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SUBJECT: Health Assessment for MagCorp Chlorine and Hydrogen Chloride Emissions

Attached is the executive summary and final health assessment report for MagCorp chlorine and hydrogen chloride emissions in Grantsville, Utah. This report was prepared in response to health concerns expressed by some citizens in Grantsville about MagCorp emissions. The report presents predicted chlorine and hydrogen chloride concentrations in Grantsville that would occur from MagCorp emissions based on a highly conservative model. Those concentrations are compared with health effects found through a comprehensive literature search.

The findings of the health assessment indicate that chlorine and hydrogen chloride emissions from MagCorp are not expected to produce chronic health effects. Based on the 1994 Toxic Release Inventory data, the highest levels would be expected to be approximately 0.15 ppm for chlorine and 0.03 ppm for hydrogen chloride. Those concentrations are below levels that would cause adverse health effects.

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Enclosure

HEALTH ASSESSMENT

MagCorp Chlorine and Hydrogen Chloride Gas Emissions
Grantsville, Utah
April 16, 1997

Utah Department of Health
Bureau of Epidemiology
Environmental Epidemiology Program

EXECUTIVE SUMMARY

In response to health concerns expressed by some citizens in Grantsville, the Environmental Epidemiology Program of the Utah Department of Health conducted a health assessment related to chlorine (Cl_2) and hydrogen chloride (HCl) from Magnesium Corporation of America (MagCorp). The assessment included: 1) the use of a mathematical model developed by the EPA to predict the maximum possible human exposure to chlorine and hydrogen chloride gasses in the Grantsville population; 2) a comprehensive literature search related to the health effects from chronic low level exposure to chlorine and hydrogen chloride; and 3) an assessment of the potential adverse human health effects that could be expected at those predicted worst-case chlorine and hydrogen chloride levels.

The model was used to predict the worst-case (maximum) airborne concentrations possible for these pollutants in Grantsville emitted from MagCorp. Worst-case concentrations were estimated using reported emission amounts and weather patterns (temperature, wind patterns and environmental conditions). Data from the Toxic Release Inventory were used for the years 1989, which reported the largest historical release of these pollutants; and 1994, the most recent year for which data were available. The model using 1994 data predicted a range between 0.12 and 0.15 parts per million (ppm) for chlorine and between 0.027 and 0.032 ppm for hydrogen chloride. Using the highest historical emissions from MagCorp (1989), maximum possible levels were determined to be 0.32 for chlorine and 0.05 ppm for hydrogen chloride under ideal weather conditions. However, these weather conditions exist approximately 11 days each year, so predicted values are much *worse* than the exposure that actually occurs. The highest recorded hydrogen chloride concentration in Grantsville was 0.014 ppm, recorded in 1995. The highest chlorine concentration measured in Grantsville since December 1996 was 0.022 ppm.

The comprehensive literature search found that minimal observable health effects from chlorine exist in humans with exposure between 0.5 ppm and 1.0 ppm. No harmful human health effects (temporary or permanent) were found at 1.0 ppm of hydrogen chloride. Chlorine is detectable to the average person by smell at approximately 0.3 ppm (although some persons can smell chlorine below this level). Hydrogen chloride is detectable by smell at approximately 0.77 ppm. This means that chlorine and hydrogen chloride can be detected by smell at levels below which is harmful to healthy persons.

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If emissions from MagCorp remain constant and continuous, the predicted maximum possible exposure levels of chlorine and hydrogen chloride should cause no harmful health effects in the general Grantsville population. However, persons with pre-existing asthma or allergies may experience minor temporary respiratory distress when levels of chlorine are greater than 0.3 ppm (the level which is detectable by smell). No adverse respiratory health effects would be expected in sensitive individuals from hydrogen chloride emissions.

HEALTH ASSESSMENT

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INTRODUCTION

Some citizens in Grantsville have expressed concern about the potential health impact from the number of different air pollution sources in Tooele County. In December of 1995, the Bureau of Epidemiology, Utah Department of Health, concluded a review of cancer rates in Grantsville. That study was initiated in September of 1994 at the request of Myron Bateman, Director of the Tooele County Health Department. That study found that prostate, colorectal, breast, cervical and lung/bronchial cancers were increasing in Grantsville between 1973 and 1993. However, the major risk factors associated with those cancers were familial or behavioral in nature. None of the cancers could be shown to be due to an environmental air pollutant (Blindauer 1995).

Several citizens of Grantsville have formed a community action group known as the West Desert Health Environment Alliance (HEAL). HEAL has asked that additional health studies be conducted, specifically one looking at the impacts of the chlorine (Cl_2) and hydrogen chloride (HCl) gas emissions from the Magnesium Corporation of America (MagCorp) facility in Tooele County. The purpose of this health assessment is to estimate the potential maximum exposure levels of chlorine and hydrogen chloride gas that residents of Grantsville could expect from MagCorp emissions and to evaluate the potential health effects of those exposures.

MagCorp is a magnesium extraction facility located in Rowley, Utah, near the south shore of the Great Salt Lake. The facility is approximately 26 miles (42,000 meters) from the town of Grantsville and is North-Northwest (329 degrees) of the town (see Map 1). MagCorp extracts magnesium from the water of the Great Salt Lake by concentrating the lake water into a brine water using evaporation ponds. Chlorine is used to convert the magnesium in the brine water to magnesium chloride ($MgCl_2$), which is then separated from the other salts in the brine water. The magnesium and chlorine are separated using electrolytic technology. The chlorine is captured under vacuum and reused. Hydrochloric acid is also used in the removal of sulfate from the brine water. Some chlorine and hydrogen chloride are lost to the environment as air emissions and that amount is reported to the Toxic Release Inventory (TRI) annually.

In 1994, approximately 25,228 tons of chlorine and 3,056 tons of hydrogen chloride were released into the air in Utah by several industries (NLM 1994). Of the 25,228 tons of chlorine released, MagCorp accounted for 25,075 tons, or approximately 99% of the total chlorine

emissions in Utah. Of the 3,056 tons of hydrogen chloride released, 2,800 tons were released by MagCorp in Tooele County, accounting for approximately 92% of the total hydrogen chloride emissions in Utah. Currently the only other active chlorine and hydrogen chloride emissions source in Tooele County is the Utah Test Range (UTTR), approximately 17 miles Northwest of the MagCorp site. Hill Air Force Base uses the UTTR to destroy Poseidon Missiles. Chlorine and hydrogen chloride are generated during the destruction of the missiles. However, those emissions from UTTR are not reported to the Toxic Release Inventory. The bureau currently does not have information on the quantity of chlorine or hydrogen chloride released into the atmosphere as part of UTTR activities. Several other potential sources of chlorine are inactive (e.g. Climax) or undergoing construction (e.g. Laidlaw).

Once in the air or water, chlorine reacts with water, ammonia or other chemicals present to form hypochlorous (HOCl) and hydrochloric acids (HCl), chloramines, chloride salts and chlorinated organic chemicals (Das 1993, USEPA 1994, Krenzelok 1995, WHO 1982). Because of its reactivity, chlorine is not likely to move into ground waters, and plants and animals apparently do not store chlorine (USEPA 1994).

