# HEALTH BASED RISK AUDITING

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# NOMENCLATURE

| | |
|---|---|
| ACL | Ambient Concentration Level |
| ATSDR | Agency of Toxic Substances and Disease Registry |
| BCF | Bioconcentration Factor |
| BP | Boiling Point |
| CBA | Cost Benefit Analysis |
| CEA | Cost Effectiveness Analysis |
| CERCLA | Comprehensive Environmental Resource Compensation and Liability Act |
| CFR | Code of Federal Register |
| CI | Cancer Incidence Rate |
| CO | Cutting Oil |
| CRTK | Community Right to Know Act |
| CSF | Cancer Slope Factor |
| DA | Decision Analysis |
| EC50 | Effective Concentration - to affect 50 percent of test population |
| EEE | Environmental Education Enterprises |
| EI | Environmental Index |
| EMB | Engineering Mass Balance |
| EPA | Environmental Protection Agency |

| | |
|---|---|
| FP | Flash Point |
| FR | Federal Register |
| FW | Formula Weight |
| GIS | Geographic Information System |
| HEAST | Health Effects Assessment Summary Tables |
| HEI | Highest Reasonably Exposed Individual |
| HH | Human Health Index |
| HHE | Human Health and the Environment |
| HQ | Hazard Quotient |
| HWIW | Hazardous Waste Injection Well |
| IRIS | Integrated Risk Index System |
| IRIS | EPA's - Integrated Risk Information System |
| IRR | Internal Rate of Return |
| ISCST2EM | Industrial Source Complex Short Term Extended Memory Model |
| IWTF | Internal Water Treatment Facility |
| LC50 | Lethal Concentration to kill 50 percent of test population |
| LD50 | Lethal Dose to kill 50 percent of test population |
| LDlo | Lowest dose to kill test species |
| LOAEL | Lowest Observable Adverse Effects Level |
| MAA | Materials Accounting Analysis |
| MEI | Maximum Exposed Individual |
| MEK | Methyl Ethyl Ketone |
| MO | Mineral Oil |

| | |
|---|---|
| MSDS | Material Safety Data Sheet |
| MTD | Maximum Tolerated Dose |
| MW | Molecular Weight |
| NAS | National Academy of Sciences |
| NHWIW | Non-hazardous Waste Injection Well |
| NOAEL | No Observable Adverse Effects Level |
| NPDES | National Pollution Discharge Elimination System |
| NPV | Net Present Value |
| NRC | National Research Council |
| OSHA | Occupational Safety and Health Act |
| PEL | Permissible Exposure Limit |
| POTW | Publicly Owned Treatment Works |
| RAGS | Risk Assessment Guidance for Superfund |
| RCBA | Risk Cost Benefit Analysis |
| RCRA | Resource Conservation and Recovery Act |
| REI | Reasonably Exposed Individual |
| RfC | Reference Concentration |
| RfD | Reference Dose |
| RI | Risk Index |
| RTECS | Registry of Toxic Effects of Chemical Substances |
| SAB | Science Advisory Board |
| SARA | Superfund Amendments and Reauthorization Act |
| SCRAM | Support Center for Regulatory Air Models |

| | |
|---|---|
| SWLF | Solid Waste Landfill |
| TA | Toxicity Assessment |
| TCA | Total Cost Accounting |
| TIGER | Topologically Integrated Geographic Encoding and Referencing System |
| TSCA | Toxic Substance Control Act |
| USCB | United States Census Bureau |
| UTM | Universal Transverse Mercator |
| VOC | Volatile Organic Chemical |
| WHO | World Health Organization |
| WWTP | Wastewater Treatment Plant |

# CHAPTER I

# INTRODUCTION

## The Problem

William Reilly, former Administrator of the United States Environmental Protection Agency (EPA), has compared our system of environmental regulation to the video game space invaders - "Each time a new issue appeared on the radar screen of public concern, we would unleash an arsenal of control measures" (Reilly, 1991). Concern over water pollution spawned the Safe Drinking Water Act and the Clean Water Act. Improper waste handling and disposal prompted the Comprehensive Environmental Recovery and Liability Act and the Resource Conservation Response Act. With each law came a new set of regulations.

As industry struggles to deal with these cumbersome and often confusing regulations, it is easy to lose sight of their original intent. Regulations promulgated under the various environmental laws are designed to insure protection from past and potential future environmental problems, thereby improving the welfare of humanity. Too often, though, a firm's environmental program comes down to compliance auditing. This approach tends to involve making a checklist of environmental regulations and marking off what is and isn't being done. Compliance auditing is also encouraged by the EPA Audit Policy (51 FR 25,004) which states that EPA will take into consideration whether a company has a compliance program when issuing enforcement penalties for non-compliance issues. Although compliance is important, it does not always fulfill the original intent of environmental legislation, to protect human health and the environment (HHE), nor does it always prove useful for long range planning and environmental goal setting.

This contradiction between compliance with federal regulations and protection of HHE was brought home vividly by a joint EPA and Amoco Corporation venture called the Yorktown Project (Solomon, 1993). The project was named for an Amoco refinery located in Yorktown, Pennsylvania, where under new federal regulations passed in 1990, Amoco was required to build a $41 million enclosed wastewater treatment and collection system to capture benzene emissions. Benzene, a known human carcinogen, is a by-product of the refining process and as such is regulated by the EPA. Using data from a 1959 study, these regulations were fashioned under the assumption that the majority of benzene emissions from the refinery process could be attributed to volatilization from open aerated wastewater tanks. But there were those, both within the industry and EPA, that questioned the validity of that assumption.

This prompted the joint Yorktown Project whereby benzene emissions were monitored throughout the refinery to determine if compliance with this regulation would indeed be most protective of human health. Through monitoring, it was discovered that most of the refinery's benzene emissions came from the loading dock area where product was transferred from storage to barges for shipping and not from the wastewater tanks. Also, it was discovered that for $11 million, pollution abatement equipment could be installed in other areas of the plant that would reduce five times the emissions over those removed by the $41 million treatment plant.

The upshot of the Yorktown Project called for tailoring a "solution to each industrial facility because each plant has its own unique pollution problems" (Solomon, 1993). The problem then becomes how does an industry build a comprehensive environmental program that can assess which of its emissions has the greatest potential for harm to human health and the environment and how could an industry make use of this information?

## Needs

As we have seen, a gap exists between the intent of environmental legislation and how it is implemented. Complying with a checklist of regulations is not always protective of human health and the environment. Given unlimited time and money, the problem could be solved as in the Yorktown Project through intensive monitoring and testing to identify harmful emissions. However, since companies have only limited environmental budgets, this is not a feasible solution. EPA has recognized the need to embrace a more comprehensive view of environmental problem solving and risk-based decision making is one of the tools they are using to do so (Habich, 1991). A 1990 Science Advisory Board report encouraged EPA to use this tool to help identify, prioritize and cost effectively reduce environmental risks of national concern (SAB, 1990). A similar risk based management tool could also provide industry with a means to compare and rank health risks associated with the handling and disposal of chemicals as they move through the manufacturing process.

A need exists for a comprehensive management tool that can aid an industry in keying in on those emissions with the greatest potential for causing harm and which is flexible enough to meet the needs of a variety of industries.

## Objectives

The objective of this dissertation project is to develop a risk based management tool to identify industrial chemical emissions that pose a potential risk to HHE, rank them based on that risk and determine the most cost effective method to reduce the risk. A sub-objective is to evaluate individual management options that can be used to expedite risk analysis in a private industry. This management tool will identify chemicals leaving an industry, where they enter the environment, who will potentially be exposed and at what concentrations. This is done so limited economic resources can be used to reduce the greatest risk.

# CHAPTER II

# LITERATURE REVIEW

Environmental risk can be defined as the probability of injury, damage or loss to human life, property or the environment from exposure to a potential environmental hazard multiplied by the severity of that loss or injury. Risk analysis attempts to place a quantitative value on the potential outcome of an event, for example chemical releases to the environment (Gratt, 1989). Recently, the Environmental Protection Agency (EPA) has shifted its internal policy towards risk based decision making as a means to identify and prioritize environmental problems of national concern (Habich, 1991). Public policy is also moving towards risk analysis, Title III of the Clean Air Act Amendments will require industries that emit carcinogens to determine the residual risk to a maximum exposed individual after Maximum Achievable Control Technology is in place to insure that risk to human life from regulated air emissions does not exceed one death in a million. Previously, EPA has used risk analysis to identify health risks and set clean up standards at hazardous waste sites (55 FR 51532).

Increasingly, private industries are exploring the use of risk analysis as a basis for dealing with environmental problems (Kolluru, 1991). Articles discuss industry application of risk assessment to prioritize clean up sites in the oil industry (Cayias and Gordon, 1992), reduce emission's impacts from power plants (Balson et al, 1992) and characterize indoor air problems throughout industries (Naugle and Pierson, 1991).

McCarthy and Burbank (1989) describe a program to assess risks to workers and the general population from air toxics released from a spill. However little information exists on the use of risk analysis as a tool for building a comprehensive industrial program that has as its goal prioritizing chemical emissions to be reduced based on health risks. Akesson (1990) uses risk analysis to evaluate the health effects of radioactive, sulfur and nitrogen oxide air emissions from a nuclear reactor. The intent was to prioritizing them based on human health risks, but the actual research focused on modeling emissions.

## Risk Analysis

The Environmental Protection Agency, which uses the National Academy of Sciences risk paradigm, divides risk analysis into two components: risk assessment and risk management. Risk Assessment is the scientific assessment of the type and magnitude of risk and consists of four steps: Hazard Assessment, Toxicity Assessment, Exposure Assessment and Risk Characterization. Risk management combines the outcome of a risk assessment with information concerning technical and economic resources, as well as social and political values, to determine the best means to reduce or eliminate a risk (Cohrssen and Covello, 1989). Guidance for performing a risk assessments can be found in EPA's Risk Assessment Guidance for Superfund or RAGS (EPA, 1989).

