carcinogenic than other types (Regional Copper-Nickel Study 1977b). Most asbestos-related diseases have occurred from inhalation of asbestos.

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Concern about gastrointestinal cancer from ingestion of mineral fibers in drinking water is based upon the observation that asbestos workers experience increased rates of gastrointestinal cancer (presumably from swallowing sputum containing inhaled fibers). Nearby sources of mineral fibers include Reserve Mining Company's open-pit mine near Babbitt and possibly Erie Mining Company's open-pit mines on either side of the Reserve Mine. Mineral fibers have also been detected in road dust (up to 5%) in gravel roads in the area. Ambient air concentrations of all fibers combined are 10,000-40,000 fibers per cubic meter (1-4 X 10^{-2} fibers per cubic centimeter) in the Study Area (see Volume 3, Chapter 3-Air Resources).

2.10.2.3 Analysis of Susceptible Populations--Workers involved in exploration, open-pit mining, underground mining, and processing are at risk. Although some of these workers may not actually work in areas where mineral fibers would be produced, mineral fibers in fugitive dust emissions could pose a hazard to all workers. Spouses of asbestos workers have developed mesothelioma, as have people living in close proximity to asbestos industrial activity. Those potentially at risk of gastrointestinal cancer from ingestion of mineral fibers in drinking water would be those with surface sources of drinking water and near copper-nickel development. Communities which obtain drinking water all or in part from surface sources and near the Duluth Gabbro include Hoyt Lakes, Aurora, Ely, and Winton. Cigarette smokers who are exposed to asbestos have much higher rates of lung cancer than non-smokers exposed to asbestos.

2.10.2.4 Analysis of Environment--Techniques used to mine and process copper-nickel ores are different from those used by the taconite industry. Therefore, even if hydrous minerals are present in copper-nickel ore to the same extent that they are present in Reserve's taconite ore, mineral fiber production could be markedly different. Crushing operations would probably be the greatest

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source of mineral fibers; however, blasting, drilling, haulage, and fugitive emissions from tailings ponds are other potential sources of air-borne mineral fibers (see Volume 3, Chapter 3-Air Resources).

2.10.2.5 Impact Assessment--Asbestosis, lung cancer, mesothelioma, and gastrointestinal cancer are all severe diseases which cannot be successfully treated and often lead to death soon after diagnosis. These diseases do not occur until many years (usually 20-40) after initial exposure to asbestos. This long period between exposure and observed disease makes monitoring very difficult. One method for assessing the potential hazard of mineral fibers from copper-nickel development is to make use of the Minnesota Department of Health study of people living in Babbitt, Silver Bay, Duluth, Two Harbors, and other North Shore residents south-west of Silver Bay since these people have received exposures for about twenty years. If increased rates of asbestos-related diseases show up in these communities; all mineral fiber sources, including copper-nickel, should be carefully exa-mined. Conversely, if nothing shows up in these communities the potential risk from mineral fibers would be of less concern, assuming exposures to fibers from copper-nickel development in addition to existing sources would be equal or less than those presently experinced in the area.

2.10.2.6 Controls--Controls consist of reducing and limiting exposure to mineral fibers. This may be done by ventilation, use of wet processes, dust control devices to prevent emission of mineral fibers into ambient air, keeping tailings ponds wet to prevent blow-off of mineral fibers, and, for workers, isolation of dusty areas. Work clothes should not be taken home. Special filtration of drinking water supplies protects against ingestion of mineral fibers. The effectiveness of these controls is difficult to assess because of the long period between first exposure and observed disease. These controls should

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reduce the magnitude of the hazard as compared to that experienced by workers in the past; however, if any exposure to asbestos may cause disease, as is believed possible for carcinogens, some risk may always be present. Uncertainty concerning safe levels of asbestos exposure is exemplified by the fact that the occupational standard has been lowered twice in the past ten years and proposals to reduce the standard again have been filed.

2.10.2.7 Qualitative Risk Assessment--Much of the concern about mineral fibers can be attributed to the case of Reserve Mining. Although there is considerable evidence that mineral fibers from Reserve's activities have entered the environment and come into contact with humans, no evidence of increased incidences of asbestos-related diseases from ingestion or inhalation of mineral fibers in northern Minnesota residents exists at this time. However, a sufficient time has not elapsed for disease to occur. At this time it is difficult to assess the risk posed by mineral fibers generated from copper-nickel development. Safe levels of asbestos exposure, if they exist, are not known. In light of the great concern generated by the Reserve Mining case, it would be prudent to monitor the progress of health studies of the residents of northeastern Minnesota, and to treat the potential mineral fiber impact from copper-nickel with the same attention as is given to Reserve Mining. Given the potential for significant exposures to mineral fibers in Northeastern Minnesota from mining and other activities and the complete look of health affects data applicable to the specific mineral fibers in question, it would be prudent to initiate an extensive research program addressing this health affecting issue.

2.10.3 Cadmium

2.10.3.1 Potential Impact--Increased body burdens of cadmium in children residing near smelters.

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2.10.3.2 Analysis of Agent--Cadmium is a toxic substance. It has been found to accumulate in humans (Regional Copper-Nickel Study, 19781). Levels of cadmium in concentrate samples from the Duluth Gabbro have averaged 40 ppm (Table 15), which is low compared to other areas (Table 16). Cadmium in cigarette smoke is an additional source for those who smoke. Ambient air levels of cadmium in northeast Minnesota average 0.8 ng/m^3 (Regional Copper-Nickel Study 1978p).

2.10.3.3 Analysis of Susceptible Populations--Elevated levels of cadmium have been observed in the hair of children residing in towns near (within four miles) most U.S. copper smelters (Baker et al. 1977). The size of the population at risk would depend on the proximity of a smelter to nearby communities. Babbitt and Hoyt Lakes are the only Study Area communities within four miles of the Duluth Complex, but a smelter may be located anywhere in the region.

2.10.3.4 Analysis of Environment--Cadmium levels in the ore appear to be lower than most other areas with copper smelters (compare Tables 15 and 16). Because increased levels of cadmium in the hair of children have been observed near most U.S. copper smelters, the smelting stage is probably the stage of most concern regarding cadmium. Increased exposures to cadmium from dusts and soil may occur for years after a smelter has shut down (see Volume 3, Chapter 1-Soils).