Hydrochloric acid or hydrogen chloride (HCl) is a highly reactive acid of chlorine. Natural sources of hydrogen chloride, such as volcanoes, marine flora, microorganisms and bodies of salt water may make an important contribution to atmospheric levels of hydrogen chloride. Worldwide, natural sources produce about 4 million tons of hydrogen chloride. The main anthropogenic (man made) sources of atmospheric hydrogen chloride is the burning of fossil fuels, particularly coal and the incineration of domestic and industrial wastes (chlorinated plastics and paper). Ambient atmospheric concentrations are generally in the range of 0.00025-0.0025 parts per million (ppm). The maximum ambient concentrations will reach 0.020 - 0.030 ppm (Kamrin 1992, WHO 1982, WHO 1992).

Hydrogen chloride is highly soluble in water, hygroscopic, highly reactive and ionizes completely in solutions. Hydrogen chloride will rapidly dissolve in cloud water or rain and is readily washed out of the atmosphere. As a gas, it is quickly removed from the atmosphere through reaction by almost any surface that it contacts. Long-range transport of hydrogen chloride is probably of limited importance. Significant health risk levels are most likely found closer to the emission source (Kamrin 1992).

The occupational Permissible Exposure Level (PEL) for chlorine is 0.5 ppm based upon an 8 hour time weighted average. The maximum 15 minute Ceiling Short-Term Exposure Limit (STEL) and the Threshold Limit Value (TLV) are 1.0 ppm. For hydrogen chloride, the TLV and STEL is 5.0 ppm. There is no PEL value for hydrogen chloride (ACGIH, 1995). The National

Research Council Committee on Toxicology Short-Term Public Exposure Limit (STPL's) for chlorine is 0.5 ppm for a 60 minute exposure. The 60 minute and 5 hours/day, 3-4 days/month STPLs for hydrogen chloride are 2 ppm and 0.7 ppm respectively (NAS, 1976).

The air olfactory odor (smell) threshold for chlorine is approximately 0.31 ppm, with sensory irritation occurring approximately an order of magnitude above the odor threshold (Klonne, 1987). The odor threshold for hydrogen chloride is approximately 0.77 ppm (Amoore, 1983). In general, the odor of chlorine and hydrogen chloride can be detected below the levels that are considered safe (see Table 1).

HEALTH EFFECTS OF CHLORINE AND HYDROGEN CHLORIDE

The effects of chlorine and hydrogen chloride on human health and the environment depend on how much chlorine or hydrogen chloride is present and the length and frequency of exposure (USEPA 1994). Effects also depend on the health of a person or condition of the environment at the time of exposure. Chlorine and hydrogen chloride are irritants, and can affect the moist mucous membranes of the eyes and the upper respiratory system (Krenzelok 1995). Chlorine is able to penetrate the lower respiratory tract and at elevated levels can cause water retention in the lungs, coughing and chest pain. Hypochlorous and hydrochloric acids have less penetration ability and primarily affect the upper respiratory tract (Das 1993). Because it is highly soluble in water, hydrogen chloride is normally deposited in the nose and other regions of the upper respiratory tract (WHO 1992). The toxicity of hydrogen chloride after inhalation or ingestion is due to local effects on the mucous membranes at the site of absorption. The acidity within the mucous lining of the respiratory tract can be neutralized (Kamrin 1992).

Short Term (Acute) Exposure to Chlorine

Many studies have been conducted on World War I and industrial exposure to high levels of chlorine. Short term effects of acute exposure to high concentrations of chlorine gas include: mucous membrane irritation, cough, hemoptysis (expectoration of blood from respiratory tract), chest tightness, shortness of breath, tachypnea (increased rate of respiration), hypoxemia (deficiency of oxygenation of the blood), wheezing, vascular congestion, patchy consolidation and pulmonary edema. Pulmonary function changes observed generally consist of obstructive pulmonary defects, restrictive defects and decreased diffusing capacities. Pulmonary function abnormalities generally resolve in the majority of individuals over a course of one week to one month following exposure (Das 1993).

Only a few studies have looked at low level acute exposure in humans and have focused primarily on the effects of chlorine on pulmonary function. Those researchers found that significant changes in pulmonary function occur with 4 to 8 hour exposures to chlorine at 1 ppm. Those changes were more pronounced in individuals with nonspecific airway hyper-reactivity to irritants (which includes clinical asthma), and allergic rhinitis (hay fever). Those pulmonary function changes returned to normal within 24 hours. No significant changes were observed in individuals with or without nonspecific airway hyper-reactivity at exposures of 0.4 or 0.5 ppm chlorine. When the one subject who exhibited an exaggerated pulmonary response to 1.0 ppm chlorine was exposed to 0.5 ppm chlorine, his specific airway resistance doubled after 4 hours (Rotman 1983). Subjects experienced itchy eyes, runny nose, and mild burning throat at 1 ppm. Those two studies demonstrate that individuals with preexisting airway hyper-reactivity (such as asthma) and allergic rhinitis (hay fever) may manifest an increased pulmonary response to chlorine gas inhalation (D'Alessandro 1996, Rotman 1983). It is possible that this sensitive sector of the population could experience exaggerated pulmonary response to long term exposure to chlorine as low as 0.5 ppm.

Long Term (Chronic) Exposure To Chlorine

One of the most significant studies in humans on the effects of chronic low level exposure to chlorine was conducted by Patil *et al* (Patil 1970). Patil studied the dose-response relationship among 332 chlorine production workers exposed to chlorine and 382 control workers not routinely exposed to chlorine from 25 chlorine manufacturing plants in a variety of environmental situations in North America. Time-weighted exposure levels (based on an 8-hour day) ranged from 0.006 to 1.42 ppm with a mean of 0.15 ppm (±0.29). Only 1.8% of the workers were exposed to levels above the current threshold limit value of one ppm as established by the American Conference of Governmental Industrial Hygienists (ACGIH). The majority (93.7%) of the workers were exposed to levels below 0.45 ppm. The history of exposure ranged from one year of employment to more than 20 years. All of the workers and controls were in good health. Approximately 60% of members of both groups smoked up to two packs of cigarettes a day. Through medical exams and bimonthly industrial hygiene surveys, the researchers studied the workers and exposure levels for one year. The study found no correlation with chlorine exposure levels and chest x-ray or pulmonary function tests. Workers were not significantly affected at the low levels of chlorine exposure.

Several researchers (Klonne 1987, Wolf 1995) have conducted animal studies at similar and higher levels of chlorine exposure. No significant health effects were observed in monkeys exposed to 0.1 or 0.5 ppm chlorine for 1 year. Monkeys exposed to 2.3 ppm chlorine exhibited signs of ocular irritation, superficial conjunctival irritation, and treatment related lesions in the

respiratory epithelium of the nasal passages and trachea (Klonne 1987). In a study conducted in rodents, treatment related lesions were observed only in the nasal passages of mice and rats exposed to 0.4, 1.0 and 2.5 ppm chlorine for up to two years (Wolf 1995). The incidence of neoplasia (cancer) in the animals exposed to chlorine were not increase compared to the unexposed control animals. The monkeys appeared to be less sensitive to chlorine toxicity than the rat. The difference in toxicity of chlorine between monkeys and rodents is important since studies conducted in nonhuman primates are more applicable to humans than studies conducted in rodents.

