CN 007

ANALYSIS OF POTENTIAL IMPACTS ON HUMAN HEALTH FROM COPPER-NICKEL DEVELOPMENT

STEP 1 -- GENERAL PRIORITIZATION

Regional Copper-Nickel Study

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ABSTRACT

Potential impacts on human health are being analyzed by a three-step process to focus attention on the impacts most likely to affect health. This paper presents the results of the first step--the prioritization of impacts on health potentially arising from copper-nickel development in general.

Twenty-two agents, which have potential for impacts on health, were examined through literature reviews and/or other methods. Another twenty-nine agents, considered less likely to affect health, were examined in less detail.

Potential impacts were placed into one of four priority groups to direct further analysis efforts. The rationale for this prioritization is presented and the priority groups are summarized in tables.

INTRODUCTION TO THE REGIONAL COPPER-NICKEL STUDY

The Regional Copper-Nickel Environmental Impact Study is a comprehensive examination of the potential cumulative environmental, social, and economic impacts of copper-nickel mineral development in northeastern Minnesota. This study is being conducted for the Minnesota Legislature and state Executive Branch agencies, under the direction of the Minnesota Environmental Quality Board (MEQB) and with the funding, review, and concurrence of the Legislative Commission on Minnesota Resources.

A region along the surface contact of the Duluth Complex in St. Louis and Lake counties in northeastern Minnesota contains a major domestic resource of copper-nickel sulfide mineralization. This region has been explored by several mineral resource development companies for more than twenty years, and recently two firms, AMAX and International Nickel Company, have considered commercial operations. These exploration and mine planning activities indicate the potential establishment of a new mining and processing industry in Minnesota. In addition, these activities indicate the need for a comprehensive environmental, social, and economic analysis by the state in order to consider the cumulative regional implications of this new industry and to provide adequate information for future state policy review and development. In January, 1976, the MEQB organized and initiated the Regional Copper-Nickel Study.

The major objectives of the Regional Copper-Nickel Study are: 1) to characterize the region in its pre-copper-nickel development state; 2) to identify and describe the probable technologies which may be used to exploit the mineral resource and to convert it into salable commodities; 3) to identify and assess the impacts of primary copper-nickel development and secondary regional growth; 4) to conceptualize alternative degrees of regional copper-nickel development; and 5) to assess the cumulative environmental, social, and economic impacts of such hypothetical developments. The Regional Study is a scientific information gathering and analysis effort and will not present subjective social judgements on whether, where, when, or how copper-nickel development should or should not proceed. In addition, the Study will not make or propose state policy pertaining to copper-nickel development.

The Minnesota Environmental Quality Board is a state agency responsible for the implementation of the Minnesota Environmental Policy Act and promotes cooperation between state agencies on environmental matters. The Regional Copper-Nickel Study is an ad hoc effort of the MEQB and future regulatory and site specific environmental impact studies will most likely be the responsibility of the Minnesota Department of Natural Resources and the Minnesota Pollution Control Agency.

INTRODUCTION

Potential impacts on human health from copper-nickel development will be analyzed according to the diagram shown in Figure 1. Collection of background information has emphasized an understanding of agent-host-environment relationships which might occur with copper-nickel development in Minnesota. Other information inputs include a study of the mortality experience of other counties in the United States with copper or nickel development and studies prepared by other staff of the Regional Copper-Nickel Study.

A three-step process will be 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.

This paper presents the results of the first step of this process. Categories of potential impacts on health have been placed into four priority classifications depending on whether they might apply to copper-nickel development in general. Categories classified as priority one or two will undergo further evaluation as outlined by the three-step process discussed above. Categories 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. A brief discussion of the information used for this prioritization process is presented.

STUDY DESCRIPTION AND METHODS

Initially, a literature review about the environmental health hazards of copper and nickel development was prepared (Regional Copper-Nickel Study 1976). From this literature review came recommendations for additional literature reviews on arsenic, sulfur dioxide, particulate air pollution and silica. These four agents, along with asbestos (because of the proximity of Reserve Mining), were placed in a priority group. Other subjects for literature reviews were chosen based on an analysis of the concentrate from a 10,000 ton bulk sample from INCO's Spruce Road Site (Table 1) and recommendations from staff of the Regional Copper-Nickel Study. A list of the literature reviews is presented in Table 2. This list was reviewed by the Health Studies Advisory Committee and other health professionals in February, 1977. At that time the list contained osmium, but not manganese. Osmium was later dropped from the list because it has not been detected in ore samples from the Duluth Gabbro and the quantities produced as byproducts of other copper or nickel smelters are minimal.

In addition to the review on copper and nickel, reviews on asbestos, particulate air pollution, and sulfur oxides were contracted out to the Epidemiology Department of the University of Minnesota, Minneapolis. These reviews were contracted out because of the large volume of literature and the high potential for impacts on health each presented. Literature reviews on the remainder of the topics in Table 2 were prepared by the Health Studies staff during the summer of 1977. Emphasis was placed on collecting recent (within the past ten years) literature and studies which were directly applicable to copper-nickel development, although supplementary information beyond these boundaries was also collected. Abstracts of all literature reviews are included in this report.

Priorities for potential impacts on health from copper-nickel development in general were determined by applying the agent-hose-environment concept. Agents are the subjects of the literature reviews. Hosts, or susceptible populations, are divided into four groups; workers, families of workers, the general community, and visitors (e.g. tourists, seasonal residents, and other transients).

Environments are used here as the five discrete stages of copper-nickel development prepared by the Technical Assessment group of the Regional Copper-Nickel Study; exploration, underground mining, open-pit mining, processing, and smelting and refining.

These definitions have been used to prepare Table 3, which summarizes the possible agent-host-environment categories. Each category has been placed in one of four priority groups according to the definitions in Table 4.

Two agents that were not the subjects of literature reviews have been included in Table 3: mercury and population pressures. Mercury has recently been found to exceed the Food and Drug Administration (FDA) standards in fish from some of the lakes in northeast Minnesota and has recently been detected in ore samples from the Duluth Gabbro at low concentrations (less than one ppm). Population pressures, (i.e. the pressures a rapidly growing or changing population places on the social structure of the population and community services) present potential impacts which are very difficult to measure; they have been included here to make the reader aware that such impacts may occur and may have impacts on health.

Additional agents which have been detected in some ore samples or identified from other sources are presented and prioritized in Table 5. These agents, all of which have been classified as priority three or four, were only briefly considered and have therefore not been divided into stage of copper-nickel development or susceptible population group.

A brief discussion of the information used in the prioritization process for Tables 3 and 5 is presented below.

DISCUSSION

Accidents

Sources--Accidents are ever-present possibilities in all stages of copper-nickel development.

Review of Literature--The minerals industry is one of the most hazardous industries in the United States. Congress, recognizing the hazards inherent to the mining industry, passed the Federal Metal and Nonmetallic Mine Safety Act (PL 89-577) in 1966. This law is currently administered by the Mining Enforcement and Safety Administration.

Accident frequency rates for workers in underground mines are generally three times those in surface mines and mills (e.g. 37.78 vs. 13.13 and 11.76 disabling injuries per million man-hours worked, respectively, in 1975). Other stages of mineral development--open pit mining, milling, smelting and refining--tend to be more hazardous when compared to averages of all industries (including industries besides the mineral industry) combined, but are much less hazardous than underground mining. Usually the location of the ore deposit dictates whether surface or underground mining methods may be used.

Miners with less than two years of experience are more likely to be involved in accidents than other miners. Machinery, haulage, fires, fall of ground, fall of person, and electricity are the major causes of fatal accidents. Most accidents can be prevented either through adequate attention from supervisors or the elimination of unsafe acts of workers. Strong safety programs, which have reduced accident rates by fifty percent, have been reported.

In 1975 Minnesota had no underground mines. Accident frequency rates for surface mines and mills in the state were one-half and one-fourth, respectively, of the rates for all surface mines and mills in the U.S. The accident record of the copper industry has been similar to that of the minerals industry in general, over the past few years. Data from the nickel industry are of little use because there is only one nickel mine and smelter in the United States.