2.10.3.5 Impact Assessment--Acute cadmium poisoning appears unlikely because cadmium levels are so low. Chronic cadmium poisoning, affecting the kidney, respiratory tract, and/or the cardiovascular system would be the most likely impact from cadmium if any impacts were to occur. Many years may elapse before chronic cadmium poisoning can be detected. Exposures to cadmium can be monitored through hair, urine, and blood samples; however, the relationship between these body burdens and disease are not well-defined. Due to the accumulative nature of cadmium young population groups should be prevented from receiving increased exposure.

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2.10.3.6 Controls--Cadmium from smelter emissions is of most concern. Controls preventing emission of dust in general would control cadmium at the same time. Such controls have proven to be quite effective elsewhere.

2.10.3.7 Qualitative Risk Assessment--Increased levels of cadmium in the hair of children living near most U.S. copper smelters suggest that cadmium exposures could occur from a smelter in northeast Minnesota. On the other hand, the relationship of increased cadmium in hair samples to effects on health are not well understood. Cadmium levels in concentrate samples from the Duluth Gabbro are low compared to concentrates from other copper smelters; however, cadmium levels in the ore are variable and varying smelter operating methods can affect cadmium emissions. In addition, a new smelter will have better controls at the start than existing smelters. The Regional Copper-Nickel Study estimates that cadmium levels in the air could reach a maximum 24-hour average of 10 ng/m^3 three km from the smelter under worst case conditions (see Volume 3, Chapter 3-Air Resources). This level is more than three orders of magnitude less than the TLV of 50 ug/m^3. Taking all these factors into account, potential impacts on health from cadmium are of uncertain, but probably little, significance; however, biological sampling of hair and urine combined with environmental and emission monitoring would be prudent.

2.10.4 Iron

2.10.4.1 Potential Impact--Siderosilicosis and lung cancer in underground miners and processing and smelting workers.

2.10.4.2 Analysis of Agent--Iron oxide has been reported to cause lung cancer in underground hematite miners (Boyd et al. 1970). This study was not conclusive, however, and it was pointed out that radioactivity may have been the responsible agent. Siderosis and siderosilicosis are respiratory diseases in

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which iron oxide plays a role (Regional Copper-Nickel Study, 1978m). In all three diseases iron oxide may be only a cofactor; that is, it may not cause the disease by itself but when combined with other agents it may incite disease. Inhalation of iron oxide is the route to entry into body. Other soueces of iron oxide are the numerous taconite mines. Iron occurs as magnetite in the taconite industry. Ambient air levels of iron average more than one u/gm^3 in northeasten Minnesota (Regional Copper-Nickel Study 1978p).

2.10.4.3 Analysis of Susceptible Population--Workers engaged in underground mining, processing, and smelting would be at risk. Smokers would have an even greater risk of developing respiratory diseases.

2.10.4.4 Analysis of Environment--Enclosed, poorly-ventilated areas would be of most concern. Such areas include underground mines, mills, and smelters. Previous studies observing effects from iron oxide, which occurred as hematite, may not be applicable to copper-nickel development in Minnesota where iron oxide would be primarily magnetite. The size of the taconite industry in northeastern Minnesota is such that the amount of iron oxide released in copper-nickel mining and processing is likely to be dwarfed by comparison. Approximately 10-12 percent of the copper-nickel ore is iron, as is 25-35 percent of the bench scale concentrates. Taconite is approximately 25 percent iron and the pellets contain 65 percent iron.

2.10.4.5 Impact Assessment--Both lung cancer and chronic respiratory diseases may take many years to develop even with repeated exposure to iron oxide. These diseases can be severely disabling. Early detection of chronic respiratory disease and subsequent removal from additional exposures may limit the disease to a relatively mild stage. Evidence to date suggests that iron oxide is more likely to be a cofactor in disease causation than a direct cause of disease.

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2.10.4.6 Controls--Dust control and isolation of inherently dusty areas could provide effective control of iron oxide.

2.10.4.7 Qualitative Risk Assessment--A number of factors suggest that the potential impacts on health from iron oxide are not very significant. Evidence linking iron oxide directly with disease is not very persuasive; instead it appears that iron oxide is a cofactor, enhancing disease caused by other agents. Dust controls have reduced the occurrence of pneumoconioses in recent years and are expected to be quite effective for copper-nickel development.

Additionally, if iron oxide poses a significant public health hazard, one might expect that such hazards would have been identified and examined in the iron industry in Minnesota. (However, the possibility remains that such a hazard exists but no one has investigated this possibility.) The possible link between iron oxide and lung cancer may be of greater significance, even if iron oxide acts only as a cofactor, because workers in the minerals industry tend to smoke more than the general population. At this time the evidence suggesting potential impacts on health from iron oxide is not strong enough to suggest that these impacts would be significant.

2.10.5 Lead

2.10.5.1 Potential Impact--Increased body burdens of lead in children residing near smelters.

2.10.5.2 Analysis of Agent--Lead is a toxic substance which accumulates in humans (Regional Copper-Nickel Study 1978h). At this time, lead levels in copper-nickel concentrate samples appear to be relatively low compared to other copper smelters (Tables 15 and 16). Other potential sources of lead include leaded gasoline, lead-based paints, improperly-glazed earthenware pottery, and

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cigarettes. Ambient air levels of lead in the Study Area average 58 ng/m^3 (Regional Copper-Nickel Study 1978p) compared to a range of 8 (remote areas) to 5,000 (Los Angeles) ng/m^3 for other areas of the United States (Waldron and Stofen, 1974).

2.10.5.3 Analysis of Susceptible Population--Elevated levels of lead have been observed in the hair of children residing in towns within four miles of existing U.S. copper smelters; however, blood lead levels were normal in most of these children. Elevated blood lead levels (indicative of lead poisoning) have been found to be very common in children living near some lead smelters. The size of the population at risk would depend on the proximity of a smelter to nearby communities. Babbitt and Hoyt Lakes are the only Study Area communities within four miles of the Duluth Complex, but a smelter could be located any where in the Region. Children are more susceptible to lead poisoning because a higher percentage of ingested lead is absorbed from the gastrointestinal tract than in adults. In studies near lead smelters children under five years were found to have the greatest incidence of lead poisoning; evidence of increased lead exposure was less common in older age groups.