Short Term (Acute) Exposure to Hydrogen Chloride

Few human studies have been conducted to assess the effects of gaseous hydrogen chloride exposures in humans. Older studies indicate that gaseous hydrogen chloride exposure levels above 10 ppm impair work performance. Common health effects associated with high levels of gaseous hydrogen chloride exposure include sensory irritation of eye, nose and throat; coughing, bronchoconstriction, and edema of conducting airways or alveoli (Kamrin 1992). Unlike chlorine, gaseous hydrogen chloride does not appear to produce an exaggerated pulmonary effect in individuals with preexisting airway hyper-reactivity (such as asthma). No adverse respiratory health effects were observed in a study of young adult asthmatic subjects exposed to 0.8 ppm and 1.8 ppm hydrogen chloride (Stevens 1992).

Most acute animal studies have been in the range of thousands of ppm which makes it difficult to extrapolate the health effects observed in the animals to possible health effects expected in humans at much lower ambient exposure levels. Well known anatomical and physiological differences between rodents and primates (including humans) also makes the extrapolation of those studies to humans difficult. Exposure to high levels of hydrogen chloride has been shown to cause pulmonary edema in rodents but not in primates. That difference appears to be due to the differences in respiratory anatomy and scrubbing ability of the upper airway in primates (Kamrin 1992).

Long Term (Chronic) Exposure to Hydrogen Chloride

Minimal information is available about long-term effects of hydrogen chloride in either humans or animals. No treatment related lesions or changes in respiratory parameters were observed in guinea-pigs exposed to hydrogen chloride at 10 ppm for 2 hours/day, 5 days/week for 7 weeks (WHO 1992). Laryngeal hyperplasia was observed in rats exposed to 10 ppm hydrogen chloride for 2 years (6 hours/day, 5 days/week). No treatment related effects were seen in rabbits and guinea pigs, and 1 monkey exposed to 33 ppm hydrogen chloride gas for 6 hr/day, 5

days/week for 4 weeks (NAS 1976). Ten ppm is considered the lowest observed effect level for hydrogen chloride. Adverse effects have not been observed at levels below 10 ppm (Kamrin 1992). The International Agency for Research in Cancer, World Health Organization, has determined that there is inadequate evidence for carcinogenicity in humans or animals of hydrochloric acid. Hydrochloric acid is not classifiable as to its carcinogenicity to humans (Group 3) (WHO 1992).

Summary of Health Effects of Chlorine and Hydrogen Chloride

A threshold of health effect for chlorine gas appears to be approximately 0.5 ppm (D'Alessandro 1996, Patil 1970, Rotman 1983). Individuals with preexisting airway hyper-reactivity (such as asthma) and allergic rhinitis (hay fever) may manifest an increased pulmonary response to chlorine gas inhalation at levels as low as 0.5 ppm (D'Alessandro 1996, Rotman 1983). At chlorine levels lower than 0.5 ppm, the human respiratory tract system appears to be able to clear the chlorine and minimize the damage. Minimal observable effect exists in humans with exposure between 0.5 and 1.0 ppm (D'Alessandro 1996, Patil 1970). For an acute exposure, the data suggest that humans with or without airway hyper-reactivity can recover within 24 hours. Rare cases may take longer.

A 2 year study in rodents evaluated the potential for chlorine gas to induced neoplasms from chronic exposure. The incidence of neoplasia (cancer) in the animals exposed to chlorine at levels up to 2.5 ppm were not increase compared to the unexposed control animals (Wolf 1995). Neither chlorine or hydrogen chloride have been shown to cause cancer in humans or animals.

Unlike chlorine, gaseous hydrogen chloride does not appear to produce an exaggerated effect in individuals with preexisting airway hyper-reactivity (such as asthma). No adverse respiratory health effects were observed in a study of young adult asthmatic subjects exposed to 0.8 ppm and 1.8 ppm hydrogen chloride (Stevens 1992).

EXPOSURE MODELING

Using a Gaussian plume diffusion modeling technique based on 1989 and 1994 TRI data (see Table 2, Appendix A), the projected maximum calculated concentrations of chlorine and hydrogen chloride in Grantsville were estimated. The model predicted ground concentrations at varying ranges downwind from the MagCorp facility and the results are presented in Figure 1

and Table 3, Appendix A. Those figures are for 70° F with most stable environmental conditions. The modeling parameters and assumptions are presented in Appendix B.

The TRI provides data on the total emissions of chlorine and hydrogen chloride by MagCorp from 1987 to 1994. During that time, the highest emission rates were during 1989. There are six separate stack vents and four additional plant sources that were independently modeled. In this procedure, an assumption was made that the chlorine and hydrogen chloride gases were equally distributed in each cubic foot of emissions, and that the emissions rates were constant in time. A summation of each source's contribution of gas down range gave a predicated maximum continuous exposure level for a receptor (person) 1.5 meters tall.

No specific information is available to determine whether all of the chlorine and hydrogen chloride released are evenly distributed in each cubic foot of effluent, or that the emissions are constant throughout the day and year. In the modeling portion of this study, those sources were deliberately weighted conservatively in order to maximize the down wind concentration. It is possible that levels of chlorine could reach levels high enough to be detected by smell since the smell (olfactory) detection thresholds are approximately 0.31 ppm and 0.77 ppm for chlorine and hydrogen chloride respectively (Amoore 1983).

In worst case modeling, the highest concentrations are developed under the most stable atmospheric and wind conditions. The most stable winds are considered to be 4.4 miles per hour (USEPA 1986, USEPA 1992, USEPA 1995, Till 1983). At that wind speed it would take 5.8 hours to transport individual molecules of gas released from MagCorp to Grantsville. In 5.8 hours there is ample time for all of the original chlorine to be photolyzed. The free chlorine ($Cl^{\cdot}$) produced can form a variety of chlorides, some of which will eventually be lost from the atmosphere into other environmental media, and some of which may recombine to form chlorine. In a six hour transport time, it is estimated that 15 percent of the original hydrogen chloride would be photolyzed. Additional hydrogen chloride may be formed from the transformation of free chlorine ($Cl^{\cdot}$). Since hydrogen chloride is very hydrophilic, substantial loss of hydrogen chloride can occur by reaction with water and metal ions dissolved in water. However, during the evening when there is no sunlight, degradation of chlorine and hydrogen chloride will be reduced considerably.

Wind speeds of 12 mph (20 kph) would still take 2 hours to transport those molecules of gas, however with those wind speeds, the plume integrity would be severely compromised. In that length of time, there is still ample opportunity for decay of chlorine to occur. Data on wind speeds and directions in the area of Grantsville and MagCorp obtained from the Division of Air Quality indicate that the wind blows from MagCorp toward Grantsville on a yearly average of 7

percent of the time. The most stable wind speeds occur only about 3 percent of the time in a year (11 days).