Rationale for Priority Categories--Priority one: Accidents are a universal occupational hazard. High fatality and disability rates indicate that mining is one of the most hazardous industrial occupations. Accident rates for underground mining are 2-3 times higher than those for surface mining.

Priority Three: New residents would be unfamiliar with roads. The rural parts of Minnesota tend to have relatively more accidental traffic deaths than urban areas. The number of accidents may be expected to increase because of increased traffic; however, because accident rates are so low, such an increase may be difficult to distinguish from natural variation if the population increase is only a few thousand. Families of workers and the general community would have an increased risk of accidents; visitors may also be affected, but to a lesser extent.

References: U.S. Department of the Interior 1975; Regional Copper-Nickel Study 1978a.

Aluminum

Sources--Mine dust, mill dust (from crusher), other sources of dust.

Review of Literature--Aluminum is a major constituent in the environment, comprising over eight percent of the earth's crust. It has been detected in Minnesota waters (0-2.9 ug/ml), and air concentrations range from 0.01 ug/m^3 over oceans to 8 ug/m^3 in urban areas. Typical adult intake of aluminum is 10-100 mg per day.

Respiratory disease associated with aluminum was observed in ammunition workers during World War II; however, it occurred only when aluminum particles were less than 7 um in size.

Nonoccupational diseases associated with aluminum have been limited to side effects from medicinal uses of aluminum. These include encephalopathy in uremic patients on dialysis who had been treated with phosphate binding gels for more than three years and phosphate deficiency causing osteomalacia in patients using aluminum hydroxide as an antacid.

Animal studies have supported the human findings of respiratory effects and adverse effects on uremic patients therapeutically treated with aluminum. Experimental studies have also indicated that dermatitis or growth retardation may occur from excessive aluminum exposure.

The threshold limit values (TLVs) are 10 mg/m^3 for alundum and corundum (both Al_2O_3), and both compounds are classified as nuisance particulates. There are no standards for aluminum in drinking water, air, or food.

Rationale for Priority Categories--Priority Three: Respiratory disease due to aluminum has been observed in workers exposed to dust with high levels of aluminum. Workers in underground mines or processing (crushing) would have the most potential for being exposed to high levels of aluminum.

Priority four: Adverse effects of aluminum have only been observed in very dusty occupational settings or from medicinal uses of aluminum; therefore, the remaining eighteen categories have been placed in this priority group.

References--Sorenson et al. 1974; Regional Copper-Nickel Study 1978i.

Arsenic

Sources--Dust in smelter emissions, mine dust, mill dust (from crusher), other sources of dust.

Review of Literature--Arsenic ranks twentieth (2-5 ppm) in abundance in the earth's crust, and twelfth (0.2-0.3 ppm) in the human body. It has been used for a wide variety of purposes including medicines, herbicides, insecticides, wood preservatives, and rat poisons. Arsenic has been found in the air near coal burning industries and smelters, and in some public water supplies. Typical adult intake of arsenic is 900 ug per day, although those frequently consuming seafood may ingest up to five times this amount.

The trivalent form of arsenic (arsenic trioxide, arsenites) shows some tendency to accumulate in the kidney and liver, as well as in hair, nails, and skin; and is considered to be much more toxic than pentavalent arsenic (arsenates), which does not accumulate.

Exposure to arsenic has been epidemiologically linked to lung cancer in a number of occupations, including copper smelting. The lowest arsenic exposure associated with increased risk of lung cancer is 3 ug/m^3 for less than one year. Time between first exposure and onset of cancer is a minimum of fifteen years. Skin cancer has also been observed; and there have been one or two reports associating arsenic with lymphatic cancers and liver cancer. Dermatitis has been observed in a number of occupational settings.

A study of children, age 1-5 years, living in eleven towns within four miles of a U.S. copper smelter, found hair arsenic levels significantly higher than controls in all eleven towns and urine arsenic levels significantly higher than controls in eight of the eleven towns. Dermatitis has been observed in a community which was exposed to arsenic emitted from a gold mine-mill site. An epidemiological study has suggested a relationship between lung cancer and industrial air emissions containing inorganic arsenic.

Attempts to produce cancer in animal experiments have been unsuccessful, with two possible exceptions. Because of this, the question of whether arsenic is a carcinogen remains controversial.

The threshold limit values (TLVs) for arsenic are: arsenic trioxide (As_2O_3 production, 0.05 mg/m^3; arsenic trioxide handling and use 0.25 mg/m^3; and arsine (AsH_3), 0.2 mg/m^3. The National Institute of Occupational Safety and Health (NIOSH) has recommended lowering the TLV for inorganic arsenic to 0.002 mg/m^3. The U.S. Environmental Protection Agency has set the maximum contaminant level (MCL) of arsenic in drinking water at 0.05 mg/l.

Rational for Priority Categories: Priority One: Arsenic from copper smelters has been linked to lung cancer and dermatitis in workers, their families, and the general community.

Priority Two: Arsenic from an underground gold mine has been linked to lung cancer and dermatitis in workers.

Priority Three: In light of the above reports concerning arsenic, arsenic from other sources, such as underground mining, open-pit mining, and milling and processing, might present a public health hazard to workers, their families, and the general community.

Priority Four: It is unlikely that the limited quantity and length of exposure to arsenic from exploration and construction would pose a public health problem. Visitors would be unlikely to develop arsenic-related disease because of their limited length of exposure.

References--U.S. Environmental Protection Agency 1977a; Regional Copper-Nickel Study 1978c.

Asbestos

Sources--Mill dust (from crushing); dust from blasting, drilling, and transportation of ore.

Review of Literature--"Asbestos" is a general term applied to a group of fire-resistant mineral silicates that are similarly fibrous in structure but very different in respect to several other properties. The two main mineral subdivisions are serpentines (chrysotile) and amphiboles (crocidolite, amosite, tremolite, actinolite, anthophyllite). The distinction between fibers of natural commercial asbestos and cleavage fragments involves minor differences in their structural and chemical makeup. The actual fibers existing in northern Minnesota are cummingtonite-grunerite cleavage fragments most closely resembling commercial amosite.

Workers exposed to varying types, sizes, and concentrations of commercial asbestos fibers in air have experienced increased rates of asbestosis, respiratory cancers, gastrointestinal cancers, and pleural and peritoneal mesotheliomas. Two studies of occupational exposure to noncommercial asbestos cleavage fragments gave conflicting results concerning carcinogenicity: one study found a three-fold increase in respiratory cancer in workers exposed for at least 60 months, while the other found no increase of respiratory or abdominal cancer in workers with at least 21 years of employment with the mining company.

Persons without occupational exposure may show evidence of exposure to asbestos. Asbestos fibers and asbestos bodies have been found in the lungs of persons with no occupational exposure; radiological changes have been demonstrated in populations living in close proximity to an asbestos mine or factory; and mesothelial tumors have been found in persons with no occupational exposures to asbestos. Two nonoccupational studies have reported no excess cancer rates due to ingestion of city water supplies containing high concentrations of noncommercial asbestos minerals in the cummingtonite-grunerite series; however, the time between first exposure and the times of the studies may have been insufficient for the development of cancers.

Several theories about the mechanism of carcinogenicity have been proposed: the fiber theory, the trace metal theory, the organic materials theory, and the multifactor theory. Smoking appears to increase the risk of lung cancer among asbestos workers. The risk of mesothelioma in man and animals seems to be higher for crocidolite than amosite or chrysotile. Long fibers and thin fibers both seem to be more carcinogenic.

The TLV for asbestos (all forms) is two fibers per cubic centimeter greater than five micrometers in length.

Rationale for Priority Categories--Priority Two: Fibers may be formed during the blasting, drilling, or crushing of copper-nickel ore if hydrous minerals are present. When these conditions occur in enclosed areas, such as underground mines or processing plants, air-borne fiber concentrations may rise to unsafe levels. In these cases, workers in the exploration, underground mining, open-pit mining, and processing (crushing) stages may have increased risk of asbestosis, lung cancer, or mesothelioma.