2.10.5.4 Analysis of Environment--Lead levels in concentrate samples from the Duluth Gabbro appear to be lower than those in the concentrates of most other U.S. copper smelters (compare Tables 15 and 16). Increased exposure to lead from dusts and soil may occur for years after a smelter has shut down (see Volume 3, Chapter 1-Soils).

2.10.5.5 Impact Assessment--Lead poisoning can develop over a relatively short period of exposure. Blood lead levels are a good indicator of the potential hazard of one's lead exposure. However, the possibility of lead poisoning may not be readily obvious to the physician, especially if the disease is not of

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occupational origin. If detected in the early stages, lead poisoning can usually be treated successfully. Severe cases may cause brain damage, recurrent epileptic seizures, cerebral palsy, and blindness. Lead in hair is indicative of increased external exposure to lead, but has been difficult to relate to disease.

2.10.5.6 Controls--Lead from smelter emissions is of greatest concern. Controls preventing emission of dust in general would control lead at the same time. Such controls have proven to be quite effective elsewhere.

2.10.5.7 Qualitative Risk Assessment--Increased levels of lead in the hair of children near most U.S. copper smelters suggests that lead exposures could occur from a smelter in northeast Minnesota. On the other hand, the relationship between lead in hair and effects on health is not well understood. The relationship between blood lead and effects on health is well understood. However, a study which found elevated levels of lead in the hair of children residing near copper smelters found no correlation between hair lead levels and blood lead levels (Baker et al. 1977). The Regional Copper-Nickel Study estimates that ambient air levels of lead could reach a 24-hour average of 50 ng/m^3 three km from the smelter under worst case conditions (see Volume 3, Chapter 3-Air Resources). This compares to the ambient air standard of 1500 ng/m^3 proposed by the U.S. Environmental Protection Agency (1977a). Taking these factors into account, potential impacts on health from lead are of uncertain, but probably of little, significance. Biological monitoring of hair and blood lead levels combined with environmental monitoring would be prudent.

2.10.6 Mercury

2.10.6.1 Potential Impact--Mercury poisoning from consumption of contaminated fish.

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2.10.6.2 Analysis of Agent--Mercury is toxic, persistent in the environment, and accumulated by fish and other organisms (U.S. Environmental Protection Agency, 1976b). It has been detected in copper-nickel ore samples (below 100 ppb) and concentrate samples (177 ppb--compare with Table 16). Using these levels, an estimated 110 kg/year would be emitted from a smelter, and 1,150 kg/year would be discharged with tailings for every 100,000 tons of copper plus nickel produced (see Volume 2-Technical Assessment). Although at present there are no obvious sources of mercury in the region, the source of mercury in northeast Minnesota lakes is believed to be air-borne. Mercury has been detected in fish from some of these lakes at levels above the Food and Drug Administration (FDA) standard of 0.5 ppm (Minnesota Department of Health, 1977). Consumption of contaminated fish is the most likely mechanism by which mercury may affect health. Ambient air levels of mercury average 0.2 ng/m^3 in northeast Minnesota (Regional CopperNickel Study 1978p).

2.10.6.3 Analysis of Susceptible Populations--All segments of the population which consume fish from local lakes are potentially at risk of mercury poisoning. Visitors are included since many come to northeast Minnesota specifically to fish.

2.10.6.4 Analysis of Environment--Tailings from processing are expected to contain most (90%) of the mercury, although wastes generated from smelter controls and stack emissions are additional sources. Mercury in tailings may be less mobile initially than mercury from smelter emissions. Due to its persistence in the environment, potential impacts on health from mercury may exist for many years after a processing plant closes down.

2.10.6.5 Impact Assessment--Symptoms of organic mercury poisoning may take from three to eight weeks after exposure to show up. Mild cases of mercury poisoning

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can be treated successfully. Victims of severe cases may be left with brain damage and mental disorders. Congenital defects may occur in new-born infants even if the mother is free from symptoms of mercury poisoning. Mercury levels in blood can be measured to give an indication of mercury exposure; however, the relationship between blood mercury and health effects is not completely understood.

2.10.6.6 Controls--Controls preventing mercury from leaving tailings ponds would be one method. Limiting consumption of potentially contaminated fish is probably the most common control.

2.10.6.7 Qualitative Risk Assessment--The Regional Copper-Nickel estimates that ambient air levels of mercury could reach a 24-hour average of 0.5 ng/m^3 three km from the smelter under worst case conditions (see Volume 3, Chapter 3-Air Resources). This level is five orders of magnitude below the TLV of 50 ug/m^3 for mercury. It is difficult to attach much significance to the low levels of mercury in copper-nickel ore from the Duluth Gabbro. On the other hand, it is difficult to explain how some fish in northeast Minnesota lakes have mercury levels above the FDA standards when there is no apparent source of mercury in the region. Until new information is found concerning the source of mercury in fish from northeast Minnesota, the most prudent course would be to monitor fish and to carefully evaluate and control additional sources of mercury as much as possible. Limiting consumption of potentially contaminated fish would probably reduce the potential impact of mercury on health to a low level of significance.

2.10.7 Nickel

2.10.7.1 Potential Impacts--Lung cancer from exposure to nickel in workers employed in exploration, underground mining, open-pit mining or processing, and in their families and the general community residing near open-pit mines.

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2.10.7.2 Analysis of Agent--Nickel carbonyl ($Ni(CO)_4$) and nickel subsulfide (Ni_3S_2) are the forms of nickel most often implicated as carcinogens; however, other forms may also be carcinogenic (Regional Copper-Nickel Study, 1976). Lung cancer may result from inhalation of dusts containing sufficient levels of nickel. Because safe levels of exposure to carcinogens have not been determined, any exposure to nickel may pose a risk of lung cancer. Nickel is considered non-toxic when ingested in food and water.

2.10.7.3 Analysis of Susceptible Population--Workers involved in exploration, underground mining, open-pit mining, and processing would be at risk. The size of the population potentially affected, consisting of families of workers and the general community, would depend upon the proximity of residences to copper-nickel development. Smokers may be at increased risk of lung cancer in an environment containing nickel dusts. Families of workers, particularly spouses, may have increased exposure to nickel dusts if the workers wear their work clothes home.