The 1989 emissions data represents the highest releases reported to TRI between 1987-1994. The 1989 emissions data resulted in an expected maximum continuous concentration of 0.309 ppm for chlorine and 0.049 ppm for hydrogen chloride in Grantsville at 70° F (see Table 4, Appendix A). Those values represent a standardized continuous exposure level. Using 1994 data, the expected maximum continuous concentration are 0.141 ppm for chlorine and 0.031 ppm for hydrogen chloride in Grantsville at 70° F. The temperature of 70° F is the standard temperature used in atmospheric modeling since concentrations are proportional to temperature (concentrations increase with increasing temperature). Concentrations were also calculated for temperature extremes of -20° F and 100° F (see Table 5, Appendix A) . If the assumption that the release is continuous with time is true, then those values would represent the maximum historical exposure levels.

Very little research has been conducted to determine the environmental half-life and transport fate of chlorine in the atmosphere. Chlorine undergoes relatively rapid photolysis in the atmosphere to produce chlorine ions (NAS 1976, Hampton 1975, Levine 1985). Because free chlorine ($Cl^{\cdot}$) is highly reactive, it will rapidly react to form hydrogen chloride and a variety of chlorides (see Figure 2, Appendix A). The nature and rate of those reactions are dependent on a variety of physical (density, humidity and temperature), chemical (cation concentration and species) and environmental (pressure, sunlight, and the state of the earth's surface) properties of the atmosphere, most of which change frequently and randomly. The resulting chloride species are not as reactive and will remain in the atmosphere longer in either a gaseous or particulate state (USEPA 1971, Krenzelok 1995, NAS 1976). Because chlorine is denser than air, under very stable atmospheric conditions with light winds, chlorine and chlorine daughter products will tend to concentrate near the ground (NAS 1976).

Many chloride species are produced naturally, particularly by ocean and other bodies of salty water. The global mean ambient air levels of chloride species range from 0.9 to 3.4 ppm at 4,200 ft elevation (USEPA 1971, Krenzelok 1995, NAS 1976). It is difficult to speculate on the molar concentration of chlorine as chloride in the air, however, the natural levels of chlorides are much higher than those expected by the decay and resolution of chlorine gas released from the MagCorp facility.

Chlorine and Hydrogen Chloride Monitoring in Grantsville

The Division of Air Quality (DAQ), Utah Department of Environmental Quality (DEQ) established a monitoring station at Grantsville (90 South Park Street) in April 1993 that monitors for hydrogen chloride. A monitor for chlorine was also installed in December 1996 by DAQ at the monitoring station in Grantsville.

At the end of 1995, a total of 287 measurements (each measurement is on a 72-hour sample) for hydrogen chloride had been taken. The arithmetic mean for those measurements is < 0.0013 ppm (<2.0 $\mu g/m^3$). The highest recorded 72-hour sample for hydrogen chloride was 0.014 ppm (21 $\mu g/m^3$). That data indicates that a substantial amount of the hydrogen chloride is lost in transport due to its short environmental half-life (0.031 ppm predicted vs. 0.014 ppm measured).

Between December 1996 (when the chlorine monitor became operational) and March 12, 1997, only 0.7% of the chlorine measurements had levels above the detection limit of 0.003 ppm. The highest 1-hour level measured at the Grantsville monitoring station was 0.022 ppm. The chlorine concentrations in Grantsville during this time period may be atypically low due to the low number of inversions experienced in the area during the time that these measurements were made.

The low concentrations of hydrogen chloride and chlorine measured in the ambient air at the monitoring station in Grantsville suggests that the chronic exposure levels of residents in Grantsville are much lower than what worst case modeling would suggest.

CONCLUSION

In this report, the maximum continuous exposure levels of chlorine and hydrogen chloride gases were predicted for residents in Grantsville due to releases from MagCorp using a mathematical model. Those levels were calculated based on assumptions that would generate a "worst case scenario."

The predicted maximum continuous concentration, based on 1994 TRI data and adjusted for temperature, was determined to range between 0.12 - 0.15 ppm for chlorine and between 0.027 - 0.032 ppm for hydrogen chloride. The maximum historical continuous exposure would have been 0.32 ppm for chlorine and 0.05 ppm for hydrogen chloride using 1989 TRI data. Since the ideal conditions only exist approximately 11 days out of the year, exposure to chlorine and hydrogen chloride at the maximum predicted levels would not be continuous and only for short

periods of time. A review of current monitoring data and published literature show that ample time exists for considerable loss of the chlorine during the daylight hours. Levels of chlorine and hydrogen chloride would be expected to be higher in the evening than during the daytime when photolysis of the chlorine and hydrogen chloride occurs.

The literature indicates that the health risks of chronic exposure to chlorine at concentrations that can easily be detected by smell (>0.3 ppm) may include transient minimal pulmonary function loss in individuals with asthma or hay fever, and mild irritation of the eyes (D'Alessandro 1996, Rotman 1983, Algen 1981 cited in Das 1993). For hydrogen chloride gas, 1 ppm is the lowest threshold below which no adverse respiratory effect is detectable (Kamrin 1992). Concentrations of hydrogen chloride in Grantsville would not be expected to reach levels that would cause ocular or respiratory irritation.

The findings of this health assessment indicate that if the chlorine and hydrogen chloride emissions from MagCorp are constant and continuous, the expected chronic exposure of residents in Grantsville would not cause any adverse health effects. Based on 1994 TRI data, the highest levels would be expected to be approximately 0.15 ppm for chlorine and 0.03 for hydrogen chloride. It is possible that if chlorine (not hydrogen chloride) reach levels that can be detectable by smell (> 0.3 ppm), individuals with asthma or hay fever could experience minor transitory respiratory distress. Some individuals are able to detect chlorine or hydrogen chloride at concentrations well below the average smell detection threshold of 0.3 ppm for chlorine, and at levels that would not elicit a response from asthmatics or residents with hay fever.