Spouses of asbestos workers have been observed to have an increased risk of mesothelioma. This potential risk may be applicable to underground mining, open-pit mining, and processing. Dust emissions containing fibers and contamination of water supplies by fibers discharged with the tailings may present increased risks of disease to the families of workers and the general community living near open-pit mines or processing plants.

Priority Three: Because fibers tend to accumulate in the lungs, fibers released from underground mining could pose a public health hazard to the general community and visitors. Similarly, air emissions of fibers from open-pit mining or processing could also pose a hazard to visitors. However, these situations present less of a risk than those discussed above in priority two, and there is little evidence that these lower exposures could adversely affect health.

Visitors drinking water containing fibers (from disposal of tailings from processing) are included in this category.

Priority Four: Fibers are not produced during smelting and refining; and production of fibers during exploration and construction would probably be too limited to pose a risk to anyone except workers in enclosed areas.

References--Becklake 1976; Regional Copper-Nickel Study 1977b.

Cadmium

Sources--Mine dust, mill dust (from crushing), smelter emissions, leaching from waste rock or tailings ponds.

Review of Literature--Cadmium has not been determined to be an essential element to man. It has been found in food, water, and air, and has been shown to accumulate in the kidney and liver of man.

Acute effects from exposure to cadmium metal or oxide fumes generally consist of respiratory effects such as pneumonitis and pulmonary edema. In one incident the lethal dose of cadmium oxide was calculated to be 8.6 mg/m^3 for five hours. Chronic exposure to cadmium most commonly results in emphysema and proteinuria. One researcher estimated that 10-20 years of exposure to 50 ug/m^3 of cadmium fume or dust could result in proteinuria.

In the nonoccupational setting cadmium poisoning has most commonly arisen when cadmium has been leached out of food or drink containers. Itai-itai disease, a type of osteomalacia affecting mainly women over 45 years of age occurred in Japan when rice, irrigated by water containing cadmium from mine wastes, accumulated cadmium to very high levels. Cadmium levels in the water used for irrigation were below 0.01 ppm. A study of children, age 1-5 years, living in eleven towns within four miles of a U.S. copper smelter, found hair cadmium levels significantly higher than controls in nine of the eleven towns.

Experimental work has substantiated the effects on the kidney, lung, and bone, and has also indicated other possible health effects. Evidence of a relationship between chronic exposure to low levels of cadmium and occurrence of hypertension, heart disease, and carcinogenesis has been shown in animals. Calcium and zinc appear to decrease the effects of cadmium.

The TLV for cadmium oxide fume is 0.05 mg/m^3. The MCL set by the Environmental Protection Agency for drinking water is 0.01 mg/l.

Rationale for Priority Categories--Priority Two: Elevated body burdens of cadmium have been observed in children living near copper smelters; however, these have yet to be related to adverse effects on health.

Priority Three: Cadmium appears to be concentrated somewhat during milling and processing. In Japan, cadmium poisoning was attributed to rice which had accumulated cadmium from contaminated water. Because of the popularity of wild rice in Minnesota, the possibility of wild rice becoming contaminated with cadmium, if cadmium levels in water increase, presents a potential hazard.

Priority Four: Cadmium, from exploration or mining sources alone, occurs in very low concentrations and would have little opportunity to enter the environment.

References--Friberg et al. 1975; Regional Copper-Nickel Study 1978j.

Carbon Monoxide

Sources--Byproducts from explosives, diesel machinery, and other sources of combustion.

Review of Literature--Carbon monoxide is a colorless, odorless, and tasteless gas. Manmade sources of carbon monoxide arise from incomplete combustion of carbon-containing compounds. Carbon monoxide exerts its effects on humans by competing with oxygen for binding sites on the hemoglobin molecule and thereby reducing the availability of oxygen to body tissues.

In the occupational setting carbon monoxide poisoning has occurred in places with poor ventilation and a source of carbon monoxide. It is a well known hazard in underground mines. Carbon monoxide poisoning may: affect the brain, as manifested by personality changes; aggravate cardiovascular disease in terms of angina pectoris, intermittent claudication, and altered electrocardiogram; and affect vision, with blindness observed in severe cases. The relationships between carbon monoxide concentrations and effects on human health have been well defined.

Studies of rabbits and dogs have suggested that these animals may be able to adapt to increased carbon monoxide concentrations.

The TLV for carbon monoxide is 50 ppm. Standards for carbon monoxide in ambient air are 9 ppm as an eight-hour average and 35 ppm as a maximum one-hour average.

Rationale for Priority Categories--Priority One: Carbon monoxide is a well known public health hazard in underground mines and other poorly ventilated areas in which combustion may occur.

Priority Four: With the possible exception of underground mines, formation of carbon monoxide is unlikely to occur in significant amounts. Even if carbon monoxide could be formed, in the presence of oxygen, it is rapidly converted to carbon dioxide, a far less toxic gas.

References--Stewart 1975; Regional Copper-Nickel Study 1978d.

Cobalt

Sources--Refinery dust, other sources of dust.

Review of Literature--Cobalt is generally recovered as a byproduct of copper or nickel mining. It is essential to man being physiologically active in Vitamin B_{12}.

Respiratory disease attributed to cobalt has been observed in tungsten carbide workers. Reports of dermatitis from cobalt have also appeared in the literature. Cobalt given therapeutically or added to beer has caused dermatitis and heart disease.

Animal studies have confirmed the respiratory damage which may occur and have shown that injection of cobalt or cobalt oxide may induce tumor growth. Studies using nickel refinery dust have shown that the cobalt oxide present can induce tumors in rats but not in mice.

The carcinogenic properties demonstrated in animals and the respiratory damage from large doses shown in both animals and man, indicate the need for much further study on the toxic effects to man from low level cobalt exposures.

The TLV for cobalt is 0.1 mg/m^3.

Rationale for Priority Categories--Priority Three: Cobalt oxide from nickel refinery dust has caused tumors in rats (an indication of possible carcinogenicity). Populations potentially at risk from smelter and refinery emissions include workers, their families, and the general community.

Priority Four: Cobalt is an essential element and, with the possible exceptions noted above, has adversely affected health only in situations unrelated to copper and/or nickel development.

References--Schroeder et al. 1967; Regional Copper-Nickel Study 1978k.

Copper

Sources--Mine dust, mill dust, refinery dust, smelter emissions, tailings.

Review of Literature--Copper is ubiquitous in man's environment. It is a common constituent of the earth's crust and has found wide use in man's utensils and artifacts since the Stone Age. Because of this lengthy and familiar association, metallic copper has long been accepted as an innocuous substance.

In the occupational setting there have been occasional reports of metal fume fever caused by copper. Copper miners have been found to experience a greater than expected mortality from heart disease, respiratory neoplasms, tuberculosis, and influenza and pneumonia, and an excess in morbidity from pneumoconiosis and accidents. Workers engaged in copper smelting and refining have experienced an elevated mortality from heart disease, respiratory cancer, tuberculosis, and cirrhosis of the liver, and an increased morbidity from chronic respiratory disease, and arsenical melanosis, dermatosis and perforation of the nasal septum. It is difficult to pin-point the causative agents of the diseases observed in workers involved in copper mining, smelting and refining; arsenic and sulfur dioxide have been the agents most often suspected.

In the nonoccupational setting, an epidemiological study found that persons residing in the 36 counties in the United States with major copper, zinc, or lead industries experienced lung cancer rates greater than other U.S. residents. People from mining communities have also often been found to experience excess morbidity from chronic and acute respiratory disease. Copper and its compounds are generally not hazardous; however, poisonings from large exposures have occasionally been reported.

Experimental studies have found large doses of copper sulfate to cause an excess mortality, decreased body weight in survivors, and to accumulate in the liver, kidney, intestines, and brain. Copper oxide and copper sulfide were found not to be carcinogenic in rats or mice through the intrafemoral route. Metallic copper has been found to affect the reproductive system of rats.

The TLVs for copper are: 0.1 mg/m^3 for copper fume, and 1.0 mg/m^3 for copper dust.