# Risk Assessment

## Hazard Assessment

Hazard Assessment is a qualitative examination of whether the potential for harm to HHE exists (Covello and Merkhofer, 1993). To establish that a hazard exists, there must be a chemical, physical or biological source of exposure, a potentially exposed population and a pathway from the source to the population. In an industrial setting, chemicals used in manufacturing processes and emitted into the environment present the potential for harm. Environmental emissions include air and water discharges, as well as solid and hazardous waste taken to landfills.

## Toxicity Assessment

Toxicological data for chemicals involved in risk assessments are obtained in the Toxicity Assessment (TA) or Dose-Response Evaluation. A TA provides information on health effects that may occur at a given level of exposure from a particular chemical (Focht, 1993). Toxicological information is based on human studies, short term bacteria and cell culture studies, animal studies and structure activity relationships (Covello and Merkhofer, 1993). Chemical effects are classified as either carcinogenic (tumor forming) or non-carcinogenic (acute, chronic, mutagenic, teratogenic, or reproductive). The outcome of the dose-response evaluation for non-carcinogenic chemicals is a Reference Dose (RfD) for ingested chemicals and a Reference Concentration (RfC) for those inhaled. EPA defines a RfD/RfC as "an estimate within one order of magnitude of a lifetime daily dose which is likely to be without significant risk to human populations" and is derived by dividing the "no observed adverse effect level" (NOAEL) by an uncertainty factor (Focht, 1993). Uncertainty factors increase with the suspected toxicity of a chemical, lowering the RfD/RfC and providing a margin of safety to sensitive populations. The RfD and RfC are based on the concept that a threshold level for non-carcinogenic chemicals exists. Exposure can be tolerated up to this level, before adverse effects are seen or felt.

Carcinogenic chemicals are assigned a Cancer Slope Factor (CSF). This is based on the maximum tolerated dose (MTD) which will not impair the growth or functions of the test species yet will produce cancer (Focht, 1993). The CSF represents Plausible Upper Bound Estimate, below which 95% of all cancer-causing doses are captured. EPA assumes linearity for low doses or that all carcinogens have no threshold and any exposure has the potential to be tumor producing. The CSF can be used to find the likelihood of a tumor being produced at a given exposure level.

A firm is not likely to be involved in producing toxicological data, but would use the outcome of such an assessment. This information is available through the EPA's Integrated Risk Information System (IRIS), Registry of Toxic Effects of Chemical Substances (RTECS) and Health Effects Assessment Summary Tables (HEAST) or the Agency of Toxic Substances and Disease Registry (ATSDR) Toxicity Profiles provide toxicity information for selected chemical. The RTECS provides toxicity information, including ambient air standards, on over 70,000 pollutants and can be found on-line or in hard copy. It is updated regularly and contains information on more substances than other sources, however, no estimate is given as to the quality of the data. Additional sources of toxicity data can be found in various other reference books.

## Exposure Assessment

Exposure Assessment evaluates the nature and extent of exposure, including: identifying and quantifying the risk agents that target organisms are exposed to, prioritizing chemicals of concern, determining levels of exposure, and developing exposure scenarios. Exposure scenarios pinpoint target populations, routes of exposure, the length of time and under what circumstances exposure will occur (Cohrssen and Covello, 1989).

### Source Quantification

Quantifying chemicals released from an industry to the environment is accomplished through testing and/or chemical balancing. A wastestream is a by-product of a manufacturing process containing materials not incorporated into the final product. To estimate the composition and concentration of chemicals in a wastestream, chemical balancing can be use. Mass balance and materials accounting are two commonly used procedures.

Materials Accounting Analysis (MAA) and Engineering Mass Balance (EMB) are both quantitative procedures whereby materials input to a manufacturing process are balanced against product output and estimated system losses to the environment (Pojasek and Lawrence, 1991). Examples of these losses are air emissions due to evaporation, emissions to surface water from NPDES permitted discharges or solid waste disposed of in landfills. MAA is often the first step in a waste reduction or minimization program, allowing manufacturers to identify chemical losses that can be of economic and environmental concern (Pojasek, 1991). It is less expensive and exacting than an EMB, because specific rate measurements are not needed. MAA builds on information already on hand at a manufacturing firm, for example purchasing records, data from SARA 313 reports, and/or laboratory analyses required for NPDES permits or air permits and requires less technical knowledge than an EMB. Once problem areas are identified, more rigorous analyses can be performed if necessary. The drawback to the MAA method is errors caused by the use of indirect measures (NRC, 1990a). However, the NRC does find MAA useful for "tracking the flow of chemicals across the companies borders."

Pojasek and Lawrence (1991) describe the MAA process as follows. The first step is to diagram the manufacturing process, then assign quantities of input materials to each process using purchasing records. The next step is to assign known losses to the appropriate process, from environmental analyses and in-plant data on scrap and recycled materials. Knowledge of process and stoichiometric relationships can also be used (NRC, 1990a). Finally, process outputs are assigned and the results verified by an on site manufacturing engineer (NRC, 1990a). Once an initial MAA is performed, the process can be streamlined through identification of information gaps, computerizing results and integrating the process into the plant environmental program. The output of a MAA is a list of wastestreams and the quantity of chemicals (e.g. pounds) present in each. The output of a EMB takes this one step further and quantifies the actual rate of release (e.g. $gr/m^3/sec$).

### Selecting Chemicals of Concern

Once chemical emissions to the environment have been enumerated and quantified, it is necessary to prioritize chemicals to be included in a risk assessment so that limited resources are not wasted on chemicals presenting little risk. RAGS (EPA, 1989) recommends prioritizing chemicals of concern based on RfC/RfD and CSF. Those with lower RfC/RfD and steeper CSF's would be ranked first. However, this information does not exist for all chemicals. A second possibility is to include only regulated chemicals such as those appearing on the RCRA Hazardous Waste (40 CFR 261, Subpart C) or CERCLA Hazardous Substance (40 CFR 302.1) lists. Another method of selecting toxic air pollutants uses chemical vapor pressure and documented health effects, however no ranking method is suggested (McCarthy and Burbank , 1989).

Rosenblum et al (1985) proposed an Integrated Risk Index System (IRIS) for ranking and prioritizing chemicals to be included in a human health risk assessment. It is a qualitative first step in a human health risk assessment aimed at providing fast and consistent insights, even with limited data. It is not intended to attach a quantitative level of risk to a chemical. A risk index of 120 does not indicate it presents twice the risk as a chemical bearing an index number of 60 (Rosenblum et al, 1985). The Integrated Risk Index (IRIS) is expressed by the equation:

$$RI = P(2PH + 2HH + EH), \text{ where :}$$

P = Potential Exposure Factor, considers: annual production of a chemical and the number of potentially exposed people.

PH = Physical Hazard Factor, considers: chemical flammability and reactivity

HH = Health Hazard Factor, considers: acute and subchronic toxicity, carcinogenicity, mutagenicity, teratogenicity and reproductive effects

EH = Environmental Hazard Factor, considers: ecological damage

The complete Risk Indexing System with all criteria can be found in Appendix A.

In a subsequent article Rosenblum (1987) discusses expanding IRIS to provide a more comprehensive survey of a chemical risks, however, no further citations were found in the literature. Several years later the EPA's Office of Toxic Substances funded a research project to develop a Computerized Risk Scoring System based on a more quantitative index than Rosenblum's (Whitmyre et al, 1990), but using many of the same criteria. The software was never released as it did not provide a significant numerical spread between chemicals. This resulted from using the same default values for each chemical when data were sparse (Delpire, 1995). Rosenblum et al's (1985) ranking scheme allows the user to select graded default values based on information that is known about the chemical.

### Exposure Concentration

Computer models are used to simulate the fate and transport of contaminants in the environment when measured environmental concentrations are not available (Cohrssen and Covello, 1989). Computer models exist that simulate contaminant movement in air, surface water, soil and groundwater. The accuracy of these models depends on selecting the correct model and input values. Selection criteria for regulatory uses can be found in 40 CFR 51 Appendix W (air quality models), EPA's <u>Selection Criteria for Mathematical Models Used in Exposure Assessments:</u>

Groundwater Models (EPA, 1988) for groundwater models and Identification and Compilation of Unsaturated/ Vadose Zone Models (EPA, 1994) for unsaturated soil.

An important input value is the emission rate. As stated earlier, chemicals may enter the environment via air, water or soil. For certain wastes, such as surface water discharges covered by a National Pollution Discharge Elimination System permit, rates are known. Wastes sent to a solid or hazardous waste landfill, when properly handled and disposed of, present a problem only if the storage containers and landfill both leak. A probabilistic analysis is required to predict the likelihood of these two events occurring, before emissions rates can be estimated. In addition to direct measurement of air releases, emission factors for certain industrial releases can be found in EPA's AP-40 Handbook (EPA, 1995) or calculated through emissions equations (McCarthy and Burbank, 1989). However, EPA finds that emission factors estimates made from the output of a MAA may be more reliable than measured rates or AP-40 emission factors (EPA, 1995).

The recommended model for estimating exposures from toxic chemicals released at an industrial site is the EPA's Industrial Source Complex model (51 CFR Pt. 51, App.W). It is a steady state Gaussian Plume model, that assumes a vertical wind speed of zero and constant uniform horizontal wind speed for each hour. This model estimates exposure levels ranging from several hours to years from a continuous release. The ISCST2EM model and documentation can be found on the computerized Support Center for Regulatory Air Models (SCRAM) Bulletin Board supported by the USEPA.

### Exposure Scenarios

Exposure Scenarios describe conditions under which populations will be exposed. It includes enumerating receptors, age groups, route of entry (e.g. breathing, showering, eating), number of people, frequency and duration of exposure (EEE, 1994). Much of the population data can be found in the Topologically Integrated Geographic Encoding and Referencing System (TIGER), which contains census data broken down by county into census tracts and blocks. A census tract is "small, relatively permanent statistical subdivisions of a county (USCB, 1990)." Size for a census tract is relative to the population living there. Population attributes included in TIGER for census tracts are sex, age, income and household makeup. This population information can be tied to atmospheric pollutant concentrations using a Geographic Information System (GIS). GIS can depict and analyze data commonly found on maps. Data describing different map attributes are overlain on geographic areas to determine relationships such as number of people exposed to varying levels of air pollution. Results of a GIS can be presented in table or graphic form.