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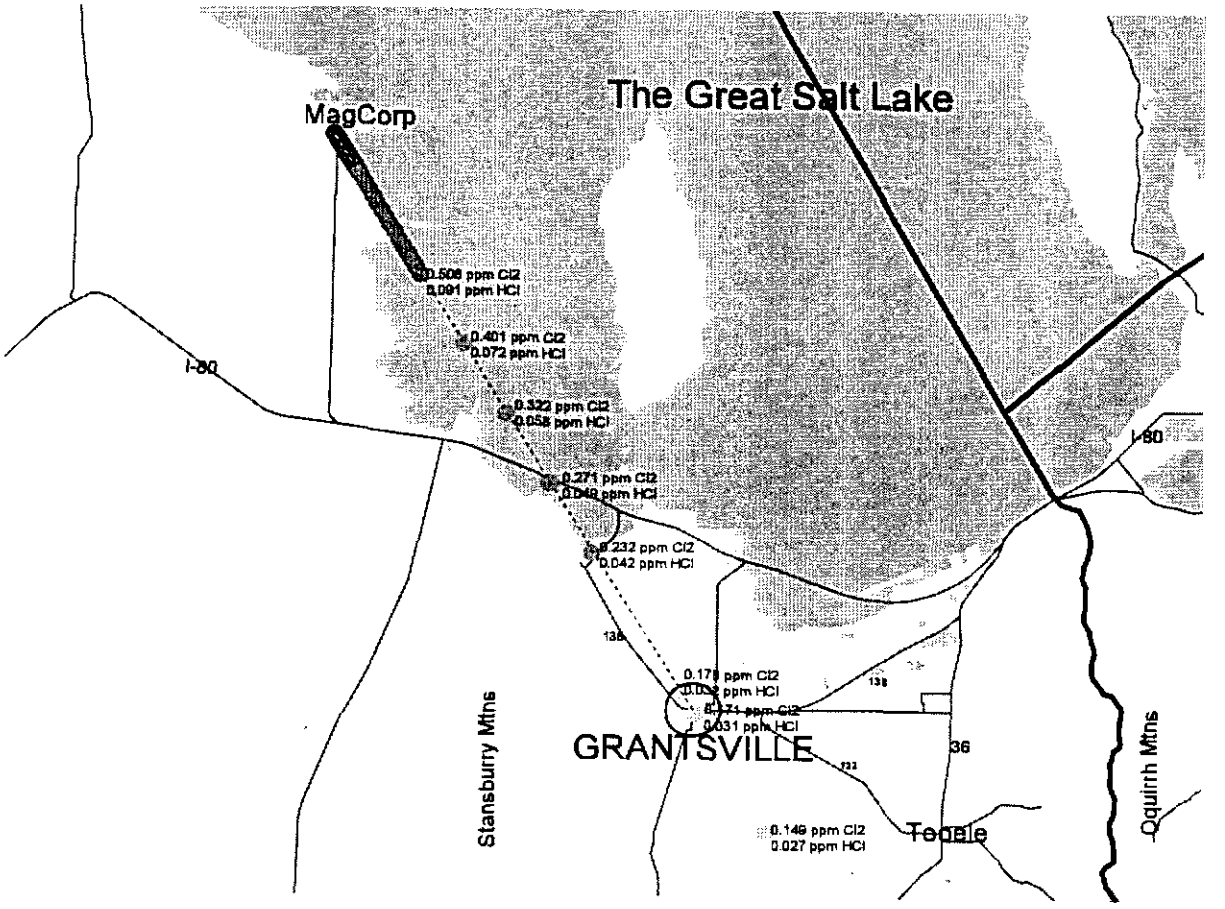
APPENDIX A

TABLES, MAPS AND FIGURES

MagCorp Chlorine and Hydrogen Chloride Gas Emissions
Grantsville, Utah
April 16, 1997

Map 1. **Area of Tooele County Including Grantsville, MagCorp (Rowley), the Great Salt Lake, and Geographic Features. Concentration Plot is for Model Predicted Chlorine and Hydrogen Chloride Gas Concentrations from the MagCorp Facility Towards Grantsville in Parts Per Million using 1994 Toxic Release Inventory Data Modeled at 70°F.**



MagCorp Chlorine and Hydrogen Chloride Gas Emissions
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Figure 1. Model Predicted Concentrations of Chlorine and Hydrogen Chloride Downrange from MagCorp Using 1989 and 1994 Toxic Release Inventory Data.

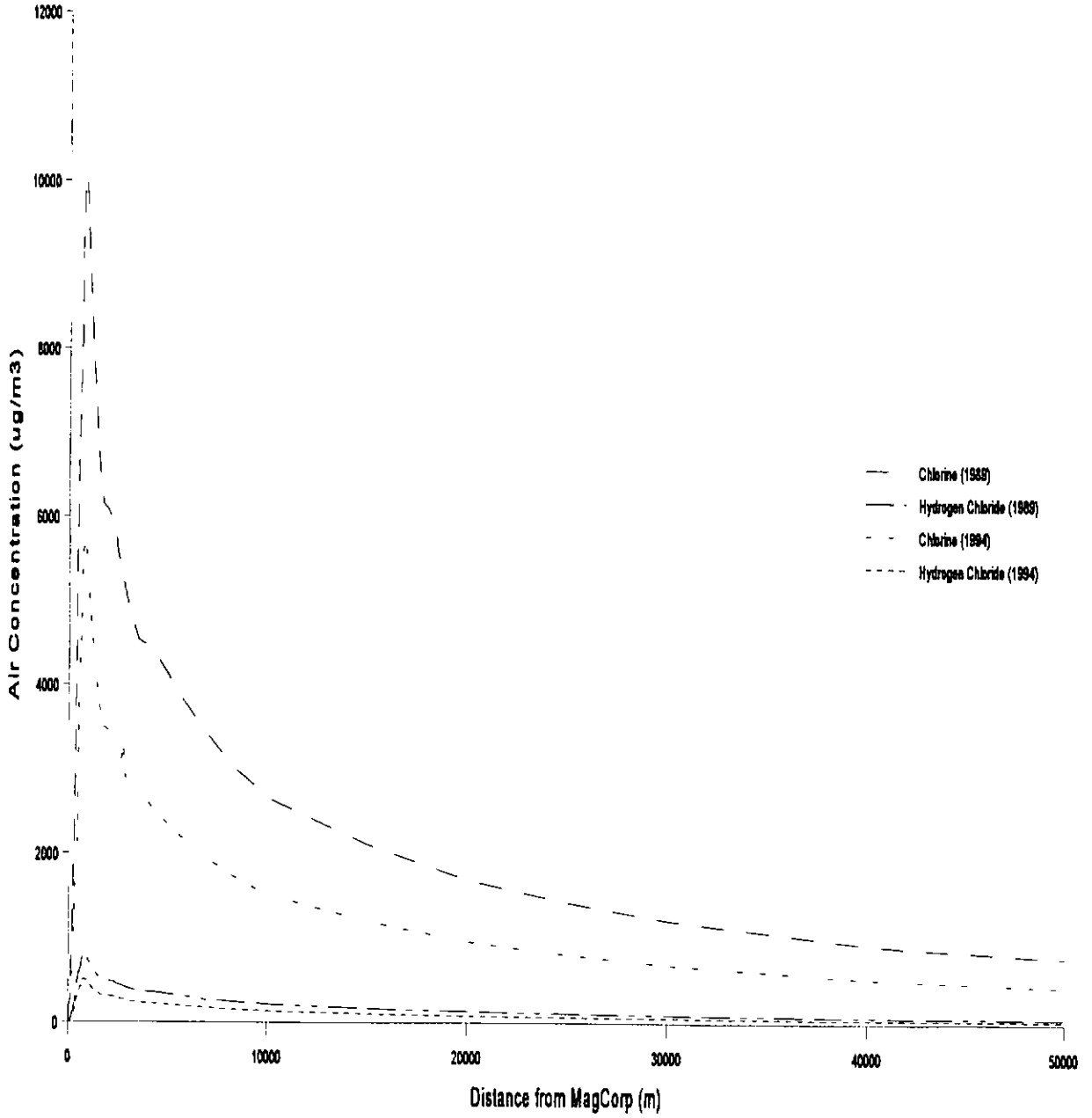

Figure 2. **Fate of Chlorine in the Atmosphere (Hemond 1994, Stern 1976a, Stern 1976b).**