Rationale for Priority Categories--Priority Three: Copper interferes with spermatogenesis in rats and is used to increase the efficiency of some contraceptive agents. Workers, families of workers, and the general community may be at risk from long, protracted exposures to copper dust generated by the various stages of copper-nickel development.

Priority Four: Exploration would not be a significant source of copper dust. Visitors would be unlikely to experience any effects because of their intermittent exposure.

References--National Research Council 1977; Regional Copper-Nickel Study 1976.

Explosives

Sources--Used for blasting in underground and open-pit mining.

Review of Literature--Ammonium nitrate blasting agents are widely used in the mining industry and account for ninety percent of all blasting done in the U.S. Low cost and relative freedom from the hazards of accidental detonation account for the popularity of these blasting agents.

Safety hazards are involved with the use of any explosive. During the years 1970-1975 there were 28 deaths related to explosives in metal and nonmetallic mines in the U.S. Extensive safety recommendations have been recently published by the Bureau of Mines.

Toxic gases, most notably nitrogen dioxide and carbon monoxide, may be formed as byproducts of explosions. Hazardous levels of these gases may persist following detonation, particularly in poorly-ventilated, enclosed areas.

Nonoccupational hazards of explosives may include increased noise and dust production, flying rock, and under extraordinary circumstances, dermatitis from ingestion of ammonium nitrate.

Rationale for Priority Categories--Priority One: Explosives are used only in the underground and open-pit mining stages. Deaths attributed to the use of explosives occur almost every year.

Priority Three: Potential hazards due to flying rock or other debris from surface mining explosions may exist for the rest of the population, if public access is allowed near the mining operation.

Priority Four: Explosives are not used for exploration, processing, or smelting and refining. Hazards of explosives used for underground mining are applicable only to workers.

Reference--Regional Copper-Nickel Study 1978b.

Iron

Sources--Mine dust, mill dust, other sources of dust, tailings.

Review of Literature--Iron, the metal most widely used by man, comprises five percent of the earth's crust. In the past iron ore mined in Minnesota was predominantly hematite (ferric oxide), while today taconite, which is predominantly magnetite (ferrous oxide) is mined.

Iron is essential to human life. It is needed primarily for the formation of hemoglobin, but has other roles as well. Underground hematite miners have experienced increased incidences of lung cancer although this may have been due to radiation exposure instead of iron oxide. Similar observations have not been made for surface miners. Respiratory diseases, including siderosis, siderosilicosis, silicosis, and silicotuberculosis have also been observed; however, dust suppressive measures have greatly reduced these problems.

In the nonoccupational setting, adverse effects on health from iron have been limited to poisonings, particularly from ferrous sulfate. Animal studies suggest that iron cannot induce cancer by itself, but may enhance the effects of other carcinogens.

The TLV for iron oxide fume is 5 mg/m^3.

Rationale for Priority Categories--Priority Two: Iron oxide is a cancer promoting agent and has been shown to be a factor in certain respiratory diseases. These diseases have been observed in underground hematite miners. Workers in underground mining, processing (crushing), or smelting and refining would have the most potential for exposure to high levels of iron oxide.

Priority Three: Iron oxide levels in the air may pose public health hazards to workers in open-pit mining, and their families and the general community exposed to emissions from smelting and refining; however, there is little evidence whether or not these potential hazards could actually occur.

Priority Four: Iron is an essential element to human health and one which is often not adequately present in the diet. Nonoccupational reports of iron-induced disease are generally limited to poisonings, due to ingestion of large quantities of iron salts, such as iron sulfate.

References--Boyd et al. 1970; Regional Copper-Nickel Study 1978l.

Lead

Sources--Mill dust, tailings, smelter emissions.

Review of Literature--Lead has been used by man for thousands of years. Major uses of lead today include batteries, battery oxides, and gasoline antiknock additives. Levels of lead in the air vary widely ranging from 5 ug/m^3 in Los Angeles to less than 0.01 ug/m^3 in wilderness areas. Dietary sources of lead average 300 ug daily in the United States, of which 5-10 percent is actually absorbed in the body by adults. Less than 10 percent of lead intake comes from air and water.

Health effects of lead poisoning have been known for years and have been studied in detail. These effects vary considerably depending on whether lead is in an organic or inorganic form. Inorganic lead poisoning has occurred in groups such as lead smelter and battery workers, manifesting itself through a wide variety of hematological, neurological, renal, and gastrointestinal effects. Lead has had an adverse effect on reproduction, causing sterility, miscarriages, and still-births in women exposed to lead. Organic lead poisoning, which usually occurs in workers exposed to leaded fuels, exhibits itself primarily as a psychotic state with a wide range of neurological effects.

Children living in towns near copper smelters show evidence of external exposure to lead, but not systemic exposure. Families of lead workers have shown evidence of lead poisoning, as have children living in close proximity to lead smelters. Women and children appear to be more susceptible to the effects of lead than males. Experimental studies have helped to better define dose-response relationships and mechanisms of lead poisoning.

The TLV for lead fumes and dusts is 0.15 mg/m^3. The Environmental Protection Agency (EPA) has proposed an ambient air standrd of 1.5 ug/m^3 for lead. The MCL for lead in drinking water set by the EPA is 0.05 mg/l.

Rationale for Priority Categories--Priority Two: Children living near copper smelters have been found to have elevated body burdens of lead. These elevated levels have yet to be linked to disease.

Priority Three: Lead (metal sulfide) appears to be concentrated somewhat during processing. Workers, their families, and the general community may be affected by lead in air emissions.

Priority Four: Lead, from exploration or mining sources alone, occurs in very low concentrations and would have little opportunity to enter the environment. Visitors, because of their limited exposure, would not be at risk from processing or smelter and refining operations.

References--National Research Council 1972; Regional Copper-Nickel Study 1978e.

Manganese

Sources--Mill dust, smelter dust, other sources of dust.

Review of Literature--Manganese is the twelfth most abundant mineral in the earth's crust and is essential for plant and animal life. In humans it is essential for normal bone formation and the functioning of several enzymes. Normal daily intake for adults is 3 mg, most of which comes from food. Manganese has been detected in urban air, averaging 0.10 ug/m^3, and may increase because of the replacement of lead by manganese in gasoline. Manganese cations are more toxic than anions.

Manganism, a disease affecting the central nervous system, has been a recognized occupational hazard for over 100 years. Chronic manganism has been found at manganese dust concentrations as low as 20 ug/m^3. Manganic pneumonia, caused by manganese oxides, has been observed in occupational settings outside the United States. Manganese poisoning has been observed in communities near ferro-manganese industries.

Animal studies have further explored the relationship of manganese to respiratory and neurological diseases. Manganese has also been shown to inhibit reproduction.

The TLV of manganese is 5 mg/m^3.

Rationale for Priority Categories--Priority Three: Manganese dust (particularly MnO_2) has been shown to cause respiratory disease. This dust may pose risks to workers in the processing (crushing) or smelting and refining operations.

Priority Four: Occupational reports of manganese-induced disease are limited to sporadic cases of poisoning which are not applicable to copper-nickel development. Manganese in dust from exploration or mining activities would be too low to cause disease.

References--National Research Council 1973; Regional Copper-Nickel Study 1978m.

Mercury

Sources--Present in ore and concentrate, may be released into the environment in wastewater and smelter emissions.

Rationale for Priority Categories--Priority Two: When mercury occurs in water it may be accumulated by fish. In the past year fish of some lakes in northeast Minnesota have been found to contain levels of mercury exceeding the Food and Drug Administration standards. The source of this mercury is unknown. If mercury released from processing or smelting reaches the aquatic environment, contamination of fish could pose a threat to public health. All segments of the population would be at risk, including visitors, many of whom come to northeast Minnesota to fish.

Priority Three: Potential sources of air emissions of mercury may include underground and open-pit mining; however, there is little evidence whether such emissions could present public health hazards.

Priority Four: Emissions of mercury from exploration are believed to be too small to be of any significance.

References--U.S. Environmental Protection Agency 1977b; Minnesota Department of Health 1977.