Limitations to using the TIGER files and GIS is that populations are assigned to census tracts and blocks as a whole without specifying where in each census block people live. This is dealt with by assigning populations to a specific area (Voorhees et al, 1989) or spreading the population evenly throughout a tract or block (Mohin et al, 1989). Another drawback to small business in using GIS is that the required computer hardware and software can be expensive and difficult to use without adequate training (Franklin, 1993).

## Risk Characterization

Risk characterizations quantify risk from individual and multiple chemical exposures and assess uncertainties associated with the risk assessment (EPA, 1989).

### Quantification of Risk

A thorough risk assessment considers exposure from all possible sources and routes of entry. Exposure (E) can be characterized by the equation:

$$E = \sum_i \sum_j C_i(S) \times F_{ij}$$

where i is air, soil, water; j is inhalation, ingestion, and dermal absorption; $C_i(S)$ is the contaminant concentration in the environmental compartment i from source S multiplied by the percent uptake $F_{ij}$ (McKone and Daniels, 1990). Background levels should also be included. The EPA also suggests the consideration of chemical interactions where feasible.

Delivered environmental concentrations are converted to dose using standard assumptions about body weight, life expectancy, etc... unless site specific information is available. Risk can be expressed in terms of a "Maximum Exposed Individual" (MEI), as an increased lifetime probability of contracting disease or disability, or as a qualitative measure of exposure effects (EPA, 1989). These are all point estimates of risk. An MEI is a conservative estimate, based on a hypothetical person assumed to live in one place without ever leaving (even to go to the store), breathing, eating and drinking the same amount at the same rate over a 70 year life span. For non-carcinogens, the effective, delivered or absorbed dose is divided by the RfD and acceptable risk is a Hazard Quotient (HQ) less than one. This does not give a quantitative estimate of risk, but is considered protective of sensitive individuals within a population (Lewis and Alexeeff, 1989). When RfD/RfC's are not available, comparisons can be made to safe Ambient Concentration Levels (ACL) (Lewis and Alexeeff, 1989). When ACL's are not available in references, they can be found by dividing NOAEL's by uncertainty factors. The EPA recommends that risk assessments for air toxics emphasize the highest concentrations and averaging times for standards (51 CFR Pt. 51, App.W).

Individual lifetime risk is the probability an individual will suffer specific adverse effects due to exposure from a specific risk agent (Cohrssen and Covello, 1989). To determine individual lifetime risk for carcinogens, the estimated dose is multiplied by the CSF to approximate the risk of contracting cancer. The EPA defines acceptable risk is less than one in a million or $10^{-6}$.

Other risk measures exist, including population risk, relative risk, standardized mortality or morbidity ratios, loss of life expectancy or individual lifetime risk (Cohrssen and Covello, 1989). Population risk is the number of cases that would occur each year due to exposure to a risk agent. Relative risk compares the number of cases in an exposed population to an unexposed population. Standardized mortality or morbidity ratios are determined by dividing the number of cases in an exposed population by the number that would have occurred had no exposure taken place. Loss of life expectancy is the number of days or years lost to a person who is exposed. These require specific information on morbidity and mortality in a given area .

## Uncertainties

Uncertainties abound in a risk assessment as each step is based on the probability or assumption that an event has or will occur. Gratt (1989) describes risk from air toxics (r) as the probability function, p(r) = p(s,d,e,h), where s is the emission source, d is the air toxic dispersion into the environment resulting in ambient concentrations, e is the human exposure to these ambient levels resulting in an effective dose to target organs which is converted to a health impact through a dose-response function h. Uncertainties can therefore be categorized by quantification of chemical release and transport, exposure scenarios, and by the relationship between the substance and its toxicological response in an exposed population Talcott (1993).

### (1) Quantification of Chemical Release and Environmental Transport

The primary uncertainty surrounding transport of chemicals is uncertainty in the physical and biological forces that govern the natural environment. The spread of a toxic chemical released into soil will depend on, among other factors, soil type, water movement through the soil, temperature, and the types of organisms present in the soil. How these factors interact with the toxic chemical vary and seldom act in a linear manner. Because of this, average values and/or variables estimates are often used in models (Cohrrsen and Covello, 1989).

There may be uncertainty over whether a chemical will even enter the environment. For example, a drum may be packed with 100 pounds of waste and buried in a landfill. In this case, 100 pounds have the potential for release into the environment, but if the drums and landfill do not leak, there is no emission. To estimate the risk from this situation, assumptions are made as to the probability a leak will occur and the rate at which chemicals will be released. Certain industrial emissions are well quantified, such surfacewater discharges covered by an NPDES permit, while others are not.

Sensitivity studies of gaussian dispersion models similar to the ISCST2EM air model found that they are reliable for approximating longer time-averaged concentrations than for estimating short-term concentrations at specific locations and they are reliable at estimating the magnitude of highest concentrations occurring sometime, somewhere within a given area. Errors of ±10 to 40 percent are common in estimated siting maximum concentrations (51 CFR Pt 51, Appendix W). Increasing averaging times, tends to overcome this problem.

### (2) Exposure Scenarios

Exposure scenarios make assumptions about chemical intake and the temporal and spatial distribution of a population, as well as its composition. Fixed body weights, and air, water and food intake values are standard assumptions made in a risk assessment. MEI scenarios assume maximum exposure to an individual subjected to fenceline ambient concentrations throughout his/her life, when in reality during a given day, people move through a variety of environments receiving, to varying degrees, exposure to a number of chemicals. Although temporal distribution is not treated, availability of the TIGER files can reduce uncertainties associated with population distribution and make-up.

### (3) Relationship between a harmful substance and its toxicological response

As stated previously, toxicological information for chemicals is based on human studies, short term bacteria and cell culture studies, animal studies and structure activity relationships (Covello and Merkhofer, 1993). There are uncertainties inherent with each of these methods. Epidemiological human studies relate exposure to effects, but are retrospective and can only assume causal relationships. Animal dose-response evaluations, based on short term/high exposure studies of genetically homogenous test species, are extrapolated to give long term/low exposure information about humans, a genetically heterogeneous population (Longstreth, 1987). It is assumed that absorption and metabolism at these high dose are the same as for the low doses humans usually receive. Dose-response factors generated in this way may be off by a magnitude of 1000 and probably the greatest uncertainty in a risk assessment (Gratt, 1989).

The Maximum Tolerated Dose (MTD), used to estimate the carcinogenicity slope factor, is the maximum dose a species can tolerate most of its life without impeding growth or causing any toxic effect other than carcinogenicity. Critics claim that at such high doses the animals immune system is overwhelmed and cancer can be induced, where at lower doses this might not be the case (Cohrssen and Covello, 1989). Additionally, it is assumed that cancer incidence is linear at low doses and there is no threshold. Dellarco and Kemmel (1983) point out deficiencies in non-cancer determinations, for example no risk determinations are given for doses above the RfD. To overcome these shortcomings, delivered dose is converted to mg/kg of body weight rather than in mg/l.

Assumptions are also made about uptake of harmful substances by exposed populations. The chemical concentration reaching a population is not always the concentration reaching a target organ. Dose is defined as (Ryan, 1990):

(a) delivered dose - the concentration reaching the receptor population

(b) absorbed dose - the concentration absorbed by the lungs or gastrointestinal tract

(c) the effective dose - the amount that actually reaches the target organs.

Uptake and absorption information are usually derived from animal studies or pharmacokinetics models. There are inherent uncertainties even in assuming that uptake rates are the same in individuals within a species, let alone when extrapolating data from one species to another. For this reason, in a risk assessment effective and absorbed dose are often equated with the delivered dose (Cohrssen and Covello, 1989).

Another uncertainty is the breakdown of contaminants in the body to metabolites which may pose a different (greater or lesser) risk than the parent compound and are not as well studied. Exposure often occurs to more than one chemical at a time. Up to 2,800 chemicals may be present in the ambient atmosphere, with less than 100 tested for carcinogenicity and less still for chemical interactions (Krewski and Thomas, 1992). Chemicals may react antagonistically or synergistically with each other. The only option offered in these cases is to add risks when chemicals cause the same endpoint, unless there is evidence to the contrary (51 FR 34,014).

## Overcoming Uncertainties

Although the results of risk analyses are conditional due to these uncertainties, the SAB (1990) still encourages risk analysis to prioritize resources for environmental projects as long as assumptions and data limitations are explained. Calculating a point estimate of risk then describing uncertainties is a qualitative approach often taken by EPA (Gratt, 1989). Another qualitative method described by Talcott (1992) assigns geometric standard deviations to each phase of the risk assessment process and carries them through to the final outcome. A geometric standard deviation is an arbitrary scale, where one corresponds to absolute certainty on one end of the scale and greater than 10 corresponds to extreme uncertainty at the other end. Cohrssen and Covello (1989) discuss several quantitative methods for overcoming uncertainty. These include:

1) Probability Distributions

   Monte Carlo simulation is an example. It involves drawing random values from a range of acceptable values and developing a probability distribution function (curve) which will give the likelihood that a variable actually represents a particular value. Confidence intervals are found from the distribution curve and the outcome will be a range of values rather than one number. Also sensitivity analysis determines the sensitivity of model input variables to ascertain if more resources should be spent to provide a better value.

2) Worst-Case/Best-Case

   The best estimate of the lowest and highest extremes of a value are used to create an upper and lower bound on an estimated value.

A study by Munshi and Marlia (1989), applied uncertainty analysis to the two areas of air toxic risk assessment they considered to have the greatest degree of uncertainty - model output and toxicity values. Using data from a previous study, they found the ratio of estimated environmental concentrations from the Industrial Source Complex Long Term model to actual measured concentrations was between .5 and 2.0.