2.10.7.4 Analysis of Environment--Dusts containing nickel would be produced at some point in all stages of copper-nickel development. The National Institute of Occupational Safety and Health (1977) lists nickel miners and nickel workers as occupational groups with potential exposure to nickel, and who would have an increased risk of lung cancer. Dust emissions from open-pit mining are probably more difficult to control than emissions from other stages of development. The population residing close to such a mine may experience increased exposure to dusts containing nickel. Studies have shown that people residing near smelters show evidence of increased exposure to metals, and that the emission characteristics are one of two major factors determining exposure (the other factor was proximity to the smelter). Therefore, the population residing close to any phase of copper-nickel development may have increased exposure to dusts containing nickel. Ambient air levels of nickel in the Study Area average 2 ng/m^3 (Regional Copper-Nickel Study 1978p).

2.10.7.5 Impact Assessment--Lung cancer is usually fatal shortly after diagnosis. Because of the long latent period between first exposure and development of cancer, typically 20-30 years, the existence of a public health hazard will be difficult to identify. Even though levels of nickel may be lower in the air inhaled by the general population as compared with workers, a more significant public health hazard could exist in the general population because certain segments, such as infants and the chronically ill, may be more susceptible to environmental pollutants than workers.

2.10.7.6 Controls--Dust controls can be used in all stages of copper-nickel development and vary in effectiveness depending on a number of factors. Some workers may be protected by ventilation and isolation of dusty areas. Workers should leave their work clothes at work and change work clothes frequently. New residential construction could be discouraged in areas near existing or potential copper-nickel activity.

2.10.7.7 Qualitative Risk Assessment--The carcinogenic risk presented by nickel dusts as discussed above is difficult to assess. If precautions are taken to locate industrial development away from residential areas and dust control programs are adequate, the risk to the non-occupational population would probably not be very significant. Although the risk of lung cancer to workers is greatest for refinery workers (as discussed previously), the workers in other stages of the minerals industry probably have a small increased risk over the general population. The Regional Copper-Nickel Study estimates that ambient air levels of nickel could reach a 24-hour average of 6.9 ug/m^3 0.25 km from the smelter and remain above 1.5 ug/m^3 out to 6 km under worst case conditions (see Volume 3, Chapter 3-Air Resources). This level compares to the current occupational TLV of 100 ug/m^3 for soluble nickel compounds and the NIOSH (1977) recommended level of 15 ug/m^3. These values are both within two orders of magnitude of the current TLV. A well-implemented dust control program would probably reduce these risks to a level difficult to distinguish from the risk to the general population.

2.10.8 Nitrogen Oxides

2.10.8.1 Potential Impacts--Acute and chronic respiratory disease in underground miners.

2.10.8.2 Analysis of Agent--Nitrogen oxides are formed when combustion occurs at high temperatures. Explosives and diesel machinery are two sources of nitrogen oxides which may be significant. Nitrogen dioxide is the most toxic of the various nitrogen oxides. Effects on health may occur from acute exposure due to inhalation of high levels of nitrogen oxides or long-term chronic exposure due to inhalation of lower levels of nitrogen oxides (Regional Copper-Nickel Study 1978i).

2.10.8.3 Analysis of Susceptible Population--Underground miners would be the group most at risk.

2.10.8.4 Analysis of Environment--Enclosed, poorly-ventilated areas would present the greatest hazards from nitrogen oxides. There have been few reports in the literature linking nitrogen oxides to respiratory disease in underground miners. This may be because only acute effects are likely to be attributed to nitrogen oxides, since chronic respiratory diseases are caused by a number of more common agents and take a long time to develop.

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2.10.8.5 Impact Assessment--Acute exposure to nitrogen oxides causes a severe respiratory disease and, in some cases, is fatal. Complete recovery does not always occur. The disease usually occurs within 24 hours after exposure and may last for a few months. Exposures to lower levels of nitrogen oxides may increase the frequency of respiratory diseases caused by other agents and reduce respiratory function. Effects on health from chronic exposures may be difficult to attribute to nitrogen oxides. Respiratory function tests can be used to monitor for chronic effects.

2.10.8.6 Controls--Nitrogen oxides can be well controlled by adequate ventilation and safety practices when using explosives and diesel machinery.

2.10.8.7 Qualitative Risk Assessment--Direct effects from nitrogen oxides will probably not be very significant. Indirect effects, by acting in conjunction with other agents which also cause respiratory disease, are more likely. Periodic monitoring of respiratory function should detect adverse effects on the respiratory system in early stages, so appropriate action can be taken. Overall, potential impacts from nitrogen oxides are expected to have little significance.

2.10.9 Particulates/Dust

2.10.9.1 Potential Impacts--Respiratory disease in exploration and construction workers; families of underground miners; workers' families and the general community near open-pit mines and processing plants.

2.10.9.2 Analysis of Agent--In the occupational setting particulates/dust are not measured *per se*; instead specific agents are examined (Regional Copper-Nickel Study 1977a). In the non-occupational setting particulates are usually measured, while individual agents have not been until recently. Sources of dust

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other than from copper-nickel development include transportation, the taconite industry, power plants, and wind erosion. For families of workers dust brought home on work clothes could be an additional source. Particulates 1-2 micrometers in size are of most concern. Respirable particulates may be intrinsically toxic, interfere with clearance of other particulates from the lung, or act as carriers of other toxic agents. Smoking and exposure to particulates may act synergistically.

2.10.9.3 Analysis of Susceptible Populations--Exploration and construction workers would be of secondary concern compared to other occupational groups in the minerals industry. Exposures for this subgroup would be fairly short, not more than several years. Of the non-occupational population, families of workers, particularly spouses, could have increased exposure to dust brought home on workclothes. The size and characteristics of the general population exposed to particulate emissions would depend upon the proximity of residences to copper-nickel development and the extent to which emissions are controlled. This population, which includes families of workers, may contain high risk subgroups such as the elderly and chronically ill. Smokers may have an even greater risk of respiratory disease in a dusty environment.

2.10.9.4 Analysis of Environment--Smelter emissions have been discussed in the section on priority one categories. For exploration workers, enclosed areas with poor ventilation are most hazardous. Such areas may be more likely to occur during exploration (particularly underground) than during full scale production because of management's hesitation to spend money on safeguards which may never receive much use. Emissions from surface mines and mills may reach the general community depending on the proximity of residences.

2.10.9.5 Impact Assessment--In general, very high levels of particulates increase the death rate for all causes of death. Impacts from particulates as

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discussed in this section are more likely to aggravate disease in the chronically ill, enhance the incidence of communicable respiratory disease, and decrease lung function. Acute impacts may occur when meteorological conditions inhibit dispersal of particlates. Chronic effects may develop only after years of exposure to low particulate levels.