Nickel

Sources--Refinery dust, smelter dust, mill dust, mine dust, other sources of dust, tailings.

Review of Literature--Many studies from several countries, including Great Britain, Canada, and Norway, have indicated workers involved in the refining of nickel experienced an increased risk of developing cancer of the nasal passages and of the lung. Investigators initially emphasized the role of nickel carbonyl

($Ni(CO)_4$), but nickel refining which does not involve nickel carbonyl has been found to be equally hazardous. Nickel hazards have been identified in some plants at least through 1960; the length of time between exposure to nickel and manifestation of disease is such that the existence of a hazard beyond 1960 cannot be identified at this time.

Recent studies have been directed at morbidity from chronic respiratory disease. A thorough study comparing workers who experienced heavy exposure from sulfur dioxide, metal dusts, and fumes to workers with light exposure found significantly more chronic bronchitis and significantly poorer respiratory function tests in the high exposure group; however, the respiratory function test results were within accepted normal limits for both groups. Dermatitis in the nickel occupational setting is recognized as very common. The rash is generally considered to be aggravated by heat.

In the nonoccupational setting, a study comparing residents of Sudbury, the site of a large nickel refinery, and Ottawa, as the control, found that those residing in Ottawa in general had better respiratory function test results and less chronic bronchitis. Occupational exposure, rather than general exposure, may have accounted for these disparities.

Experimental studies have generally supported the findings of epidemiologic studies. Nickel salts, injected intrafermorally or intramuscularly seem to induce tumors in inverse proportion to their solubility. Thus, lowly soluble nickel subsulfide (Ni_3S_2) is highly carcinogenic, while highly soluble nickel sulfate ($NiSO_4$) is poorly or noncarcinogenic. Nickel carbonyl absorbed through inhalation is highly carcinogenic. Conclusive studies demonstrating the carcinogenicity of metallic nickel absorbed through inhalation have not been reported. Rats fed nickel in their diets and allowed to reproduce freely produce more runts with premature deaths than do control animals.

The 1977 TLVs for nickel are: 1 mg/m^3 for nickel metal; 0.35 mg/m^3 for nickel carbonyl; and 0.1 mg/m^3 for soluble nickel compounds.

Observed Health Effects--Lung cancer, nasal cancer, dermatitis, and nickel carbonyl poisoning in the occupational setting; dermatitis in the nonoccupational setting; cancer and nickel carbonyl poisoning in animal studies.

Rationale for Priority Categories--Priority One: Workers in nickel refineries have experienced increased incidences of lung and nasal cancer. Nickel-carbonyl ($Ni(CO)_4$) and nickel subsulfide (Ni_3S_2) are the forms of nickel most often mentioned as carcinogenic; however, other forms of nickel may be carcinogenic also. Dermatitis is also an occupational hazard of nickel.

Priority Two: The National Institute for Occupational Safety and Health (NIOSH) lists nickel miners and nickel workers as occupations with potential exposure to nickel, and who might be at increased risk of diseases mentioned above. Families of workers and the general community might also have increased risk of these diseases if they live in close proximity to open-pit mines.

Priority Three: The families of workers and the general community near underground mines, processing plants, and smelters and refineries may also be exposed to nickel in dust emissions. Because safe levels of exposure to nickel have yet to be determined, these populations may be at risk of contracting nickel-related diseases.

Priority Four: Visitors, because of their limited exposure, are unlikely to be at risk of contracting nickel-related diseases. Similarly, families of workers and the general community are unlikely to be affected by nickel in dust emissions from exploration and construction.

References--National Research Council 1975b; National Institute of Occupational Safety and Health 1977; Regional Copper-Nickel Study 1976.

Nitrogen Oxides

Sources--Byproducts of combustion at high temperatures-explosives and smelter emissions.

Review of Literature--Nitrogen oxides include compounds containing nitrogen and oxygen in gaseous, acid, and certain particulate forms. Nitric oxide (NO) and nitrogen dioxide (NO_2) are the most important from the public health point of view. Of these two, nitrogen dioxide is the more common and more toxic. Manmade sources of nitrogen oxides arise chiefly from combustion processes at high temperatures.

Nitrogen dioxide has caused adverse effects on the lower respiratory tract in a number of occupational settings, including underground mines. Acute exposure may have delayed effects which may not occur until three weeks after exposure. Brief exposures to high concentrations of nitrogen dioxide appear to have greater adverse effects than longer exposures to low concentrations.

In the nonoccupational setting nitrogen dioxide has been linked with decreased ventilatory function in children and increased incidence of acute respiratory disease.

The possibility that suspended nitrates may be converted to nitrosamines (known carcinogens) in air has been discussed, but there is little evidence that this occurs to any significant extent. Some nitrogen oxide compounds have been shown to be mutagenic. Experimental studies have examined the effects of nitrogen oxides on the respiratory system in great detail.

The TLVs for nitrogen dioxide and nitric oxide are 9 mg/m^3 and 30 mg/m^3, respectively. The ambient air standard for nitrogen oxides is 0.05 ppm (100 ug/m^3) as an annual average.

Rationale for Priority Categories--Priority Two: Underground miners have developed acute respiratory disease due to nitrogen oxides emitted from underground explosions.

Priority Three: Nitrogen oxides may be formed at the high temperatures present during smelting. In this case, workers, their families, and the general community may be at increased risk of contracting respiratory disease.

Priority Four: Nitrogen oxides are generally formed only at very high temperatures such as may occur during smelting or from the use of explosives. In the case of intermittent sources, such as occur with explosives, adverse effects on health would probably occur only in confined areas. Therefore, nitrogen oxides are not formed during exploration and construction, or processing; nitrogen oxides are not confined, with the possible exception of underground workers, in underground or open-pit mining; and, in the case of smelting, visitors would have too limited exposure to be at risk of disease.

References--Morrow 1975; Regional Copper-Nickel Study 1978f.

Noise

Sources--Machinery, explosives, transportation, drilling.

Review of Literature--Noise is unwanted sound. Sound is measured in decibels, a logarithmic scale based upon the ratio of an observed sound pressure level to a reference sound pressure level. Sources of noise may be natural, such as thunder, rain, and birds, or manmade, such as machinery and traffic.

In the occupational setting, noise-induced hearing loss has been and continues to be a widespread problem. Noise less than 80 decibels (dB) is generally considered to be not hazardous. A recent survey in the mining industry found 68 sources of noise which create sound pressures of 90 dB or more. Noise may also cause temporary hearing loss. Quality of work, but not quantity, may be affected by noise above 90 dB.

Nonoccupational problems related to noise include speech interference, sleep interference, and annoyance. Annoyance by noise is controversial because one's attitude toward the noise has a great effect on whether it is annoying. Humans do not have the ability to adapt to higher levels of noise.

<u>Observed Health Effects</u>--Hearing loss and speech interference in all settings; sleep interference and annoyance in nonoccupational settings.

<u>Rationale for Priority Categories</u>--Priority One: Noise has long been recognized as a potential occupational hazard in the mining industry. Hearing loss is the predominant public health problem.

Priority Three: Noise may be an annoyance; however, the same noise may be annoying to some people but not to others. Psychological effects of noise have been difficult to prove. Noise from open-pit mines or processing plants may be objectionable to those within the community and visitors.

Priority Four: Noise from underground mines, or smelting and refining activities is generally unnoticeable in the community.

<u>References</u>--Miller 1974; Regional Copper-Nickel Study 1978g.

<u>Particulates/Dust</u>

Sources--Air emissions for mining, milling, smelting, transportation, and wind erosion.

Review of Literature--"Particulates" is an all-encompassing term used for all dispersed solid or liquid material in the atmosphere. With this definition most sulfur oxides can be considered also to be particulates. Some particles are emitted directly from chemical or industrial sources while others are formed by chemical reactions in the atmosphere.

Deposition of particles in the lung is dependent on size, shape, and density of the particles. The major site of particle deposition is the nose. Clearance of particles from the lung depends on the site of deposition. Clearance from the alveolar surface is the slowest of all areas. Deposition in the alveolae has been found to be maximum when particles are between one and two micrometers in size.