If the distribution of annual average concentrations was assumed to be uniform, .5C (C=model estimated ambient concentration) and 2C were considered the lower and upper bounds. For a normal distribution, .5C and 2C were assumed to compare to the .138 and 99.752 percentile values, with a mean of 1.25C and a variance of $(1/6(2C-.5C))^2$. Their other goals were to determine a confidence boundary for the CSF of chromium. They found two acceptable values and averaged the two for a mean, then assuming a uniform distribution used the higher as the upper bound and the lower as the lower bound.

## Risk Management

Risk management combines the outcome of a risk assessment with information about technical and economic resources, as well as social and political values, to determine the best means to reduce or eliminate a risk (Cohrssen and Covello, 1989). When risk exceeds *de minimis* or a chosen standard, risk management is used to identify risk reduction alternatives, select and implement an alternative, and then monitor its effectiveness. Unlimited resources would simplify the task of selecting an alternative, but realistically when resources are limited, various economic decision aids are available to help determine which choice will reap the greatest benefit.

### Cost Benefit Analysis

Risk cost benefit analysis (RCBA) attempts to reduce costs and benefits to a common denominator, usually a dollar value, and the costs are compared against the benefits. Future benefits are discounted and alternatives compared on the basis of the value of net benefits received over the lifetime of the project (NRC, 1990b). This value can be expressed as the Net Present Value (NPV), the Internal Rate of Return (IRR) or payback time. NPV subtracts the discounted costs from benefits and if the resulting number is greater than zero the project is acceptable. To calculate the IRR, the NPV is set at zero and the discount rate calculated. A project is then undertaken if this discount rate or IRR is greater than the cost of capital. Results can also be expressed as "payback".

RCBA is often used by both private and public decision makers to determine which projects will yield the greatest increase in net benefit from the reduction of a particular risk. Although both see risk reduction as a benefit, there is a difference between public (social) and private definitions of what constitutes an environmental risk, cost and benefit (Anderson and Settle, 1977). Costs and benefits to an industry are usually well defined as the investment needed to undertake a project and the profit it provides. Social costs and benefits, on the other hand, include not only private costs and benefits, but also such items as revenue lost to a community due to real or perceived pollution to recreational waters and/or increased income generated by the project construction. Also, private industries are concerned with the legal risk associated with regulatory non-compliance, while public officials also consider social risks including risks to HHE.

Traditionally health risks are excluded from a private RCBA, because a private firm assumes that compliance with regulations insures protection of HHE and because the costs and benefits of health risks are nebulous and difficult to define. Often a cost *may* occur, only *if* a tank leaks or *if* an accidental spill occurs. It is therefore easier to leave them out of the CBA and deal with them later should they occur. Due to the lengthy payback time and fuzzy potential liability costs, CBA has traditionally favored end-of-pipe treatment over pollution prevention which is usually more protective of HHE (EPA, 1992).

Total Cost Accounting (TCA) attempts to include risks to HHE in a RCBA by expanding costs to include liability for non-compliance fines and legal claims for property damage and personal injury (EPA, 1992). Less tangible benefits for increased revenue from enhanced product quality and image are also included. The time line for pay back is expanded past the normal three to five years. Costs associated with a particular waste generating process are allocated to that process rather than being spread out sitewide. The drawbacks are the additional time and information required to complete a TCA, and the reluctance of industries to use a financial method that is not well understood for environmental problems that are not easily quantified (EPA, 1992).

### Decision Analysis

Decision analysis is an economic decision aid which is based on the expected utility of a decision maker as opposed to the NPV in RCBA. It is considered a systematic quantitative approach to decision making under uncertainty and is employed when resources are limited and alternative risk reduction strategies manifest outcomes with "differing desirabilities and likelihoods" (Logan, 1990). The decision analysis process involves problem definition, enumeration of solutions and evaluation of outcomes for each solution based on the estimated cost and probability of the outcomes occurrence. These outcomes are then ranked based on the utility a decision maker would receive if it were implemented. The decision analysis process iterates repeatedly through three phases: deterministic, probabilistic and informational (Matheson and Howard, 1968). Sensitivity analysis is used at the end of each phase to determine if the process needs to be refined. The end results are laid out in a decision tree format.

### Deterministic Phase

The deterministic phase begins with formulating the "decision basis". This consists of defining the problem, enumerating alternatives, assigning available probability information and determining the decision makers preferences. Variables affecting each alternative are specified. They are classified as either decision or state variables. Decision variables are those that a decision maker has control over, such as whether or not to incinerate or landfill a waste, while state variables are out of a decision makers control, for example whether or not a landfill will leak. This model is evaluated initially by calculating the probability and cost of each outcome.

Lastly, an appraisal is made as to whether more information is needed. Common sense may indicate where large areas of uncertainty exist, but for those less obvious deterministic sensitivity analysis is undertaken to determine which state variables require a probability assessment (Logan, 1990). If little change in the outcome is observed as a variable value is changed, this may preclude it from probability analysis. However, variables that seem unimportant on an individual basis, may take on more significance when combined with the other variables and therefore should not be thrown out on the basis of the initial assessment (Matheson and Howard 1968).

### Probabilistic Phase

The probabilistic phase estimates the probability distribution of the outcome variables and the expected utility of each decision alternative. Information on probabilities can be obtained from various sources, including expert judgement, information provided by the decision maker or from published literature. Logan (1990) discusses several methods used in probabilistic calculations: decision trees, influence diagrams and stochastic programming.

A decision tree is characterized by nodes and branches. A square or decision node denotes the choice between alternatives. Branches extending from a circular or chance node represent possible values for uncertain state variables. Terminal nodes are the product of the probabilities of chance nodes leading up to it. An influence diagram does not use a decision tree format, but rather creates a schematic diagram of variables, their interactions and how they influence the outcome. Stochastic programming can be used to determine the probability of an outcome variable when a range of probabilities exists for each state variable.

The utility can express the amount of risk the decision maker is willing to take to see a successful outcome. The decision maker may be risk averse, risk neutral or risk seeking, depending on such consideration as the certainty of outcome and the money involved. In this way the utility function or u(v) incorporates the decision makers feelings into the final outcome. The utility of each outcome is multiplied by the probability of occurrence and the outcomes added for each alternative to obtain a single value for each solution.

## Informational Phase

The informational phase reviews the results of the previous phases and determines the cost of reducing the uncertainties associated with each of the major variables, thereby giving a dollar value to the acquisition of perfect information (Matheson and Howard, 1968). If further information is acquired or required, the decision analysis process is repeated.

## Decision Analysis Case Study

Balson et al (1992) integrated decision analysis and risk analysis to identify and manage potential health and environmental hazards posed by the power industry's activities. Risk analysis included risk assessment to characterize the source, environmental fate and transport, population exposure and population effects. Risk management used decision analysis to determine acceptable risk, define and evaluate management alternatives and then select and implement an alternative. Cost analysis included direct and indirect costs from fines, liabilities, cleanup costs and public relations. Sensitivity analysis determined where more information was needed.

The case study examined health risks to both the maximum exposed and the "hypothetically" or realistically exposed person associated with emissions from a coal fired power plant. Under hypothetical exposure, it was shown that under a variety of operating schemes plant emissions resulted in only an incremental increase in the likelihood cancer due to exposure. Under a worse case scenario, the risk of cancer to the MEI increased to one in a million. A deterministic sensitivity analysis revealed that the greatest uncertainty was associated with the number of years the plant functioned and population exposure patterns.

## Comparison of Risk Cost Benefit Analysis and Decision Analysis

In the evaluation of environmental policies, Covello and Merkhofer (1987) believe Decision Analysis is an important alternative CBA, although the two share common features. For example, both break complex problems down to their component parts, then create a systematic framework for selecting an alternative when the consequences of the alternatives are uncertain. They quantify and describe the advantages and disadvantages of the tradeoffs and then merge the information into a single number representing the value of the overall policy. Covello and Merkhofer (1987) state that the difference between the two lies in the interdisciplinary nature of decision analysis. Where RCBA utilizes the theories and methods of economics, decision analysis integrates many disciplines including: systems engineering, operations research, management science, as well as economics. The limitations to decision analysis is the assumption that all alternatives have been enumerated, the difficulty in controlling judgement biases and in separating technical and value judgments, disagreements over assigned probabilities, and problems in gaining access to decision makers (Covello and Merkhofer, 1987) . The pitfalls to both CBA and decision analysis include difficulty in obtaining reliable data, reporting data at a "level of precision" that is misleading as to its accuracy and the potential for ignoring moral and ethical issues.

## Cost Effectiveness

Cost Effectiveness Analysis (CEA) determines "how a given level of benefit can be achieved at the minimum cost, or to show how the maximum benefit can be achieved at some given level of cost (Sugden and Williams, 1985)." This is useful when social benefits are difficult to measure, as no monetary value need be assigned to the benefits. It gives the decision maker the most "bang" for a given amount of environmental dollars. CEA is a common strategy when the goal is known -- build a water treatment plant -- and the objective is to provide this service at the lowest cost (Field, 1994). Another risk ranking system based on the severity and probability utilizes CEA to determine the lowest countermeasure costs (Grose, 1993).

# CHAPTER III

# MATERIALS AND METHODS

## Introduction

The objective of this project is to develop a risk based management tool to identify potentially harmful industrial chemical emissions, rank them based on that risk and determine the most cost effective method to reduce them. The NAS risk analysis paradigm of Risk Assessment and Risk Management is used to carry out this objective using data collected at an industrial case study site. The Risk Assessment Guidelines for Superfund (EPA, 1989) document provides an outline for the risk assessment. A Materials Accounting Analysis identifies and quantifies chemicals entering the environment. Chemicals emissions are prioritized to identify those to be included in the risk assessment using the "Integrated Health Index System". The environmental concentration received by a receptor population of those selected chemicals are estimated using computer models. These concentrations are used to determine potential intake and intake is compared to standards to determine what level of risk the chemicals present.