2.10.9.6 Controls--For workers controls consist of ventilation, use of wet processes, and isolation of dusty areas. Dust controls protecting families of workers and the general population consist of emission controls, dust control on roads, and tailings beaches (using water and/or dust control compounds), and preventing tailings ponds from drying up. Point sources of particulates are much easier to control than non-point sources. The non-occupational population can also be protected by discouraging industrial development near residential areas and residential settlement near industrial activity.

2.10.9.7 Qualitative Risk Assessment--Best estimates of the threshold for adverse effects on health from short-term exposures to particulates are 70 ug/m^3 for aggravation of asthma, and 80-100 ug/m^3 for aggravation of cardiopulmonary symptoms in the elderly; for long-term exposures the best estimates of particulate thresholds for increased prevalence of chronic bronchitis in adults, acute lower respiratory disease in children, and decreased lung function in children are all close to 100 ug/m^3 as an annual average (based upon the CHESS studies). If the National Ambient Air Quality Standards of 75 ug/m^3, as an annual geometric mean, and 260 ug/m^3, as the maximum 24-hour average concentration, are not exceeded, the health of the non-occupational population should be ade-quately protected. Existing regulations for new sources of particulates are designed to prevent particulates from exceeding the National Ambient Air Quality Standards.

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2.10.10 Population Pressures

This section has been written to increase awareness of a number of subtle impacts that may occur from copper-nickel development.

2.10.10.1 Potential Impacts--A rapidly increasing population may directly and indirectly affect the health of the existing and incoming population in a number of ways--for example, straining community health services, disrupting the social fabric, and causing housing shortages.

2.10.10.2 Analysis of Agent-Host-Environment Relationships--The high level of health enjoyed by modern society is largely due to the complex web of environmental controls used to protect health. These controls take various forms, for example: treating water so it is safe to drink; sewage treatment and disposal so that wastes will not cause disease; protection of food so that it is both safe to eat and of good quality; good housing to provide adequate heat, light, shelter, privacy, and a safe home environment; good recreation areas which provide a safe environment to relieve the tensions of modern society; a health systems network which has accessible facilities and sufficient manpower available to treat injuries and illness and prevent disease; air pollution controls so the air is safe to breathe.

A rapidly increasing population may inhibit the effectiveness or even the existence of some of these controls. Rapid population growth may require operation of water and sewage treatment plants above capacity, increasing the likelihood of water-borne diseases. Rapid population growth may force the use of substandard housing, presenting health and safety hazards. Rapid population growth may lead to overuse of recreational areas, causing health and safety problems. Rapid population growth may produce haphazard residential development, without regard for protection of neighbors' water supplies, suitability of

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soils for septic tanks, or proximity to industrial activity. Rapid population growth may disrupt the social fabric when people with different habits and customs move into a new neighborhood thereby increasing stress and tension. Rapid population growth may put strains on community health services in that once adequate manpower and facilities are no longer sufficient to meet the demands of the larger population. The extent to which these impacts may occur depends on the size and rapidity of the population increase.

2.10.10.3 Impact Assessment--Impacts from population pressures would be most likely to occur as increased morbidity from communicable diseases. Increased morbidity might arise out of increased exposure to infectious agents and decreased host resistence from increased stresses. Although death from such diseases is far less common than 50-100 years ago, due to the advances of modern medicine, it takes time to recover from illness and illness generally has a depressing effect on the individual. It would be difficult to measure an increase in communicable diseases since such diseases are often poorly or not reported and baseline information may be lacking.

Severity of impacts from population pressures is directly related to the size of the population increase relative to the ability of the area to absorb such an increase and the time in which the population increase takes place. Potential for population pressures impacts are indicated in Table 19, which compares population increases from three development models to existing populations of four cities. These population increases do not include contributions from construction workers, service workers, or taconite expansion. Each development model has different implications for the cities shown; however, each city could be significantly affected by at least one of the mine development models (see Volume 5, Chapter 17).

Table 19

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Table 19. Estimated population increase due to new workers and their families for selected cities in northeast Minnesota for three development models.

	POPULATION* (1976)	ZONE 1-2** DEVELOMPMENT	ZONE 4 DEVELOPMENT	ZONE 6-7 DEVELOPMENT	ALL THREE DEVELOPMENTS
Aurora	2792	54 (2%)***	243 (9%)	820 (29%)	1117 (40%)
Babbitt	2892	550 (19%)	3300 (114%)	49 (2%)	3899 (135%)
Ely	4961	3224 (65%)	1409 (28%)	20 (-)	4653 (94%)
Hoyt Lakes	3722	27 (1%)	123 (3%)	993 (27%)	1143 (31%)

SOURCE: Residential settlement gravity models (see Socioeconomic Section).

*See Socioeconomic Section.

**Zone 1-2 = 12.35 X 10^6 mtpy underground mine and processing plant.
Zone 4 = 16.68 X 10^6 mtpy underground and open pit mine, processing plant, and 200,000 mtpy smelter.
Zone 6-7 = 20 X 10^6 mtpy open pit mine and processing plant.

***Numbers in parentheses are percent of 1976 population; (-) means less than 0.5 percent.

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2.10.10.4 Controls--The impacts of rapid population growth can be mitigated by adequate planning. Potential impacts can be identified and averted if there is sufficient preparation to cope with a rapidly increasing population. Such preparation requires adequate and reliable advance notice on the extent and timing of population changes. Historically, such notice has not been given or acted upon in time to maintain adequate community services.

2.10.10.5 Qualitative Risk Assessment--Environmental health controls do not occur spontaneously. Controls that are in use today have been developed to prevent the injuries and illnesses experienced in the past. Because many of these controls have been so successful the memory of the impacts on health and the concern for environmental controls has diminished. A rapidly growing population which would accompany copper-nickel development (estimates show that the populations of Ely and Babbitt could double--Table 19) might strain existing environmental health controls and be lax in provision of additional controls. Potential impacts from a rapid population growth could be the most significant impacts on health from copper-nickel development and yet go undetected because of the difficulties in measuring and evaluating such impacts.

2.10.11 Processing Chemicals

This section will provide only a general overview of potential impacts, because of the wide variety of processing chemicals which could be used.