Respirable particulates may be intrinsically toxic, interfere with clearance of other particles from the lung, or act as carriers of toxic materials. Increased pulmonary flow resistance, the dominant physiological alteration produced by irritant particles is further augmented by small particle size. Small particles may act synergistically or additively to affect health when mixed with various gases.

Early studies of air pollution indicated that excessively high levels of SO_2 (400 ug/m^3) and particulates (500 ug/m^3) increased mortality and morbidity, especially among the elderly and those with chronic lung and respiratory disease. Morbidity studies have demonstrated an association between the prevalence and incidence of respiratory illness, and SO_2 with particulates. Exposure to these air pollutants aggravates the symptoms of bronchitis in those already having the disease. Sulfur dioxide and particulates contribute to increased frequency and severity of acute respiratory disease in children. Best estimates of the threshold level for effects on health due to short term exposures (days) to particulates 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 (based upon the CHESS studies). For long-term exposures (years) best estimate thresholds are approximately 100 ug/m^3 with SO_2 levels of 95 ug/m^3 for increased prevalence of chronic bronchitis in adults and increased acute lower respiratory disease in children (based upon CHESS studies).

Most occupational studies on particulates have dealt with a specific kind of particulate such as silica, aluminum, or barium dust. A recent review article concluded that inhalation of most minerals and vegetable dust could lead to increased prevalence of cough and sputum and that some workers show a slight decrease in lung function after prolonged exposure to these materials.

The Minnesota ambient air standards for particulates are: 75 ug/m^3 as an annual geometric mean and 260 ug/m^3 as the maximum 24 hour average.

Rationale for Priority Categories--Priority One: Particulates (dust) are a well-known occupational hazard, with respiratory diseases the most common disease outcome. Usually particulates, per se, are not examined in occupational settings but are rather examined as individual agents. Nevertheless, particulates are the sum of all the individual agents. Families of workers and the general community living near copper smelters have been shown to have increased incidences of respiratory disease.

Priority Two: People chronically exposed to high levels of particulates are at increased risk of respiratory diseases. Open-pit mining and processing (crushing) emissions may be sources of particulates to families of workers and the general community. Families of workers may be at increased risk of disease in the case of underground mining because workers bring home dust on their clothes. Workers in exploration and construction may be exposed to high levels of dust; however, the period of exposure is shorter than for workers in other operations.

Priority Three: Visitors may have increased risk of respiratory disease due to short-term exposures to particulates. Possible sources of particulates include open-pit mining, processing (crushing), and smelting and refining.

Priority Four: Particulate emissions from exploration and construction, or underground mining are probably too low to pose a risk to nonoccupational segments of the population, with the exception of families of underground miners as noted above.

References--Biersteker 1976; Regional Copper-Nickel Study 1977a.

Population Pressures

Sources--New or rapidly growing industries attracting relatively large numbers of new workers and inducing a rapid population growth.

Background Information--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 for 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 cause water and sewage treatment plants to operate 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 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, and the preparations made to deal with these impacts.

Rationale for Priority Categories--Priority Two: A rapid increase in population may limit the accessibility and availability of adequate health services, and strain water and sewer system. Workers, their families, and the general community would be the populations affected. Large population increases may result from all phases of copper-nickel development.

Priority Four: Visitors would probably not be affected by the pressures in any phase of copper-nickel development.

References--None.

Processing Chemicals

Sources--Used in processing, smelting, and refining.

Review of Literature--Processing chemicals are used in most mining operations to extract desired metals and nonmetals from the mined ore. These chemicals can be divided into six major categories: collectors, frothers, modifiers, activators, depressants, and flocculants.

In general, potential hazards to human health include: safety hazards from the storage, handling, and disposal of chemicals; accidental spills; toxic vapors from the chemicals and decomposition products; and discharge of used chemicals.

Xanthates, the general class of collectors most commonly used in the copper-nickel industry, may decompose to carbon disulfide, hydrogen sulfide, and sulfur dioxide-compounds, which have adversely affected health in other industrial settings. Acids and bases may act as respiratory irritants and cause tissue damage upon direct contact with the skin. For the most part, the large variety of chemicals, which might be used, precluded all but a cursory examination of specific processing chemicals.

Rationale for Priority Categories--Priority Two: Processing chemicals often are potential hazards to the health of workers. Acids may cause severe burns if spilled on the skin and often act as respiratory irritants. Xanthates, which produce carbon disulfide (which causes increased heart disease), have affected health in the viscose rayon industry; however, there is little evidence to date relating xanthates to disease in the mining industry. These problems may be present for workers in processing, and smelting and refining.

Priority Three: Chemicals might enter drinking water supplies if an accidental spill occurred. Everyone using drinking water in that region would potentially be affected if this occurred. Processing, and smelting and refining are the stages in which chemicals would be used.

Priority Four: Processing chemicals are not used during exploration and construction, underground mining, or open-pit mining activities.

References--Hawley 1972; Regional Copper-Nickel Study 1978h.

Silica

Sources--Mine dust, mill dust.

Review of Literature--Compounds containing silicon and oxygen comprise most of the earth's crust. Silica (SiO_2), the compound responsible for silicosis, occurs in three forms: quartz, cristobalite, and tridymite. Uncombined forms of these minerals are called "free silica," to distinguish them from silicates which contain cations. Silicates and noncrystalline silica are not considered to be associated with disease.

Silicosis is probably the oldest occupational disease known. It is a respiratory disease; the mechanism by which silica affects lung function is well understood. Complications arising from silicosis include tuberculosis, chronic bronchitis, emphysema, and cor pulmonale.

The minerals industry is one of the many industries in which silicosis has been observed in workers. The incidence of silicosis has decreased considerably since the mid-1903s when many dust control systems were begun or improved.

Rationale for Priority Categories--Priority One: Silicosis has been a major occupational hazard to those employed in underground mining, open-pit mining, and milling and processing.

Priority Three: Silica is present in the smelter flux; however, there have been no reports of silicosis in smelter workers.

Priority Four: Silicosis is by definition an occupational hazard. Therefore, the nonoccupational segment of the population is not at risk of this disease. Workers in exploration and construction probably have too limited exposure to be at risk of disease.

References--Ziskind et al. 1976; Regional Copper-Nickel Study 1978n.

Sulfur oxides

Sources--Smelter stack emissions and fugitive emissions inside smelters.

Review of Literature--Sulfur oxides comprise a vast group of compounds, a few of which are found in the atmosphere as a result of man's industrial processes. Ninety-eight percent of all emitted sulfur oxides consist of sulfur dioxide (SO_2); other compounds include sulfur trioxide (SO_3), sulfuric acid (H_2SO_4), and various sulfates (XSO_4). Chemical reaction studies within copper smelters have indicated that the presence of sulfates and sulfites are important considerations in the study of health effects of sulfur oxides.

Sulfur dioxide is a mild respiratory irritant when administered alone. At levels far in excess of ambient levels, SO_2 has been shown to reduce ciliary activity and thereby decrease lung clearance. Since this leads to increased residence time of foreign particles within the lungs, this has been proposed as the cause of increased illness during exposure to pollution. Sulfuric acid and certain sulfates also act as respiratory irritants.

Early studies of air pollution indicated that excessively high levels of SO_2 (400 ug/m^3) and particulates (500 ug/m^3) increased mortality and morbidity, especially among the elderly and those with chronic lung and respiratory disease. Morbidity studies have demonstrated an association between the prevalence and incidence of respiratory illness, and SO_2 and particulates. Exposure to these air pollutants aggravates the symptoms of bronchitis in those already having the disease. Sulfur dioxide and particulates contribute to increased frequency and severity of acute respiratory disease in children. Long-term exposure (years) to levels of SO_2 at 92-95 ug/m^3 with 15 ug/m^3 suspended sulfates were found to be associated with excess bronchitis in the CHESS studies.