## Risk Assessment

### Hazard Assessment

Hazard Assessment qualitatively establishes a hazard exists by identifying potential sources of exposure, exposed populations and pathways of exposure. The case study industry manufactures and processes carbon steel forms. Weldmills manufacture forms from sheet metal. In another area of the plant, purchased forms are cleaned with acid and a caustic solution, then coated with zinc phosphate and lubricated with sodium stearate. Next, hydraulic machinery compress portions of the forms before they enter the main manufacturing process. From this point on both the purchased and site manufactured forms are treated in the same manner -- heat treated, cut to a designated length, stenciled with specifications, sprayed or dipped with a mineral oil based rust preventative and bundled for shipment. Four parts cleaners are located throughout the plant for equipment degreasing.

Wastestreams are produced at the metal surface cleaning/coating dip tanks, hydraulic machinery, steel weldmill, steel cutters, furnaces, stencilers, corrosion preventative applicator and parts cleaners. All wastes are handled in accordance with government regulations. Wastes are disposed of in hazardous and non-hazardous injection wells, solid waste landfills (SWLF) and some treated liquid wastes are discharged to a local Publicly Owned Treatment Works (POTW). Air emissions occur from the furnaces and through evaporation of Volatile Organic Chemicals (VOC's) and may present direct dermal and inhalation exposure. Other potential exposures exist from soil and groundwater contamination at landfills and waste injection wells.

Potentially exposed populations are also those persons living downwind from the plant, downstream from the POTW, or close to landfills. It was therefore assumed a hazard existed.

## Toxicity Assessment

The toxicity assessment was postponed until after choosing the chemicals of concern in the Exposure Assessment.

## Exposure Assessment

Exposure Assessment identifies and quantifies risk agents, prioritizes chemicals of concern, determines exposure levels and develops exposure scenarios.

### Source Quantification

Materials accounting (MAA) was chosen over the engineering mass balance to quantify environmental releases, because it was assumed emission rates would be needed only for those chemicals included in the final risk assessment. All inputs and outputs for this materials accounting are in pounds per year.

#### *Data Collection*

The first step of MAA is data collection on incoming chemicals and raw materials, process and chemical flow through the plant and known wastestreams. Data to quantify input chemicals and raw materials and product output came from the Purchasing Department, which also supplied Material Safety Data Sheets (MSDS) for input chemicals. In addition to chemical constituents and physical characteristics, the MSDS provided health and safety information for each compound. Physical data not included in the MSDS were found in the CRC Handbook of Chemistry and Physics (Weast, 1981).

Environmental loss information was assembled from laboratory analyses, Purchasing Department records, in-plant records and public documents. Solid and hazardous wastestreams and effluent from the Internal Water Treatment Facility (IWTF) were routinely analyzed for heavy metals. In addition the IWTF effluent is tested for total suspended solids, manganese, biological oxygen demand, zinc and nickel. Purchasing provided information on the cost and quantity of waste disposed of in solid waste landfills and in hazardous and non-hazardous waste injection wells. In plant records are kept on the volume and percent of zinc found in various wastestreams. Public documents included quarterly reports submitted to local authorities on hazardous waste shipments and storage and waste characterization data forms filled out by solid waste transporters. These contained data on pH and waste density. This information was validated through discussions with the plant engineer and on several plant tours. Floor plans of the manufacturing area were also provided.

### *Process Description*

From plant tours and floor plans, a general flow diagram of the manufacturing process was created and a written description of each process made. Raw materials were converted to pounds per year using specific gravity values. Next, the raw materials were matched with the appropriate process (See Diagram 3.1) and the wastestreams delineated for each process (See Table 3.1 for list and Appendix H for schematic diagrams). The last step was to determine the quantity and constituents in each wastestream. To do this, each manufacturing process was examined individually. The following section discusses each manufacturing process, and the fate of its wastestreams.

## A) Cleaning/Pickling Line

Ninety percent efficiency is assumed for each of the cleaning/pickling line processes, unless otherwise stated. This number reflects the approximate overall plant efficiency for the production of metal forms.

The Cleaning/Pickling line is a series of ten dip tanks:

1) Caustic Cleaner
2) Caustic Rinse
3) Sulfuric Acid
4) Cold Water Rinse
5) Hot Water Rinse
6) Zinc Phosphate
7) Zinc Phosphate Rinse
8) Neutralizer
9) Sodium Stearate

### 1) <u>Caustic Dip Tank</u>

To insure the zinc phosphate coating will adhere, organic material and dirt are cleaned off the forms in the caustic dip tank using an alkaline cleaner composed of sodium hydroxide, potassium hydroxide and resin acids. This combination of cleaners removes oil through one or all of the following mechanisms: saponification of fatty acids by sodium and potassium, emulsification of oils with rosin soap, or through the displacement of oil at the metal surface with water or surfactant (Spring, 1969). Sodium and potassium hydroxide dissociate in water to form sodium ($Na^+$), potassium ($K^+$) and hydroxide ions ($OH^-$). In the emulsion process, rosin acids combine with potassium or sodium to form a rosin salt surfactant (Equation 1) which is lipophilic at the rosin end and hydrophilic at the sodium end.

$$RCOOH + NaOH \text{ (or KOH)} \rightarrow RCOONa + H_2O \qquad (1)$$

The rosin end will solubilize in the oil, while the sodium stays dissolved in water, causing a decrease in the surface tension of the oil. Simultaneously, the hydrophilic end is also attracted to the metal. At a critical point the oil droplet breaks loose surrounded by rosin-salt molecules, forming a water soluble micelle and thereby emulsifying the oil.

In the above process fatty acids from the oils are released and can then form more surfactant molecules. Fatty acids may also be released through saponification. The first step in the saponification process is the hydrolysis of fat to fatty acids and glycerin. Fats are composed of esters of trihydroxy alcohols or glycerol, with carbon chains of varying lengths (Equation 2).

$$(C_xH_xCOO)_3C_3H_5 + H_2O \rightarrow 3C_3H_5COOH + C_3H_5(OH)_3 \qquad (2)$$

In the second step, caustic sodas react with the fatty acids to form a more water soluble fatty acid sodium (or potassium) salt similar to the reaction in Equation One (Feierstein and Morganthaler, 1983) that can act as a surfactant. Additionally, sodium stearate on forms being re-cleaned for further processing is solubilized and removed in this tank (Personal Communication, 1995). Waste streams include: sludge that collects on the bottom of the tank, spent caustic solution and dragout to the caustic rinse tank.

### a) *Caustic Sludge*

Built up dirt and grit on the forms is removed in the caustic tank by the rolling action of the tank as it mixes, forming a sludge that collects on the bottom of the tank. At the time these data were collected, the caustic tank was drained every nine months and the sludge removed and taken to a SWLF in 55 gallon drums.

### b) *Spent Caustic Solution*

Spent caustic solution contains sodium stearate, emulsified and saponified fats, as well as used sodium hydroxide, potassium hydroxide and rosin acids. As this waste stream is not analyzed for these chemicals and the reaction of surfactants with oil is a physical process and not a stoichiometric reaction, quantities can only be estimated based on amounts ordered and knowledge of process. The pH can be used to estimate the approximate quantity of free hydroxide ions (Niven, 1955). Spent caustic tank solution is mixed with ferrous sulfate to prevent it from gelling as it cools. It is then neutralized with sulfuric acid, solidified with cement kiln dust and disposed of in a SWLF. Treatment is performed by an off-site company.

### c) Dragout

Dragout, or the carryover of chemicals on the forms from one tank to another, can contain small amounts of sodium and potassium hydroxide, sodium stearate and emulsified oil. The rinse tank overflows to the IWTF where hydroxide ions aid in neutralization and precipitation. Emulsified oils, sodium stearate and sodium and potassium ions are soluble and would overflow to the POTW. The quantities of chemicals in each of these waste streams is unknown and must therefore be estimated.

### 2) Sulfuric Acid or Pickling Tank

Once steel pre-purchased forms are manufactured, exposure to air and moisture can oxidize iron in the steel causing an iron oxide scale to develop on the surface. Metal pickling uses acids to dissolve oxides from metal surfaces. At this plant sulfuric acid is used to dissolve iron oxides from the steel forms. The pickling process is described in Equations 3 - 7 (Fedot'ev and Grilikhes, 1959):

$$\underset{\text{(Sulfuric Acid)}}{H_2SO_4} + \underset{\text{(Iron Oxide)}}{FeO} \rightarrow \underset{\text{(Ferrous Sulfate)}}{FeSO_4} + H_20 \quad (3)$$

$$3H_2SO_4 + \underset{\text{(Iron Oxide)}}{Fe_20_3} \rightarrow \underset{\text{(Ferric Sulfate)}}{Fe_2(SO_4)_3} + 3H_20 \quad (4)$$

$$H_2SO_4 + \underset{\text{(Elemental Iron)}}{Fe} \rightarrow FeSO_4 + \underset{\text{(Hydrogen Gas)}}{H_2\uparrow} \quad (5)$$

$$4H_2SO_4 + \underset{\text{(Iron Oxide)}}{Fe_30_4} \rightarrow FeSO_4 + Fe_2(SO_4)_3 + 4H_2O \quad (6)$$

$$Fe_2(SO_4)_3 + Fe \rightarrow 3FeSO_4 \quad (7)$$

The reactions move to the right, producing ferric and ferrous sulfate from the reaction of iron oxides with sulfuric acid. Water and hydrogen gas are by-products. In the presence of excess elemental iron, ferric sulfate is reduced to ferrous sulfate. Two wastestreams are produced in the pickling process: spent pickle liquor and dragout to the acid rinse tank.

### a) *Spent Pickle Liquor*

Over time, iron concentrations begin to build up in the pickle liquor decreasing efficiency. When the sulfuric acid decreases to ten percent by volume and the iron builds up to nine percent by weight, the sulfuric acid pickling tank is emptied and the pickle liquor is shipped to a hazardous waste injection well. This wastestream contains sulfate ion, ferrous sulfate, hydrogen ions, and sulfuric acid ions ($HSO4^-$).