2.10.11.1 Potential Impact--Health and safety hazards from storage, handling, and disposal of processing chemicals by workers engaged in processing, smelting and refining.

2.10.11.2 Analysis of Agents--Processing chemicals may have toxic vapors, cause burns or dermatitis, and present safety hazards due to flammability (Regional

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Copper-Nickel Study 1978k). Indirect impacts may also occur from breakdown products of some chemicals; for example, xanthates may break down into carbon disulfide, sulfur dioxide, or hydrogen sulfide. Breakdown products may be more toxic than the original chemical. Inhalation of vapors and direct contact with the skin from spills are the mechanisms of most concern.

2.10.11.3 Analysis of Susceptible Population--Workers employed in processing, smelting, and refining would be at risk.

2.10.11.4 Analysis of Environment--Specific chemicals and quantities used would depend upon the composition of the ore and may vary over the life of the mines. Processing chemicals are used only for processing, smelting, or refining activities. The cost of chemicals (a significant factor in total operating costs) provides incentive for prudent use (Hawley, 1972).

2.10.11.5 Impact Assessment--Impacts may be either acute or chronic. Acute impacts may be caused by spills onto skin or inhalation of high concentrations of vapors. Such impacts are readily apparent and the success of treatment depends on the severity of exposure. Chronic impacts such as decreased respiratory function may take years to develop. The existence of chronic impacts is often difficult to detect, yet such impacts may be of greater significance than acute impacts.

2.10.11.6 Controls--Potential impacts from processing chemicals can be effectively controlled by proper storage and handling of chemicals, adequate ventilation, and isolation of areas where chemicals are used.

2.10.11.7 Qualitative Risk Assessment--Spills are always a possibility; however, these are not expected to have a significant impact on health. Safe storage and handling procedures are known and expected to be implemented.

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Chronic effects are also an ever present possibility because of the difficulty in proving there are no effects on health. Careful evaluation of chemicals used and prudent handling practices are expected to limit the significance of potential impacts from processing chemicals.

2.10.12 Zinc

2.10.12.1 Potential Impact--Metal fume fever from zinc oxide produced from welding wearplates to the mantel of the crusher in the processing stage.

2.10.12.2 Analysis of Agent--Zinc oxide fumes cause a transitory metal fume fever (Regional Copper-Nickel Study, 1978o). These fumes may be inhaled by those working at or near welding operations. Zinc oxide fumes would be formed intermittently and would therefore not be a constant hazard.

2.10.12.3 Analysis of Susceptible Population--Workers employed in the processing plant would be potentially at risk. However, only a small number of these might actually be potentially exposed to zinc oxide fumes.

2.10.12.4 Analysis of Environment--The specific area of risk from zinc oxide fumes is the site where wearplates are welded onto the mantel of the crusher in the pro-cessing plant. Enclosed, poorly-ventilated areas present the greatest hazard.

2.10.12.5 Impact Assessment--Zinc-induced metal fume fever is an acute, mild respiratory disease. The disease is transitory, generally lasting less than 48 hours without any long-term effects.

2.10.12.6 Controls--Zinc oxide fumes can be effectively controlled by adequate ventilation and isolation of welding areas.

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2.10.12.7 Qualitative Risk Assessment--It appears that the reason for absence of a problem from zinc oxide fumes is its recognition in the past and use of adequate controls. The widespread use of controls, the mildness of the disease and the small number of people at risk suggest that zinc oxide will not be a significant hazard.

2.11 DISCUSSION AND SUMMARY

Copper-nickel development would present a number of potential impacts on human health. In other areas where copper and/or nickel development has occurred both workers and the general population have been reported to have increased mortality rates for several different causes of death. For the most part, the agent(s) responsible for increased mortality in the non-occupational population has(have) not been identified. However, in the occupational setting, a number of cause-effect relationships between agents and disease have been established. Summaries of air and water quality guidelines for human health are illustrated in Tables 20 and 21. Worst case estimates of pollutant levels at various distances from a smelter are shown in Table 22 and compared to standards in Table 23.

Tables 20, 21, 22, 23

This report does not attempt to address the issue of whether these potential impacts are acceptable. Although adverse impacts have been discussed in detail, copper-nickel development would have beneficial effects as well. Unfortunately these beneficial effects are difficult to evaluate, just as "population pressures" were difficult to evaluate. A healthy economy is good for public health, because of the known correlation of income with health and the positive psychological effects of having a job and a steady income. However, in the case