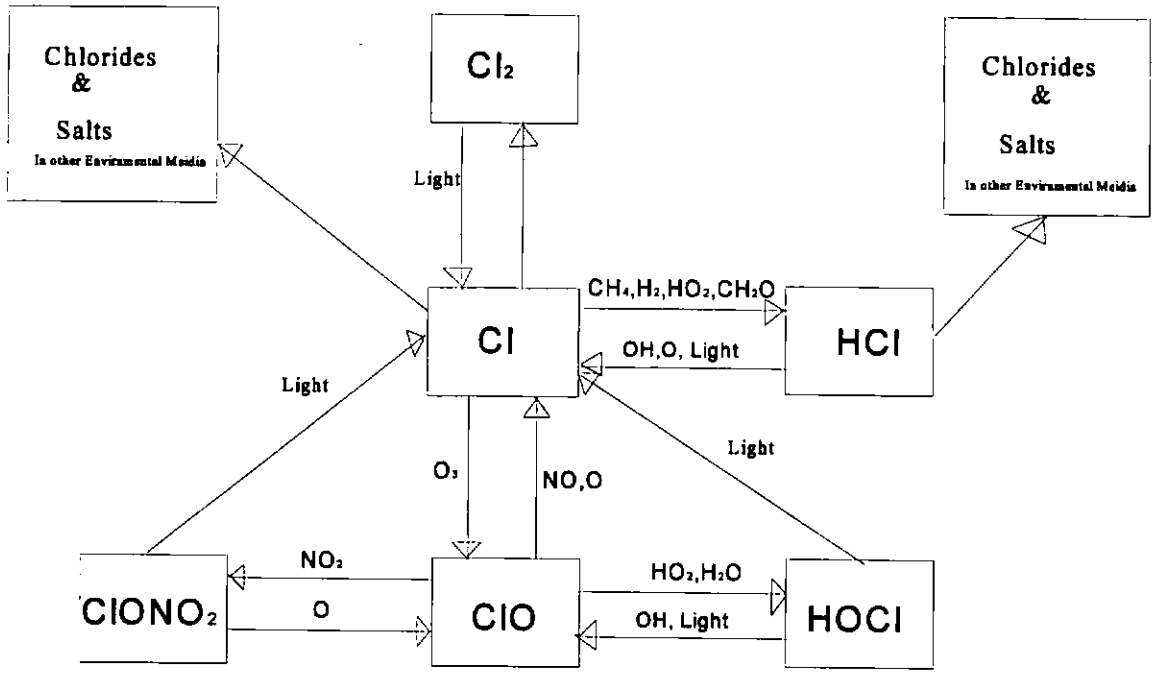

Table 1. Exposure Limits, Odor Detection and Chemical Characteristics of Chlorine and Hydrogen Chloride (Amoore 1983, ACGIH 1995).

	Chlorine	Hydrogen Chloride
8 hour Occupational Permissible Exposure Level (PEL) (ppm; v/v)	0.5	N/A
15 minute Ceiling Short-Term Exposure Limit (STEL) (ppm; v/v)	1.0	5.0
Threshold limit value (TLV) (ppm; v/v)	1.0	5.0
Volatility at 25 C (ppm; v/v)	gas	gas
Air odor threshold (ppm; v/v) **Standard error**	0.31 1.8	0.77 2.2
60 Minute Short-Term Public Exposure Limits (STPL)	0.5	2.0
5 hour/day, 3-4 days/month STPL	N/A	0.7
Odor Safety Class	less than 50% of distracted persons perceive warning of TLV	less than 50% of distracted persons perceive warning of TLV
Water TLV equivalent (ppm; w/v)	0.0065	decomposes in water
Solubility at 25 C (ppm; w/v)	6,300	1,200,000
Water odor threshold (ppm; w/v)	0.0020	decomposes in water
Molecular weight (g)	71	36
Density at 20-25 C (g/ml)	gas	gas
Water-air distribution ratio (w/v)	2.2	decomposes in water

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Table 2. Toxic Release Inventory Data for the MagCorp Facilities in Tooele County Total Discharge to the Air of Chlorine and Hydrogen Chloride.

Year	Chlorine		Hydrogen Chloride	
	lbs/yr	g/sec	lbs/yr	g/sec
1987	68,110,000	978.98	8,846,000	127.15
1988	102,148,000	1468.22	7,597,100	109.20
1989	**110,160,000**	**1583.38**	**8,9000,000**	**127.92**
1990	88,150,000	1267.02	6,890,000	99.03
1991	61,150,000	878.94	3,760,000	54.04
1992	57,150,000	821.44	3,700,000	53.18
1993	67,150,000	965.18	6,100,000	87.68
1994	50,150,000	720.83	5,600,000	80.49

$$g/sec = \frac{lbs/yr \times 453.5924\ g/lb}{365.25\ days/yr \times 24\ hr/day \times 3600\ sec/hr}$$

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Table 3. Model Predicted Concentrations of Chlorine and Hydrogen Chloride Downrange from MagCorp at 70°F.

Distance (m)	Chlorine (ug/m^3)	Hydrogen Chloride (ug/m^3)	Distance (m)	Chlorine (ug/m^3)	Hydrogen Chloride (ug/m^3)	Distance (m)	Chlorine (ug/m^3)	Hydrogen Chloride (ug/m^3)
1989 TRI Data								
100	370	30	1,600	6359	514	8,000	3112	251
200	1370	111	1,800	6123	459	10,000	2662	215
400	5489	443	2,000	6054	489	15,000	2111	171
600	7889	637	2,500	5525	446	20,000	1694	137
800	10057	812	3,000	4934	399	30,000	1220	99
1,000	8894	718	3,500	4540	367	40,000	936	76
1,200	7839	633	4,000	4462	361	**42,000**	**899**	**73**
1,400	6977	564	6,000	3736	302	50,000	782	63
1994 TRI Data								
100	210	19	1,600	3617	323	8,000	1770	158
200	780	70	1,800	3484	311	10,000	1514	135
400	3123	279	2,000	3444	308	15,000	1201	107
600	4488	401	2,500	3143	281	20,000	963	86
800	5721	511	3,000	2807	251	30,000	694	62
1,000	5060	452	3,500	2583	231	40,000	432	48
1,200	4460	398	4,000	2539	227	**42,000**	**409**	**46**
1,400	3969	355	6,000	2125	190	50,000	345	40

m = meters distance from MagCorp
ug/m^3 = micrograms of contaminant per cubic meter of air
Grantsville is at 42,000 meters (26 miles) from MagCorp
TRI = Toxic Release Inventory

The concentrations in this table were developed by the SCREEN3 modeling software, developed by EPA. The input parameters include those in Table 6 for point sources, a receptor 1.5 meters above the ground with a change in ground elevation of +7.6 meters between the sources and the receptor, worst case atmospheric stability classes as calculated by the software, simple rural terrain, no building down wash, and no fumigation.

Table 4. Individual and Cumulative Air Pollution Transport Model Results at Center of Mass in Grantsville (42,000 Meters from the Source) for Each Source at the Tooele County MagCorp Facilities for Chlorine and Hydrogen Chloride at -20° F, 70° F and 100° F Using 1989 Toxic Release Inventory Data.