### b) *Dragout*

The dragout from the pickle liquor tank to subsequent rinse tanks will be of similar composition to the spent pickle liquor and will eventually go to the IWTF, where the acid is neutralized, iron is precipitated into the sludge as iron (II) hydroxide and sulfate combines with magnesium to form water soluble magnesium sulfate. Magnesium sulfate is released to the POTW. The sludge is dried and taken to the local landfill.

## 3) Zinc Phosphate Coating Tank

In this process, a zinc phosphate-iron complex is laid down on the form's surface as a substrate for the adhesion of sodium stearate. Phosphate coatings increase surface as a substrate for the adhesion of sodium stearate. Phosphate coatings increase surface area, creating capillaries to hold the lubricator - sodium stearate (Wittke, 1989). At the metal surface, acid dissolves iron releasing elemental hydrogen (Equation 8). The hydrogen in zinc dihydrogen phosphate is replaced by the dissolved iron and the new metal complex bonds to the surface of the metal (Equation 10). The nitrate in the nitric acid and zinc nitrate act as accelerators to speed up the reaction through the production of more hydrogen. A secondary benefit is to decrease the amount of elemental hydrogen produced which can cause the metal to become brittle (Equation 9). Equations can be found in Kunst et al, 1990.

$Fe + 2H^{+} \rightleftharpoons Fe^{+2} + H_2$ Pickling ( 8)

$H_2 + 2NO_3^{-} \rightleftharpoons 2HNO_3$ Acceleration ( 9)

$Fe^{+2} + H^{+} + NO_3^{-} \rightleftharpoons Fe^{+3} + HNO_3$

$3Zn^{+2} + 2H_2PO_4^{-} + 4H_2O \rightleftharpoons$ Coating (10)

$Zn_3(PO_4)_2 \circ H_2O + 4H^{+}$

$2Zn^{+2} + Fe^{+2} + 2H_2PO_4^{-} + 4H_2O \rightleftharpoons Zn_2Fe(PO_4)_2 \circ 4H_2O + 4H^{+}$

$Fe^{+3} + PO4^{-3} \rightleftharpoons FePO4 \downarrow$ Sludge Formation (11)

Wastestreams produced in the coating process include phosphate sludge from the bottom of the tank, zinc phosphate coating on the product and dragout into the zinc phosphate rinse and sodium stearate tanks.

### a) *Zinc Phosphate Coating*

Equation 10 can be used to estimate the amount of zinc and phosphate incorporated into the product as zinc phosphate coating. Hydrogen and nitrate ions are not consumed, but re-used in this process (Equations 8 and 9).

### b) *Phosphate Sludge*

Once or twice a year, the zinc phosphate coating tank is drained and the sludge removed from the bottom. The liquid portion is reused. From Equation 11 it can be seen that excess phosphate and iron combine to form the basis of the phosphate sludge. It can be assumed that hydrogen and nitrate ions can adhere to the sludge and also settle out. That portion can only be estimated.

### c) *Dragout*

Chemicals will also be carried over into the phosphate rinse tank. This amount can be estimated by subtracting the quantities of these chemicals found in the sludge and coating from the amount ordered.

### 4) Neutralizer Tank

In this tank, sodium borate or borax ($Na_2B_4O_7$) and sodium nitrite neutralize excess acid that remains after the zinc phosphate rinse. This step is important, because excess hydrogen ions can combine with sodium stearate to form an insoluble precipitate of stearic acid. Also, a lowered pH can impair the integrity of the zinc phosphate coating. The main wastestream from this process goes to the IWTF and ultimately the POTW. When borax is mixed with water it hydrolyzes to produce an alkaline solution (Equation 13), freeing hydroxide ions to neutralize excess acid

(Jacobson, 1946).

$$Na_2B_4O_7 + H_2O \rightarrow 2NaOH + H_2B_4O_7 \qquad (13)$$

Tetraboric acid ($H_2B_4O_7$) is weakly acidic and soluble in water. It will overflow to the internal treatment plant and be neutralized by magnesium hydroxide. Borate is somewhat insoluble and can settle into the IWTF sludge.

Sodium nitrite reacts with acid to form sodium nitrate and nitrogen oxide (Equation 14). Sodium ions released in this process have the potential to combine with water to form sodium hydroxide (Jacobson, 1946).

$$3NaNO_2 + 2H^+ \rightarrow NaNO_3 + 2NO\uparrow + 2Na^+ + H_2O \qquad (14)$$

Nitrogen oxide escapes to the atmosphere. Sodium nitrate will also ionize. Sodium can form sodium hydroxide and nitrate overflows to the IWTF. Nitrate will not be precipitated; it goes to the POTW.

### 5) Sodium Stearate Lubrication Tank

Sodium stearate ($C_{17}H_{35}COONa$) lubricates, preventing metal to metal contact. Sodium stearate adheres to the zinc phosphate coating on the surface of the forms. Wastestreams include: sludge from a sodium stearate decanter and carryover on the product.

#### a) *Sodium Stearate Sludge:*

The spent sodium stearate solution goes to a decanter, where sludge settles at the bottom and is disposed of in 55 gallon drums at a SWLF. The supernatant from the decanter is reused in the sodium stearate dip tank.

#### b) *Carryover*

Carryover will flake off during handling and be taken to the SWLF, be burned off in the furnace and emitted as carbon dioxide and water, or be washed off in the caustic tank if the form is redipped for further handling.

### B) Hydraulic Machinery

Hydraulic oil is used in the hydraulic machinery which compresses portions of the forms in preparation for the main manufacturing process. Hydraulic oil wastestreams include: used hydraulic oil taken off site for energy recovery, spills sorbed to kitty liter and taken to the SWLF and oily water that collects in the empty drums and is taken to a non-hazardous deep well injection site.

### C) Main Manufacturing Process

The main wastestream from this process is sodium stearate that flakes off the forms due to handling. The sodium stearate is swept up and taken to the SWLF.

### D) Steel Weldmill

Weldmills cut sheet metal and weld it into forms. The process is 87 percent efficient. No flux is used in the welding process; the metal is fused by heat. The weld bead or "scarf" is removed and the excess material blown away with compressed air. Cutting oil and a coolant are used in the weldmills. Coolant is recycled and reused on site and scrap metal from the process is sold. If coolant becomes contaminated, it will be taken to a non-hazardous waste injection well.

This process generates the following residuals: tramp oil, carry over of cutting oil on the forms and used cutting oil that is processed off site for energy use. Tramp oil is composed mostly of oils and iron oxides and is taken to the SWLF. Up to ten percent of the cutting oil can be carried over on the forms and burned off in the furnaces. Once the cutting oil is spent, it is sold for energy reuse off site.

### E) Steel Form Cutters

All forms, once processed or welded, are cut to a pre-designated size. Wastestreams include used coolant and scrap metal. Coolant is recycled on site and scrap metal is sold.

### F) Form stenciling

Once cut, specifications are stenciled on the forms. Stenciling solutions are inks with a volatile organic base, such as methyl ethyl ketone or isopropyl alcohol. The inks are sprayed on and the volatile organics evaporate into the atmosphere. Methyl ethyl ketone is kept on hand to clean stencil tips. Wastestreams include air emissions due to evaporation and a sludgy waste of inks and solvent produced from cleaning the stenciling machines.

### G) Corrosion Preventative Application

A mineral oil based preservative or corrosion inhibitor is applied to the finished product either by spraying or dipping. The preservative also contains a barium soap of oxygenated hydrocarbon. The barium portion of the molecule is strongly attracted to the metal surface and aids in preservative adsorption. Preservative adherence is also aided by the zinc phosphate coating. Wastestreams produced in this process include carryover on the final product and evaporation of volatile organics off the forms.

### H) Parts Cleaning

There are five cleaners on the site that utilize mineral spirits to clean and degrease parts and equipment. Wastestreams include air emissions from evaporation and mineral spirits that are taken off site for recycling.

### I) Internal Water Treatment Facility (IWTF)

The Caustic Rinse, Hot Water Rinse, Cold Water Rinse, Zinc Phosphate Rinse and the Neutralizer tanks empty into the IWTF, where magnesium hydroxide is added to neutralize the pH and precipitate ions. The hydroxide combines with hydrogen ions to form water. Hydroxide and magnesium can also combine with other ions to form an insoluble precipitate or sludge. The sludge is dried and taken to the SWLF The effluent from the IWTF goes to the POTW.

*Environmental Losses*

Once process reactions and wastestreams (see wastestream list in Table 3.1) were identified, environmental losses were quantified using procedures listed below:

1) Laboratory Analyses and Waste Documentation

First laboratory analyses were looked at as indicators of wastestream composition. However, wastestreams are tested primarily for regulated chemicals and since few regulated chemicals are used on site, available laboratory test data proved to be of little help in estimating the quantity of input chemical in each wastestream. For example, sulfuric acid is used to remove metal oxides, particularly iron oxides, from metal surfaces. Due to its corrosive nature, the spent sulfuric acid solution is classified as a hazardous waste and is therefore analyzed for Resource Conservation and Recovery Act (RCRA) characteristic chemicals (40 CFR 268). Unfortunately, outside of heavy metals, these analyses give little information about process chemicals or the iron oxides removed from metal parts contained in this wastestream. In-plant records kept on zinc concentrations in various wastestreams aided the MAA.

Recycling documentation aided in estimating constituents of certain wastestreams. For example, by subtracting the quantity of mineral spirits recycled from the quantity ordered, air emissions could be estimated.

2) Percentage of Input

In the absence of laboratory data, the next procedure was to assign a percentage of the chemical input to a process to each of its process wastestreams. This was done through knowledge of process and in conjunction with the plant engineer. This procedure worked best for organic chemicals, where the input chemicals did not ionize or undergo any chemical changes during processing. For example, cutting oil is considered spent when contaminants build up to the point where the cutting oil no longer functions at a maximum efficiency. The cutting oil remained the same, but was contaminated. For input chemicals that underwent some form of chemical reaction, this procedure did not work.