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TABLE 20 AIR QUALITY GUIDELINES FOR HUMAN HEALTH

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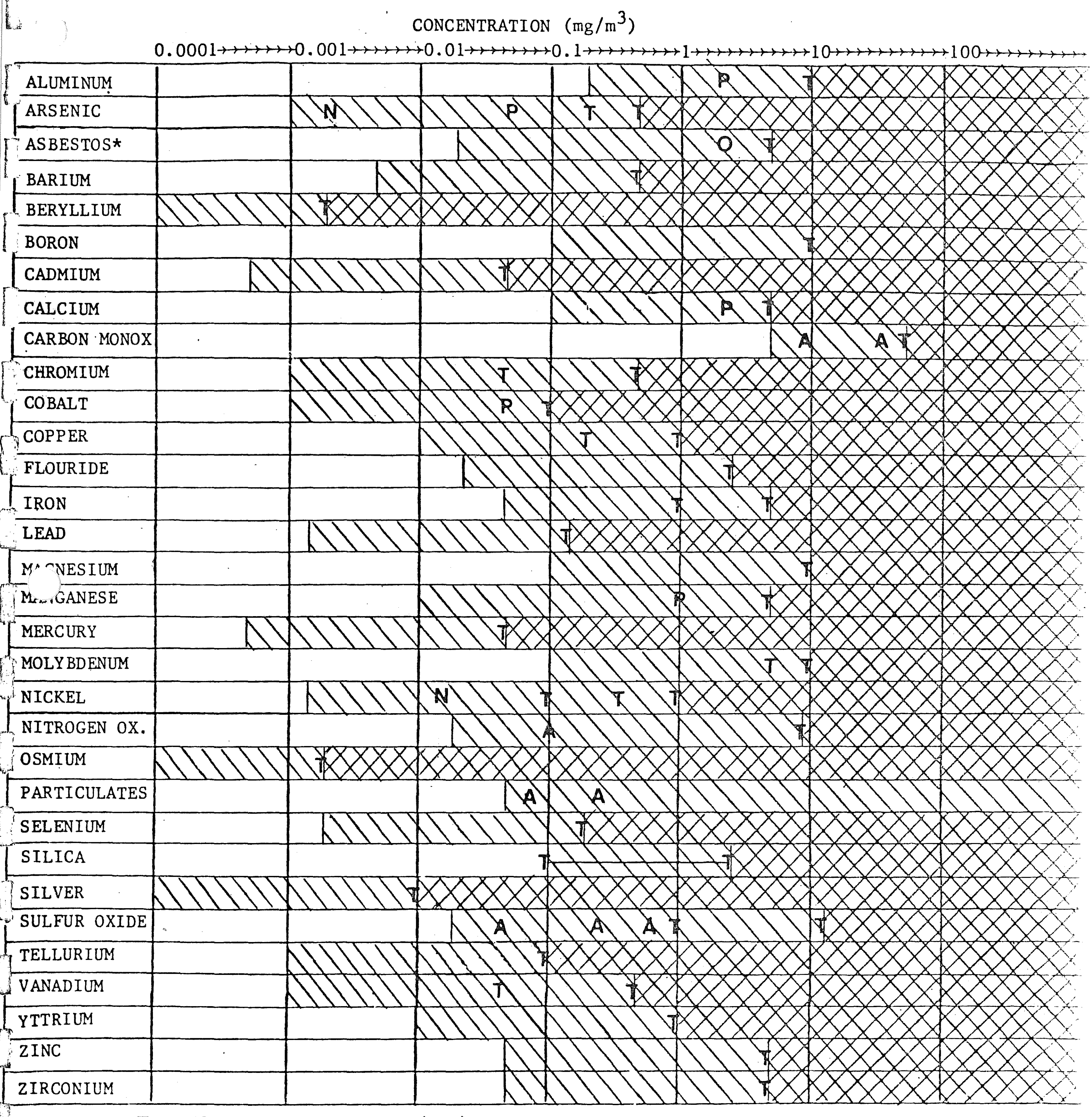


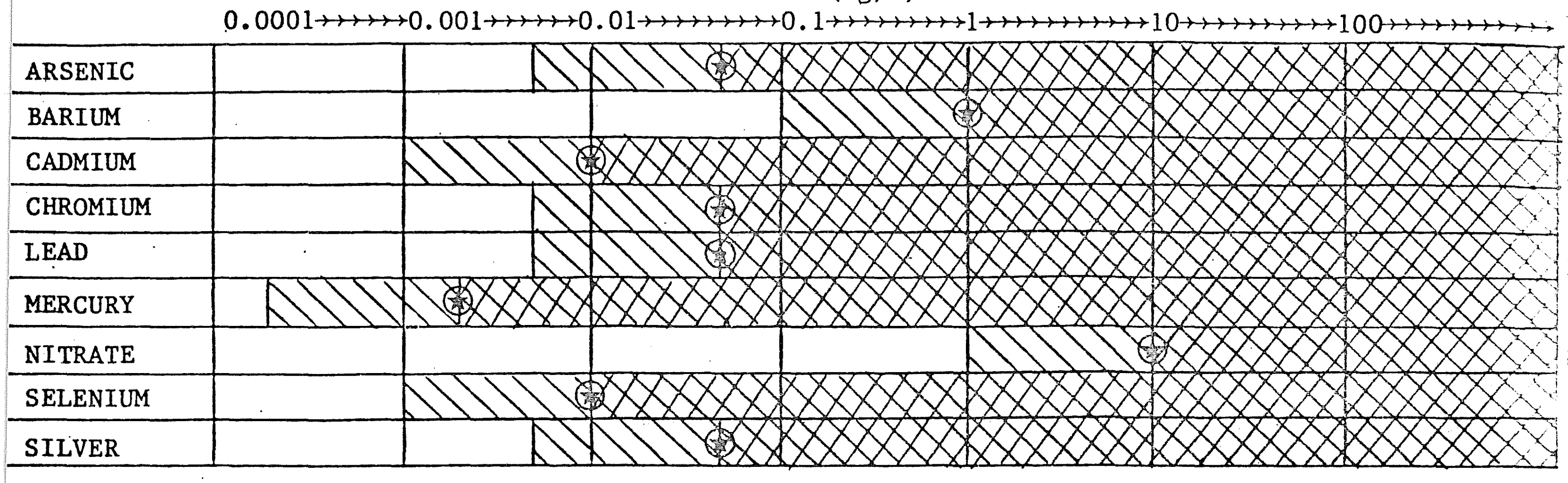
T - THRESHOLD LIMIT VALUE (TLV)
A - AMBIENT AIR QUALITY STANDARD
P - PROPOSED REVISION OF TLV
N - NIOSH RECOMMENDATION
O - OSHA STANDARD
* - FIBERS PER CUBIC CENTIMETER

- HEALTH OF GENERAL COMMUNITY MAY BE AFFECTED IN THIS ORDER OF MAGNITUDE

- HEALTH OF WORKERS AND COMMUNITY MAY BE AFFECTED IN THIS ORDER OF MAGNITUDE

TABLE 21 WATER QUALITY GUIDELINES FOR HUMAN HEALTH*

PRIMARY MAXIMUM CONTAMINANT LEVELS (MCL)
CONCENTRATION (mg/l)