Stack	-20° F (244° K)		70° F (293° K)		100° F (311° K)	
	Chlorine	Hydrogen Chloride	Chlorine	Hydrogen Chloride	Chlorine	Hydrogen Chloride
	ug/m^3	ug/m^3	ug/m^3	ug/m^3	ug/m^3	ug/m^3
Stack Dryer 01	131.8	10.6	146.9	11.9	158.0	12.8
Stack Dryer 02	155.6	12.6	179.9	14.5	188.3	15.2
Stack Dryer 03	159.7	12.9	186.1	15.0	193.9	15.7
Melt/Reactor	22.6	1.8	23.6	1.9	27.0	2.2
Emerg Off Gas	114.8	9.3	142.4	11.5	141.1	11.4
Cathode	62.2	5.0	71.7	5.8	85.3	6.9
Lrg Casthouse	48.4	3.9	47.5	3.8	47.2	3.8
Sm Casthouse E	45.3	3.7	44.6	3.6	44.4	3.6
Sm Casthouse W	45.3	3.7	44.6	3.6	44.4	3.6
Anode Oven	11.3	0.9	11.3	0.9	11.4	0.9
TOTAL	**796.9**	**64.4**	**898.8**	**72.6**	**941.1**	**76.0**
	ppm	ppm	ppm	ppm	ppm	ppm
TOTAL	**0.274**	**0.043**	**0.309**	**0.049**	**0.324**	**0.051**

F = Fahrenheit
K = Kelvin [(F+40)5/9]-40+273
ug/m^3 = micrograms of contaminant per cubic meter of air
ppm = parts per million

The concentrations in this table were developed by the SCREEN3 modeling software, developed by EPA. The input parameters include those in Table 6 for point sources, a receptor 1.5 meters above the ground with a change in ground elevation of +7.6 meters between the sources and the receptor, worst case atmospheric stability classes as calculated by the software, simple rural terrain, no building down wash, and no fumigation.

Table 5. Individual and Cumulative Air Pollution Transport Model Results at Center of Mass in Grantsville (42,000 Meters from the Source) for Each Source at the Tooele County MagCorp Facilities for Chlorine and Hydrogen Chloride at -20° F, 70° F and 100° F Using 1994 Toxic Release Inventory Data.

Stack	-20° F (244° K)		70° F (293° K)		100° F (311° K)	
	Chlorine	Hydrogen Chloride	Chlorine	Hydrogen Chloride	Chlorine	Hydrogen Chloride
	ug/m^3	ug/m^3	ug/m^3	ug/m^3	ug/m^3	ug/m^3
Stack Dryer 01	60.0	6.7	66.9	7.5	71.9	8.0
Stack Dryer 02	70.8	7.9	81.9	9.1	857	9.6
Stack Dryer 03	72.7	8.1	84.7	9.5	88.3	9.9
Melt/Reactor	10.3	1.1	10.7	1.2	12.3	1.4
Emerg Off Gas	52.3	5.8	64.8	7.2	64.2	7.2
Cathode	28.3	3.2	32.7	3.6	38.9	4.3
Lrg Casthouse	22.0	2.5	21.6	2.4	21.5	2.4
Sm Casthouse E	20.6	2.3	20.3	2.3	20.2	2.3
Sm Casthouse W	20.6	2.3	20.3	2.3	20.2	2.3
Anode Oven	5.2	0.6	5.2	0.6	5.2	0.6
TOTAL	**362.8**	**40.5**	**409.2**	**45.7**	**428.4**	**47.8**
	ppm	ppm	ppm	ppm	ppm	ppm
TOTAL	**0.125**	**0.027**	**0.141**	**0.031**	**0.147**	**0.032**

F = Fahrenheit
K = Kelvin [(F+40)5/9]-40+273
ug/m^3 = micrograms of contaminant per cubic meter of air
ppm = parts per million

The concentrations in this table were developed by the SCREEN3 modeling software, developed by EPA. The input parameters include those in Table 6 for point sources, a receptor 1.5 meters above the ground with a change in ground elevation of +7.6 meters between the sources and the receptor, worst case atmospheric stability classes as calculated by the software, simple rural terrain, no building down wash, and no fumigation.

Table 6. Emissions Parameters for the MagCorp Facilities in Tooele County Used in Modeling Chlorine and Hydrogen Chloride Emissions.

Source	Stack Height	Exit Diameter	Flow Rate	Exit Temperature		Allocation of Emissions	Dispersivity Factor
	m	m	ACFM	F	K		
Stack: Spray Dryer 01	77.72	2.70	140,000	139	332	0.196	0.473
Stack: Spray Dryer 02	77.72	2.70	174,000	144	335	0.244	0.466
Stack: Spray Dryer 03	77.72	2.70	180,000	143	335	0.252	0.466
Stack: Melt/Reactor	77.72	0.88	17,000	130	327	0.02.	0.625
Stack: Emergency Off Gas	77.72	1.07	110,000	80	300	0.154	0.583
Stack: Cathode	77.72	1.07	56,000	113	318	0.079	0.577
Building: Large Casthouse	30.48	0.91	14,000	1100	866	0.020	1.527
Building: Small Casthouse E	22.86	0.61	10,000	1100	866	0.014	2.010
Building: Small Casthouse W	22.86	0.61	10,000	1100	866	0.014	2.010
Building: Anode Oven	22.86	0.61	2,100	500	533	0.003	2.431

m = meters
ACFM = average cubic feet per minute (sum of flow rates from all sources = 713,100 ft^3/min)
F = Fahrenheit
K = Kelvin [(F+40)5/9]-40+273

APPENDIX B

MODELING SOURCE PARAMETERS, MODELING ASSUMPTIONS AND MODELING PROCEDURES

SOURCE PARAMETERS:

The MagCorp facility in Rowley, Utah has a 255-foot stack with six separate flumes. Four other sources are in the plant buildings and are 75 to 100 feet above the ground. Physical characteristics (height, exit diameter) and operational characteristics (exit temperature and flow rates) were obtained from Steve Arbaugh (DAQ). Each source was modeled separately as a point source (see Table 6).

TOXIC RELEASES INVENTORY DATA:

Toxic Releases Inventory Data was downloaded from the U.S. Environmental Protection Agencies web site via the Internet (http://www.epa.gov/TRI_Cover93, NLM 1994) and from the National Library of Medicine TRI data base (see Table 2).

OTHER PARAMETERS USED:

1. *Terrain*: The distance a plume from the MagCorp facility at Rowley would travel to Grantsville is 26 miles. The terrains includes approximately 17 miles of beach and water of the Great Salt Lake, and 7 miles of land between the Great Salt Lake and Grantsville. The MagCorp facility is at 4215 feet in elevation. The Grantsville City Offices report that Grantsville is at 4240 feet. On a direct line between the MagCorp facility and Grantsville, there are no hills or ranges. The ground gradually slopes upward to the South from the shore of the Great Salt Lake. Since that change in elevation is less than the stack height of any of the sources at the facility, a "Simple Terrain" model is appropriate. The terrain is also considered rural.

2. *Receptor Height*: Although the dispersion at 21 miles is going to be very uniform throughout the plume, a receptor height of 1.5 meters (the average breathing zone height for an adult, standing and sitting) was used. There was no difference when a receptor height of 0 to 10 meters was used.