In workers, elevated levels of sulfur dioxide (20-100 ppm) promote fits of coughing, sneezing, and other discomforts. Recent studies have shown that exposure to levels (1-5 mg/m^3) of SO_2 below the standard for occupational settings do produce a reduction in forced expiratory volume in one second, and forced vital capacity, and an increase in respiratory symptoms.

The TLVs for sulfur oxides are: 13 mg/m^3 (5 ppm) for sulfur dioxide; and 1 mg/m^3 for sulfuric acid. The Minnesota ambient air standards in Minnesota for sulfur oxides are 0.02 ppm (52 ug/m^3) as an annual arithmetic mean, 0.1 ppm (260 µg/m^3) as the maximum 24-hour average concentration, and 0.25 ppm (650 ug/m^3) as the maximum 3-hour average concentration.

<u>Rationale for Priority Categories</u>--Priority One: Sulfur oxides from smelting and refining have been associated with respiratory disease in workers, their families, and the general community living near copper smelters.

Priority Three: Visitors might experience acute effects if sulfur oxides concentrations were to rise to very high levels. In some cases sulfur dioxide is produced from drying concentrates in the concentrator. This would be a potential occupational hazard.

Priority Four: Sulfur oxides are produced primarily during smelting and refining, and would therefore not pose any risks in the other stages of copper-nickel development.

References--National Research Council 1975a; Regional Copper-Nickel Study 1977a.

Zinc

Sources--Smelter emissions, mill dust, mine dust.

Review of Literature--Zinc has been used for a number of purposes for hundreds of years. It is a constituent of all living cells and essential for human life. Average daily intake is 12.6 mg, with food the major source, and smaller contributions from water and air. Zinc compounds are relatively nontoxic to living organisms.

In the occupational setting zinc compounds (particularly zinc oxide) have been found to cause metal fume fever. This is a mild respiratory disease with complete recovery almost always occurring within 48 hours. Gastrointestinal effects and dermatitis may also occur.

Several outbreaks of zinc food poisoning, caused by leaching of zinc from galvanized containers, have been reported in the nonoccupational setting. In one case of food poisoning the average dose of zinc was estimated to be 225 to 450 mg. Recovery usually occurs within 24 hours. Zinc deficiency appears to be of more concern. It may be a limiting factor in the normal growth and development of infants. Low zinc levels have been observed in patients with cirrhosis, lung cancer, myocardial infarction, certain hematological disorders and atherosclerosis.

Experimental studies have shown that animals have a high tolerance for zinc. Zinc has been shown to mitigate the effects of cadmium, but may induce deficienries of copper, iron, and calcium.

The TLV for zinc oxide fume is 5 ug/m^3.

Rationale for Priority Categories--Priority Two: Zinc oxide fumes have been associated with transitory metal fume fever in occupational settings. In the processing of ore, one step in particular has been recognized to pose a potential hazard: the use of molten zinc for "zincing" wearplates to the mantel of the crusher.

Priority Three: Metal fume fever may also occur during smelting and refining activities; however, there is little evidence whether this occurs when zinc is a minor constituent of the material being processed.

Priority Four: Zinc, from exploration or mining sources alone, occurs in very low concentrations and would have little opportunity to enter the environment. Visitors, because of their limited exposure, would not be at risk from processing or smelting and refining operations. Families of workers and the general community would not be at risk of disease due to processing activities.

References--National Institute of Occupational Safety and Health 1975; Regional Copper-Nickel Study 1978o.

Other Agents

Three agents have been classified as priority three (Table 6). Coal use may increase because of use in smelting and increased demand for energy created by copper-nickel development. This situation is difficult to quantify. Many of the potential impacts from coal are discussed in the previous section. Fluorides have been included because of reports of plants affected by fluoride in the Study Area. Osmium is recovered commercially as a byproduct from copper and nickel smelting. Although osmium tetroxide is toxic the quantity of osmium produced worldwide is so small that possible sources from copper-nickel development are probably not significant unless osmium is actually recovered somewhere in the development.

Table 1. Average analysis of bulk concentrate produced from 10,000-ton bulk sample from Spruce Road Site.

WET CHEMICAL ANALYSES		BULK CONCENTRATE (percent)
Copper	(Cu)	13.6
Nickel	(Ni)	2.98
Cobalt	(Co)	0.14
Iron	(Fe)	31.2
Sulfur	(S)	25.3
Silicon dioxide	(SiO_2)	12.1
Calcium oxide	(CaO)	1.23
Magnesium oxide	(MgO)	4.40
Aluminum oxide	(Al_2O_3)	2.42
Arsenic	(As)	0.0031
Molybdenum	(Mo)	N.D.
Manganese	(Mn)	0.032
Lead	(Pb)	0.008
Zinc	(Zn)	0.38
Cadmium	(Cd)	0.004

SOURCE: "Description of operating concepts required to establish Preoperational Monitoring for INCO's proposed Spruce Road project" INCO test.

Table 2. Literature reviews.

INITIAL LITERATURE REVIEW

Copper
Nickel

PRIORITY LITERATURE REVIEWS

Arsenic
Asbestos
Particulate air pollution
Silica
Sulfur oxides

OTHER LITERATURE REVIEWS

Accidents
Aluminum
Cadmium
Carbon monoxide
Cobalt
Explosives
Iron
Lead
Manganese
Nitrogen oxides
Noise
Processing chemicals
Zinc

TABLE 5: PRIORITIZATION OF POTENTIAL IMPACTS ON PUBLIC HEALTH

LEGEND

- Priority one
- Priority two
- Priority three
- Priority four

	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													3				1	1	1	3
Zinc													2				3			

Table 4. Priority definitions--Step 1.

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

TABLE 5: PRIORITIZATION OF OTHER POTENTIAL IMPACTS ON PUBLIC HEALTH

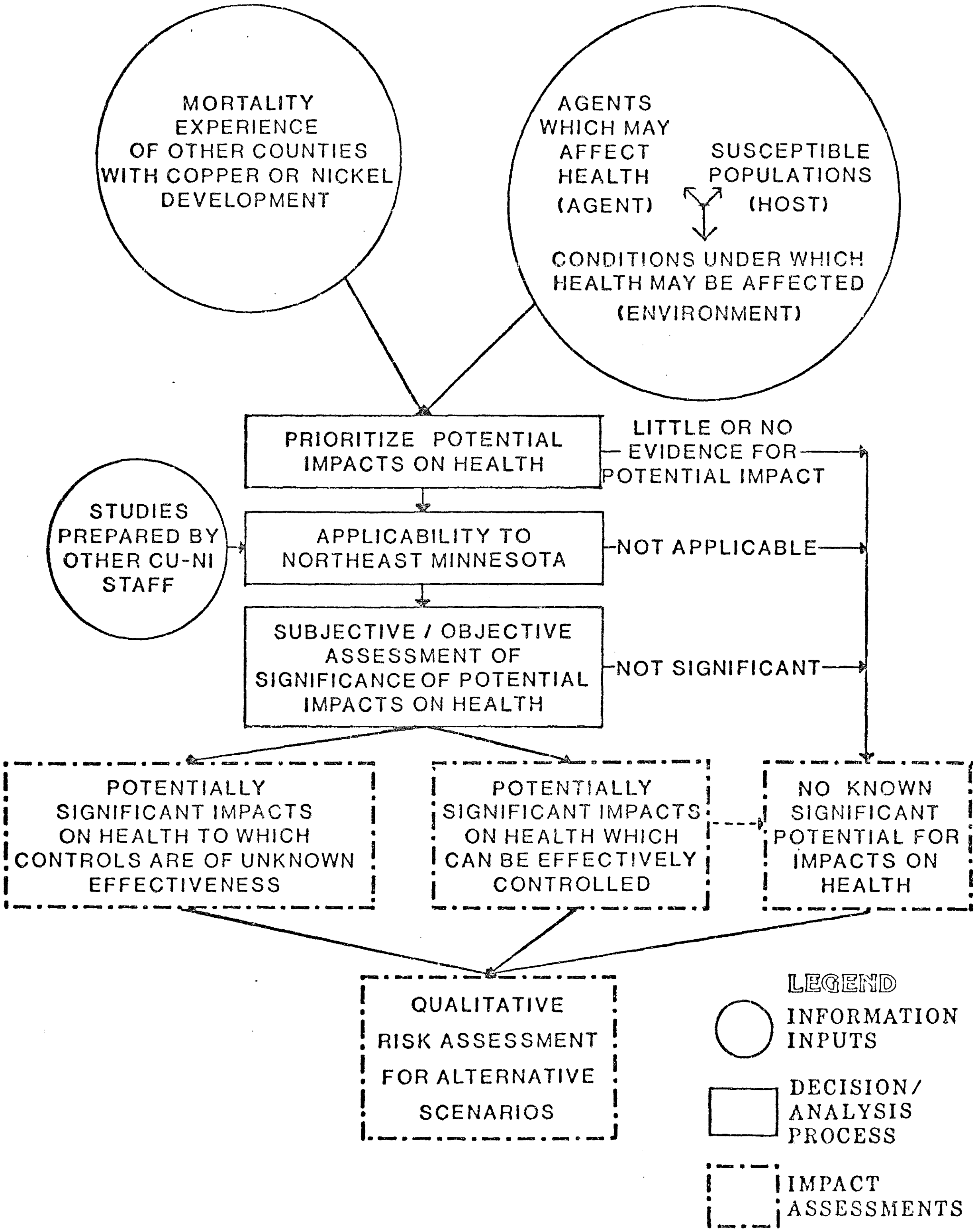
	PRIORITY				PRIORITY		
Acid Mist	see sulfur oxides			Phosphorus			
Barium				Potassium			
Beryllium				Scandium			
Boron				Selenium			
Calcium				Silver			
Cerium				Sodium			
Chlorides				Strontium			
Chromium				Tellurium			
Coal				Thorium			
Fluorides				Titanium			
Gadolinium				Vanadium			
Gallium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