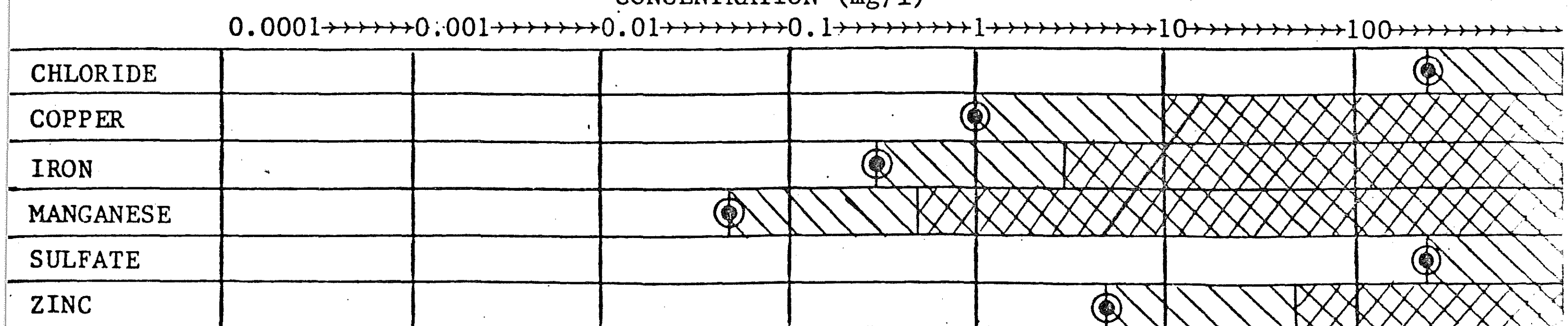


(★) - PRIMARY MCL TO PROTECT HEALTH OF CONSUMERS

(single hatch) - ACTION TO PREVENT FURTHER CONATMINATION MAY BE DESIRABLE

(cross hatch) - WATER CAN NOT LEGALLY BE SERVED TO THE PUBLIC

SECONDARY MAXIMUM CONTAMINAT LEVELS (MCL)
CONCENTRATION (mg/l)



(◉) - SECONDARY MCL TO ENSURE ESTHETIC QUALITIES OF DRINKING WATER

(single hatch) - CONTAMINANTS DETECTABLE BY A SMALL PROPORTION OF CONSUMERS

(cross hatch) - CONTAMINANTS DETECTABLE BY MOST CONSUMERS

* Source: Environmental Protection Agency, Federal Register, 40(248):59570 (12/24/75)
42(62):17146 (3/31/77).

Table 22. Worst case estimates of 24-hour pollutant levels at various distances from a smelter in ng/m^3 due to fugitive and stack emissions combined.*

	0.25 km	1.5 km	5.0 km	10.0 km	MAXIMUM	BACKGROUND
Arsenic	13	43	82	53	85 at 2 km	4
Cadmium	8	7	9	6	10 at 3 km	0.8
Lead	14	27	47	30	50 at 3 km	58
Mercury	0	0.23	0.41	0.32	0.5 at 3 km	0.2
Nickel	6,870	3,900	1,940	960	6,900 at 0.25 km	2
Particulates	170,000	95,600	51,800	26,800	170,000 at 0.25 km	11,000
Sulfur Dioxide	110,000	70,000	70,000	49,000	110,000 at 0.25 km	23,600

*Based upon models for sulfur dioxide using meteorological conditions of 2/28/77 and 10/30/77 and assuming controls sufficient to meet the new source performance standards (see Air Quality Section).

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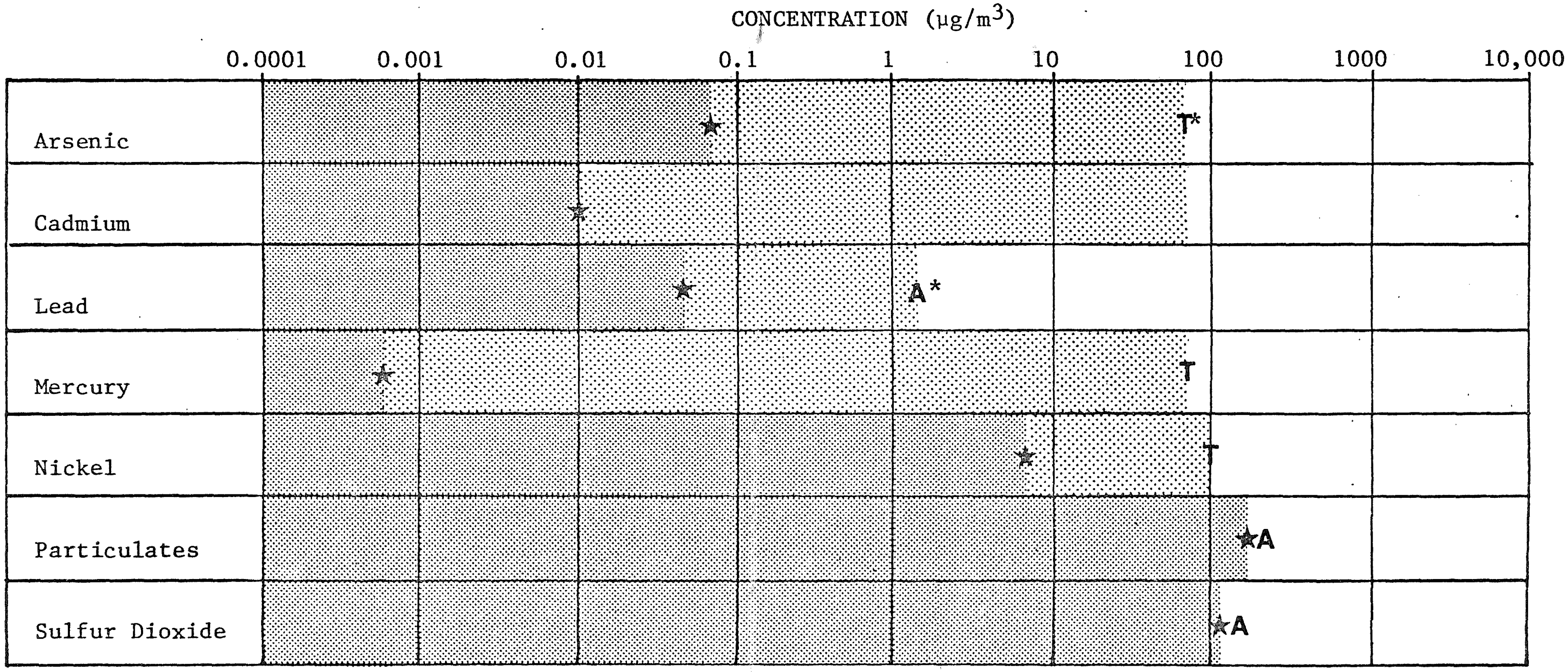
Table 23. Comparison of 24-hour worst case estimates of pollutants levels with existing standards.



★ Maximum 24-hour worst case level from Table 22.

T 1977 Threshold limit value from Table 20.

A Ambient air quality standard from Table 20.

*Proposed change.

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of potential copper-nickel development, there are also many risks involved with the jobs which would be created. These risks may or may not be acceptable. This issue is beyond the scope of the Regional Copper-Nickel Study, but should be addressed before potential impacts have a chance to turn into observed impacts.

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