3. *Environmental Conditions*: Standard environmental modeling conditions were calculated using, the most stable wind and overcast conditions, and the standard temperature of 70° F (293 K) (USEPA 1986, USEPA 1992, USEPA 1995, Till 1983). Concentrations were also calculated for temperature extremes of -20° F, and 100° F. The model does not account for other environmental variability such as moisture content and air density. The model software selects the most conservative wind stability class (speed, turbulence and pressure), by calculating all classes and selecting that class that gives the highest ground concentration.

ASSUMPTIONS ABOUT THE SOURCE AND MODEL

Inherent in all modeling studies using a Gaussian plume diffusion model are certain prerequisites and assumptions. Those include a homogeneity of turbulence, stationary turbulence conditions and a steady-state pollutant concentration, sufficiently long diffusion times, a spatially constant basic flow, a nonzero wind speed, no other atmospheric sources such as resuspension and a total reflection of the plume once it reaches ground level (USEPA 1986, USEPA 1992, USEPA 1995, Pallett 1981, Till 1983). For this study the following additional assumptions were made:

1. All chlorine and hydrogen chloride were evenly distributed in each cubic foot of effluent for all of the listed sources. The total source flow rate (total cubic feet of effluent) is 713,100 ft^3/min for the facility. It is believed that most of the chlorine and hydrogen chloride are released through the stack and only a small amount is released from the plant's buildings. The modeling process assumes that the release is directly to the outside atmosphere as a plume. In fact, the releases in the building sources escape first to the indoor building environment and then to the outside atmosphere through doors and windows. Analysis of the dispersivity of each of the sources indicated that the anode oven source yields the highest concentrations of contaminates in Grantsville. This assumption is justified because it conservatively weights the ratio of emissions to those sources whose modeled contribution will give the highest concentration at Grantsville.

$$\textit{allocation of emissions for source} = \frac{\textit{air flow output for source } ft^3/m}{\sum \textit{ of air flow outputs for all sources } ft^3/m}$$

$$= \frac{\textit{air flow output for source } ft^3/m}{713{,}100\, ft^3/m}$$

$$dispersivity\ ratio = \frac{contamination\ release\ rate\ (g/\text{sec})}{contamination\ concentration\ at\ range\ (ug/m^3)}$$

The allocation of emissions for each source and the dispersivity ratio for each source are given in Table 6.

2. Emission rates are constant throughout the day and the year. Since the purpose of this report is to look at the potential for adverse health effects due to chronic exposure, this assumption is important. If in fact, emissions from the MagCorp facilities are sporadic in nature, then it is possible that exposure levels will be much higher. In this report, the annual release data from the TRI was converted into an emission rate per second for use in the model.

$$\frac{TRI\ data\ (lb/yr) \times 453.5924\ g/lb}{365.25\ days/yr \times 24\ hr/day \times 3600\ \text{sec}/hr} = emission\ rate\ g/\text{sec}$$

If the emissions are released only in a fraction of the year rather than the whole year, then the denominator in the above formula is too large. Any sporadic nature of the release will invalidate the model, but also indicates that only occasional high level acute exposures may exist in the atmosphere. TRI data and the emission rate per second of chlorine and hydrogen chloride are given in Table 2.

3) There is no decay or other loss (such as by reaction, fumigation to the Great Salt Lake, deposition, washout or absorption to surface soil particles) of the chlorine or hydrogen chloride gases. Very little data is available on the decay rates or environmental half-lives of gaseous chlorine or hydrogen chloride. Both chlorine and hydrogen chloride undergo photo dissolution (see Figure 2). For chlorine the reaction can be very fast (photolytic constant = 5100 x 10^{-6} per second under ideal conditions). Under ideal conditions all atmospheric chlorine can be photolyzed to free chlorine ($Cl^{\cdot}$) by 3.27 minutes. However, hydrogen chloride can remain in the atmosphere for several days (photolytic constant = 7.2 x 10^{-6} per second or all hydrogen chloride converted to $Cl^{\cdot}$ and H^{+} in about 1.6 days under ideal conditions) (Hampton 1975, Levine 1985). Free chlorine ($Cl^{\cdot}$) is then available to form a variety of organic and inorganic chlorides (either gaseous or particulate).

Some of those chloride species (ClO, HOCl, $ClONO_2$, etc.) can react to form free chlorine (Cl^-) or molecular chlorine (Cl_2). Published chemical and photolytic reaction pathways for those species are given in Figure 2. The reaction rate is influenced by environmental conditions (wind, rain, humidity, sunlight, temperature) and the chemical composition of the atmosphere (ozone, peroxides, cations). Other chloride species, (both inorganic, such as NaCl, KCl, MgCl, and organic), which are less reactive, have a residence time ranging from 2 to 17 days. The global mean ambient air levels of chlorides range from 1000 to 3700 $\mu g/m^3$ (0.344 to 1.270 ppm) (USEPA 1971, Hemond 1994, Krenzelok 1995, NAS 1976, Singh 1995, Stern 1976a, Stern 1976b, Wayne 1991, WHO 1982). This assumption was made because it conservatively allows all emissions to disperse in the plume and results in a higher concentration in Grantsville when modeled.

4. The wind and atmospheric stability were calculated so that the maximum concentration possible will be generated in Grantsville when modeled. The model assumes that the wind blows continuously from MagCorp directly to Grantsville. Generally, the most stable wind conditions are thought to be about 2 m/sec (4.46 ml/hr) (Till 1983). This assumption was in order to maintain the highest plume concentration at Grantsville continuously through the year.

MODEL USED

The software "SCREEN3" developed by the US Environmental Protection Agency, Office of Air Quality Planning and Standards (Version 95250) was used. This software is based on the Gaussian plume diffusion statistic with no ground absorption (USEPA 1986, USEPA 1992, USEPA 1995),

CONVERSION TO PARTS PER MILLION

The SCREEN3 software gives the concentration in $\mu g/m^3$. Published conversion factors to convert to parts per million are:

Chlorine Gas	*Hydrogen Chloride Gas*
$1\ mg/m^3 = 0.344\ ppm$	$1\ mg/m^3 = 0.670\ ppm$
$1\ ug/m^3 = 0.000344\ ppm$	$1\ ug/m^3 = 0.000670\ ppm$

$$ppm = \frac{Concentration\ ug/m^3}{molecular\ weight \times 40.9}$$

at 25 C (77 F) and 1 atmosphere (atm), where the molecular weight of chlorine is 70.906 and for hydrogen chloride is 36.461 (Weast 1974, Finlayson-Pitts 1986). Those conversion factors are commonly used in the literature addressing the health effects of chlorine and hydrogen chloride. Parts per million data in this report will use the above conversions. Actual concentrations are dependent on the barometric pressure and meteorologic conditions of the atmosphere. The world mean air density at 4200 feet (1.28 kilometers) is 1.086 kg/m^3 (Singh 1995). At sea level the world mean air density is 1.121 kg/m^3. Actual ppm data, adjusted for density can be calculated by:

$$ppm = \frac{Concentration\ ug/m^3 \times 29828764.4424}{Density\ of\ air\ ug/m^3 \times molecular\ weight}$$