### 3) Stoichiometric Relationships

For those processes that underwent stoichiometric reactions - the sulfuric acid/pickling process and the zinc phosphate coating, the reactions were laid out in various sources. By knowing the amount of chemical purchased and estimating process efficiency, it was possible to estimate the make-up of certain wastestreams. Also, when chemicals reacted mole for mole, unknown chemical quantities could be determined if the quantity of chemical they reacted with was known. For example, the pickling process was characterized by various equations, including this one by Fedot'ev and Grilikhes (1959):

$$\mathrm{H_2SO_4} + \mathrm{Fe} \rightarrow \underset{\text{(Iron II Sulfate)}}{\mathrm{FeSO_4}} + \underset{\text{(Hydrogen Gas)}}{\mathrm{H_2}\uparrow}$$

An approximate quantity of iron in the spent pickle liquor was known, and by using this equation, it was possible to estimate the amount of sulfate in the spent pickle liquor. Also, in this instance another wastestream ($H_2$) was identified.

### 4) Non-stoichiometric Relationships

Some reactions were non-stoichiometric, as in the case of the caustic cleaning solution. The caustic cleaner is composed of sodium and potassium hydroxide and rosin acids and removes organic material and debris that build up on stored pre-purchased parts. Three processes can take place in the caustic cleaning tank: the saponification of fatty acids by sodium or potassium, emulsification of oil, or the displacement of oil by surfactants or water. These are physical processes and do not react stoichiometrically. The last two are physical processes and although sodium and potassium react stoichiometrically with fatty acids in the saponification process, there is no way of knowing the amount of fatty acids present on the parts. In these instances, the only recourse with the available information was to estimate the quantity of chemical available to react.

Appendix B contains spreadsheets for each input chemical, describing its entry point into the environment. Spreadsheets in Appendix C balance incoming materials and chemicals against environmental losses.

### Selecting Chemicals of Concern

Rosenblum's Integrated Risk Index System (IRIS) was chosen to rank environmental losses for the purpose of selecting chemicals of concern to be included in the final risk assessment. A complete description of IRIS can be found in Appendix A. It was modified slightly. The ($N_{ap}$ ) value was changed from annual quantity of chemical produced to annual environmental loss released to the environment. Also, the Environmental Hazard Index, which is normally based on a "hypothetical spill of 100 lbs of product into a flowing stream", was expanded to include effects to terrestrial animals from spills onto land. Information for the IRIS was collected from a variety of references, but primarily from the following sources:

1. Material Safety Data Sheets (MSDS): Any information contained in the MSDS on the physical, chemical and toxicological nature of the compound was used first.
2. Physical Hazard Index: CRC Handbook of Chemistry and Physics (Weast, 1981) and Ullman's Encyclopedia of Industrial Chemistry.
3. Human Health Index: Ullman's Encyclopedia of Industrial Chemistry, Grosselin et al's (1984) Clinical Toxicology of Commercial Products, and a series of Desk References edited by C.S. Lewis, including: Sax's Dangerous Properties of Industrial Materials (Lewis, 1992), Carcinogenically Active Chemicals: A Reference Guide (Lewis, 1991a), and Hazardous Chemical Desk Reference, Second Edition (Lewis, 1991b).
4. Environmental Hazard Index: Ullman's Encyclopedia of Industrial Chemistry and Weiss's Hazardous Chemical Data Book (Weiss, 1986).

A literature search was undertaken for information not contained in these sources. Table 3.2 shows the data collection form. The Risk Index (RI), as defined in Appendix A, was calculated for manufacturing inputs, product output and environmental loss chemicals using Microsoft Excel 3.0 . Calculations and references for individual RI values can be found in Appendix D.

To select the final chemicals of concern, the route of toxicity for each chemical was compared with the potential exposure pathways and routes of exposure. For example, iron is toxic when injected subcutaneously, however the potential at this site to experience this type of exposure would be low, making the risk of toxic effects low. The following criterion were used to rate the likelihood of exposure. A high potential for exposure was based on direct contact. For instance, dermal or inhalation exposure from chemicals released to the atmosphere. A medium potential for exposure was assigned to secondary exposure from a chemical, such as eating food on which the chemical may have adhered. A low level was given to those environmental losses that would have to escape confinement in order to cause exposure, for example chemicals disposed of in a landfill that is not known to leak. It was also assumed that interperitoneal and intravenous routes of exposure would be rare. Iron and iron compounds received a medium exposure score because of the quantity produced, even though they are buried in a landfill. After making these comparisons, the following three volatile organic chemicals were chosen for further evaluation: Rust Preventative, Mineral Spirits and Methyl Ethyl Ketone (MEK).

### Exposure Level

Because the chemicals of concern are volatile and have a tendency to react in the atmosphere, the short term air quality model "Industrial Source Complex - Short Term Extended Memory" (ISCST2EM) model chosen. Additionally, the ISCST2EM model was chosen because it is capable of handling fugitive (area) emissions and VOC emissions at this site are fugitive. Fugitive emissions do not leave the building by a point source such as a vent or a stack, but by simple diffusion from the process where it is generated. ISCST2EM is a gaussian model that estimates the concentration of air emissions in micrograms per cubic meter at user specified points in the environment.

The ISCST2EM model, model documentation, meteorological data, and conversion/ processing programs were downloaded from the EPA's Support Center for Regulatory Air Models or SCRAM bulletin board. This can be accessed by telneting to TTNBBS.RTPNC.EPA.GOV or 134.67.234.17. Once in SCRAM, the following are needed to run the model: ISCST2EM.EXE, MET144.EXE, PCRAMMET.EXE, surface meteorological data and upper air mixing height data. ISCST2 documentation is also available. Diagram 3.3 is a flow chart of the steps needed to run the ISCST2EM model. Many of the files are compressed and must be unzipped using PKUNZIP, also available through SCRAM. The MET144.EXE program locates missing data and expands surface data so it can be combined with the mixing height data using PCRAMMET.

The ISCST2EM documentation (EPA, 1991) explains how to set up an input file. Input data for the ISCST2EM model includes control and source information, receptor locations, meteorological conditions and output format. Example input files are found in Appendix E.

> Control Information: Model default assumptions were used, as these were recommended by EPA for regulatory modeling. Output was in chemical concentration (ug/m$^3$) and the urban setting was selected. Averaging times included every three hour, 24 hour and yearly periods. The pollutants were identified as "other". No half-life was specified, because this information was only available for only one compound - MEK.
>
> Source Information: The length, height of release and emission rate was different for each chemical (discussed below).
>
> Receptor Location: Various locations were specified: a fenceline receptor was set at 200 meters, the nearest neighborhood to the north, south, east and west; and two grids - one set at every 100 meters and another every 1,000 meters from the source - were selected.
>
> Meteorological Conditions: Surface and upper air mixing height data came from two different weather stations. Surface data was available from a weather station located close to the site, but upper air information was not. The EPA recommends taking upper air information from the next weather station located downwind in the same jetstream, when this happens. A closer weather station was located slightly upstream from the site so upper air data from that station was used. Upper air data did not exist for the year in question, so to make the files match in PCRAMMET surface air data were taken from the previous year.

Output Files: Output was in yearly average and yearly maximum concentrations at each receptor site. Output for the area grid were XYZ ascii files. Additionally, maximum and yearly averages were calculated for the fenceline (200 M) and for the nearest residential dwellings to the north, south, east and west of the plant. Dwellings were located using Map Expert.

## Release Scenarios and Emission Rate

When area or fugitive sources of the same chemical are from a collection of minor sources, with small emissions, the EPA recommends modeling them as a single point (40 CFR Pt.51 App.W). From the MA, an estimate of the pounds per year of chemical entering the atmosphere was known and from this quantity emission rates were estimated (gr/m$^3$/sec).

### Mineral Spirits

Three parts cleaners filled with mineral spirits are located in various areas of the plant. Emissions from these three cleaners were grouped together. The cleaners are kept closed other then when parts are loaded and unloaded. In reality, the mineral spirits would come to equilibrium with atmosphere in the cleaners and escape when the cleaners are opened. Mineral spirits clinging to parts would also evaporate when removed from the cleaner. The ISCST2EM is a steady state model and can not account for this intermittent release. Therefore, it was assumed that evaporation was constant over time for each of the cleaners. The area of the cleaners was added and the yearly quantity released to the environment (in grams) was divided by the area (M$^3$) and the number of seconds in a year. The release height was assumed to be one meter and the release length, the total length of the cleaners combined.

## Methyl Ethyl Ketone

Methyl ethyl ketone is used to clean the stenciler tips. Again, MEK is not released at a steady rate, but due to model limitations, that assumption was made. The release area for the two stencilers was assumed to be a combined area of one square meter and the release height was one meter. The emission rate was the quantity that evaporates each year (gr) divided by the area ($M^3$) and the number of seconds in a year.

## Rust Preventative

The preservative actually is more of a steady state release. After parts are coated with the preservative, they are bundled and stored to await shipping. Mineral oil has a low volatility, but does contain some volatile short carbon chains (Grosselin et al, 1984). These assumptions were made: after the parts are coated and bundled, rust preventative on the inner parts will probably not evaporate, so that evaporation is calculated only for the outer surface. It was assumed that the circular bundles were 1 meter in diameter, 9.144 meters long and that 26 bundles were produced each day.

## Model Output

Annual average and annual maximum concentration at each receptor site were modeled. Receptor sites included the fenceline (200 meters), the nearest neighbors to the north, south, east and west, and an area grid. A limitation to ISCST model is that only evenly spaced area grids of 31 by 31 receptor points (961 total) could be created. To overcome this, two grids of 21 by 21 were used, with the source as the center point for both. The first grid modeled concentrations closer to the industry at every 100 meters for the first 1,000 meters and the second grid modeled every 1,000 meters out to 10,000 meters. This 20,000 meter by 20,000 meter area with the source as the center point is defined as the study area. Output from the area grid was in an XYZ file, although the data could also be in output as tables. Other possible model output options were chemical concentration values in evenly spaced concentric rings radiating from the industry and the 50 highest maximum or annual values at each site.