LEGEND

- Priority one
- Priority two
- Priority three
- Priority four

FIGURE 1

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



REFERENCES

Becklake, M.R. 1976. Asbestos-related disease of the lung and other organs: their epidemiology and implications for clinical practice. American Reviews of Respiratory Diseases 114(1):187-227.

Biersteker, K. 1976. Sulfur dioxide and suspended particulate matter: where do we stand? Environmental Research 11:287-304.

Boyd, J.T., R. Doll, J.S. Faulds and J. Leiper. 1970. Cancer of the lung in iron ore (haematite) miners. British Journal of Industrial Medicine 27:97-105.

Friberg, L., T. Kjellstrom, G. Nordberg and M. Piscator. 1975. Cadmium in the environment - III, a toxicological and epidemiological appraisal. EPA-650/2-75-049. National Technical Information Service. Springfield, Virginia.

Hawley, J.R. 1972. The use, characteristics, and toxicity of mine-mill reagents in the province of Ontario. Ontario Ministry of the Environment. Toronto.

Miller, J.D. 1974. Effects of noise on people. Journal of the Acoustical Society of America 56:729-764.

Minnesota Department of Health. 1977. Quantitative assessment of human health risk associated with mercury contamination of fish in northern Minnesota. Minnesota Department of Health.

Morrow, P.E. 1975. An evaluation of recent NO_x toxicity data and an attempt to derive an ambient air standard for NO_x by established toxicological procedures. Environmental Research 10:92-112.

National Institute of Occupational Safety and Health. 1975. Criteria for a recommended standard...occupational exposure to zinc oxide. U.S. Department of Health, Education, and Welfare. HEW Publication No. (NIOSH) 76-104. U.S. Government Printing Office, Washington, D.C.

------. 1977. Criteria for a recommended standard...occupational exposure to inorganic nickel. U.S. Department of Health, Education, and Welfare. HEW Publication No. (NIOSH) 77-164. U.S. Government Printing Office, Washington, D.C.

National Research Council. 1972. Airborne lead in perspective. National Academy of Sciences. Washington, D.C.

------. 1973. Manganese. National Academy of Sciences. Washington, D.C.

------. 1975a. Air quality and stationary emission control. A report by the Commission on Natural Resources, National Academy of Sciences, National Academy of Engineering, National Research Council. Serial No. 94-4. U.S. Government Printing Office. Washington, D.C.

REFERENCES (continued)

National Research Council. 1975b. Nickel. National Academy of Sciences. Washington, D.C.

------. 1977. Copper. National Academy of Sciences. Washington, D.C.

Regional Copper-Nickel Study. 1976. Schuman, L.M. and J.S. Mandel, S. Murray, A. Lawler and H. Weiss. Copper-nickel mining, smelting, and refining as an environmental hazard to human health. A review of epidemiologic literature and study recommendations. Minnesota Environmental Quality Board.

------. 1977a. Schuman, L.M. and J.S. Mandel, M. Hanson and J. Nelms. Copper-nickel mining, smelting, and refining as an environmental hazard to human health. A review of epidemiologic literature and study recommendations on sulfur dioxide and particulates. Minnesota Environmental Quality Board.

------. 1977b. Schuman, L.M., J. Mandel and J. Wannamaker. Copper-nickel mining, smelting, and refining as an environmental hazard to human health. A review of epidemiology literature and study recommendations on asbestos. Minnesota Environmental Quality Board.

------. 1978a. Ashbrook, P. Accidents and safety hazards in the minerals industry. Minnesota Environmental Quality Board.

------. 1978b. Ashbrook, P. Ammonium nitrate blasting agents. Minnesota Environmental Quality Board.

------. 1978c. Ashbrook, P. Arsenic and human health. Minnesota Environmental Quality Board.

------. 1978d. Ashbrook, P. Carbon monoxide and human health. Minnesota Environmental Quality Board.

------. 1978e. Ashbrook, P. Lead and human health. Minnesota Environmental Quality Board.

------. 1978f. Ashbrook, P. Nitrogen oxides and human health. Minnesota Environmental Quality Board.

------. 1978g. Ashbrook, P. Noise and human health. Minnesota Environmental Quality Board.

------. 1978h. Ashbrook, P. Processing chemicals and human health. Minnesota Environmental Quality Board.

------. 1978i. Benzie, D. and P. Ashbrook. Aluminum and human health. Minnesota Environmental Quality Board.

------. 1978j. Benzie, D. and P. Ashbrook. Cadmium and human health. Minnesota Environmental Quality Board.

REFERENCES (continued)

Regional Copper-Nickel Study. 1978k. Benzie, D. and P. Ashbrook. Cobalt and human health. Minnesota Environmental Quality Board.

------. 1978l. Benzie, D. and P. Ashbrook. Iron and human health. Minnesota Environmental Quality Board.

------. 1978m. Benzie, D. and P. Ashbrook. Manganese and human health. Minnesota Environmental Quality Board.

------. 1978n. Benzie, D. and P. Ashbrook. Silicosis. Minnesota Environmental Quality Board.

------. 1978o. Benzie, D. and P. Ashbrook. Zinc and human health. Minnesota Environmental Quality Board.

Schroeder, H.A., A.P. Nason and T.H. Tipton. 1967. Essential trace metals in man: cobalt. Journal of Chronic Diseases 20:869-890.

Sorenson, J.R.J. and I.R. Campbell, L.B. Tepper and R.D. Ling. 1974. Aluminum in the environment and human health. Environmental Health Perspectives 8:3-95.

Stewart, R.D. 1975. The effect of carbon monoxide on humans. Annual Review of Pharmacology 15:409-423.

U.S. Department of the Interior. 1975. Administration of the federal metal and nonmetallic mine safety act (PL 89-577). Annual report of the Secretary of the Interior.

U.S. Environmental Protection Agency. 1977a. Arsenic. EPA-600/1-76-036. National Technical Information Service. Springfield, Virginia.

U.S. Environmental Protection Agency. 1977b. Toxicology of metals-volume II. EPA-600/1-77-022. U.S. Government Printing Office. Washington, D.C.

Ziskind, M., R.N. Jones and H. Weill. 1976. Silicosis. American Review of Respiratory Diseases 113:643-665.