### Plotting Concentration Data

Concentration data from XYZ files generated by ISCST2EM were plotted using GRASS4.0. The longitude and latitude of the source location was found using Map Expert and converted to UTM's (Universal Transverse Mercator). Grid points in each XYZ file were converted from meter distances to UTM's. Grid co-ordinates were sorted by Y's (Northings) decreasing and X's (Eastings) increasing. A header was created containing the number of rows and columns in the area grids and the UTM's at the north, south, east and west boundaries. Because GRASS4.0 does not recognize numbers less than one, environmental concentrations in each data file were multiplied by 10, 100, 10,000 or 100,000. The X and Y columns were then deleted, the file saved in an ASCII format and imported into GRASS4.0. Examples of these files can also be found in Appendix E. In GRASS4.0, the ASCII files were converted to rastor files for combination with census data.

A Geographic Information System (GIS) was used to tie populations together with various exposure levels for each of the chemicals. Census tracts that fell within the study area were digitized and re-numbered (Diagram 3.3a), then the square study area (Diagram 3.3b) extracted from this map. Again, the study area is the 20,000 by 20,000 meter area concentration grid created by the ISCST2EM model. Two ASCII files were created in EXCEL3.0 for each census tract, one containing total population data and another with only adult population (ages 14-44). These files were imported into GRASS4.0, where the average number of people and adults per square meter in a census tract were assigned to that specific census block. To determine the potentially exposed population, MASKs were created using concentration rastor files. These rastor files masked out all areas less than a set exposure level. Population data were overlain those areas left after the MASK was applied and the number of people experiencing a concentration above the set exposure level in each census tract tabulated.

An example of how a MASK works is found in Figure 3.4. Figure 3.4a displays that part of the study area receiving rust preventative concentrations greater than or equal to 1 ug/m$^3$. In the next Figure (3.4b) the area of exposure increases as the MASK reveals the portion of the study area experiencing concentrations of greater than or equal to .1 ug/m$^3$. The area increases once again in Figure 3.4c when the MASK reveals greater than or equal to .01 ug/m$^3$ exposure areas. GRASS4.0 combines the revealed portions of each census tract with the population living there to provide not only exposure concentrations but the number of people living there, as well. Another computer program that displays concentration data is Surfer. An example output from Surfer, using average yearly Mineral Spirits data, is seen in Figure 4.5. Surfer can not combine this output with census data.

## Toxicity Assessment

Reference Concentrations (RfC's) were not available for the rust preventative or mineral spirits, so Ambient Concentration Level's (ACL) were used to estimate the RfC's for all three chemicals (Radan, 1990). The ACL for mineral oil was applied to the rust preventative. The ACL, similar to the RfC, is determined by dividing the NOAEL by a safety factor. This is considered to be an exposure level protective of the most sensitive portion of a population. To estimate the RfC's, the ACL was multiplied by the average breathing rate of 20 $m^3$/day and divided by the average weight of 70 kg (See calculations in Appendix G). The use of the rust preventative to calculate cancer incidence is illustrative only, so no CSF exists. It was assumed value of .51. This value is probably much higher than the actual value.

Exposure scenarios are limited to inhalation for the maximum exposed individual, the nearest neighbor and the highest potentially exposed individual

## Risk Characterization

The Hazard Quotients (HQ) and Cancer Incidence (CI) were calculated using the Risk Assessment Guidance for Superfund document (EPA, 1989). Example calculations can be found in Table 3.3. The Maximum Exposed Individual (MEI) was calculated using the highest maximum fenceline value and standard assumptions: that a person weighs 70 kg and will breath this same concentration at a constant rate for 70 years, 24 hours a day, everyday of the year. The Reasonably Exposed Individual (REI) was calculated using both the annual average and maximum value for each of the closest north, south, east and west neighbor and assuming that a person would live here for 30 years and breath this concentration for four hours a day everyday of the year. Additionally, the HQ for person most likely to be exposed to the chemicals of concern outside the industries boundaries was calculated (HEI). The highest concentrations occur immediately surrounding the study site, where other industries are located. To calculate the HEI it was assumed that a person working at one of these industries in the area would be exposed 8 hours a day, 5 days a week for 50 weeks of the year over a 25 year period.

According to their MSDS's, none of these chemicals are identified as carcinogens, however, since part of this project was to look comprehensively at all risks, certain assumptions were made. Several sources describe components of mineral oil as having the potential to cause cancer (Lewis, 1991a), so cancer risk was determined for the mineral oil based rust preventative. Cancer incidence was determined at the fenceline and for the nearest neighbor. Population exposure as used here refers to the number of individuals exposed at a particular chemical concentration as determined through the GIS.

## Uncertainties

Uncertainties were handled with a qualitative discussion of the uncertainties associated with each chemical as it moved through the risk assessment process. Additionally, those portions of the risk assessment that produced quantitative numbers, the MAA, emission factors, model output, reference concentrations and the final risk assessment output for each chemical, were compared qualitatively to each other.

## Table 3.1. Processes and Wastestreams

A) **Cleaning and Coating Process**

1) Caustic Dip Tank
    - Caustic Sludge
    - Spent Caustic Solution:
    - Dragout to Rinse Tank
2) Sulfuric Acid or Pickling Tank
    - Spent Pickle Liquor
    - Dragout to Rinse Tank
3) Zinc Phosphate Coating Tank
    - Zinc Phosphate Coating
    - Phosphate Sludge
    - Dragout to Rinse Tank
4) Neutralizer Tank
    - Internal Water Treatment Facility
5) Lubrication Tank
    - Lubricant Sludge
    - Carryover

B) **Hydraulic Compressors (Hydraulic Oil)**
- Off site energy recovery
- Spills sorbed to kitty liter and taken in drums to a Solid Waste Landfill
- Oily water from empty drums taken to a non-hazardous deep well injection site

C) **Main Process**
- Lubricant that comes off the metal parts and taken to a Solid Waste Landfill

D) **Weldmill**
- Cutting Oil carried over on metal parts and burned off in furnaces
- Cutting Oil processed off site for energy use
- Tramp oil is composed of oils from the sheet metal and iron oxides
- Coolant recycled and reused on site
- Scrap Metal

E) **Metal Cutters**
- Scrap Metal

F) **Parts Stenciling**
- Air emissions due to evaporation
- Sludge composed of inks and solvent produced from cleaning the stenciling machines

G) **Corrosion Preventative Application**
- Carryover on the final product
- Evaporation of volatile organics off the metal parts

H) **Parts Cleaning**
- Air emissions from evaporation
- Off site recycling

I) **Internal Water Treatment Facility**
- Effluent to Publicly Owned Treatment Works
- Sludge to Solid Waste Landfill

## Table 3.2 IRIS Data Collection Sheet

**Citation:** ____________________________________________
____________________________________________________
____________________________________________________

**Library number:** ________________________________________

**Chemical Name:** ______________________ **CAS No#:** __________

**Yearly Production:** ____________________ **Appearance:** _________

**Physical and Chemical Properties:**

**Flammability:** Flash Point: ________ Boiling Point: ______

**Reactivity (Stable/Unstable with):**

Water (S or U) Temp (S or U) Pressure (S or U) Confine (S or U)
Explosive (Y or N) Combustible Dust or Solid (Y or N)
Explain: ____________________________________________

**Environmental:** Bioaccumulates: Y or N BAF or BCF: __________

Env. Effects: ________________________________________

**Human Health Hazard:**
*Acute Toxicity:*
Acute oral $LD_{50}$: __________________________
Acute dermal $LD_{50}$: __________________________
Acute inhalation $LC_{50}$: __________________________
Skin irritation Draize : __________________________
Eye irritation Draize : __________________________
Skin sensitivity: __________________________

*Subchronic Toxicity:*
NOEL oral: ________ NOEL dermal: _______ NOEL inhalation: ________

**Carcinogenicity*: Y or N (Positive) Positive Mut test: Y or N
One Test: Y or N Two Tests: Y or N (List tests on back)

**Mutagenicity:* Positive Y or N Test(s) Dscrpt: ____________________

**Teratogenicity:* Positive Y or N Test(s) Dscrpt: ____________________

**Repro Effects:* Positive Y or N Test(s) Dscrpt: ____________________
*Information needed on the no# of positive test results in different species and within the same species

**Health Effects:** ____________________________________________
____________________________________________________
____________________________________________________
____________________________________________________
____________________________________________________

## Table 3.3. Example Risk Calculations

### Calculations to Determine Hazard Index for the MEI

| *Chemical* | *Location* | *Average or Maximum* | CA *Concent. in Air ug/m3* | IR *Inhalation Rate m3/hour* | ET *Exposure Time hours/day* | EF *Exposure Frequency days/year* | ED *Exposure Duration years* | BW *Body Weight kg* | AT *Averaging Time Days* | *Intake mg/kg-d* | *Hazard Index* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mineral Spirits** | Fenceline | Maximum | 46.067 | 0.83 | 24 | 365 | 70 | 70 | 25550 | 1.31E-02 | 1.31E-02 |

$$\frac{CA \times IR \times ET \times EF \times ED}{BW \times AT} = \text{Intake (mg/kg-d)}$$

$$\frac{\text{Intake (mg/kg-d)}}{\text{RfC (mg/kg-d)}} = \text{Hazard Index}$$

*note: RfC for Mineral Spirits is 1 for short term exposure*

### Calculations to Determine Cancer Incidence for Rust Preventative

| *Chemical* | CA *Conc. in Air ug/m3* | IR *Inhalation Rate m3/day* | ET *Exposure Frequency days/year* | EF *Exposure Duration years* | ED *Body Weight kg* | BW *Averaging Time Days* | AT *Intake mg/kg-d* | CSF *Cancer Slope Factor** | *Cancer Incidence* |
|---|---|---|---|---|---|---|---|---|---|
| Rust Preventative | 0.1 | 20 | 365 | 70 | 70 | 25550 | 2.86E-08 | 0.51 | 1.46E-08 |

$$\frac{CA \times IR \times ET \times EF \times ED}{BW \times AT} = \text{Intake (mg/kg-d)}$$

**Intake (mg/kg-d) x CSF = CI**

* *CSF is a hypothetical value*

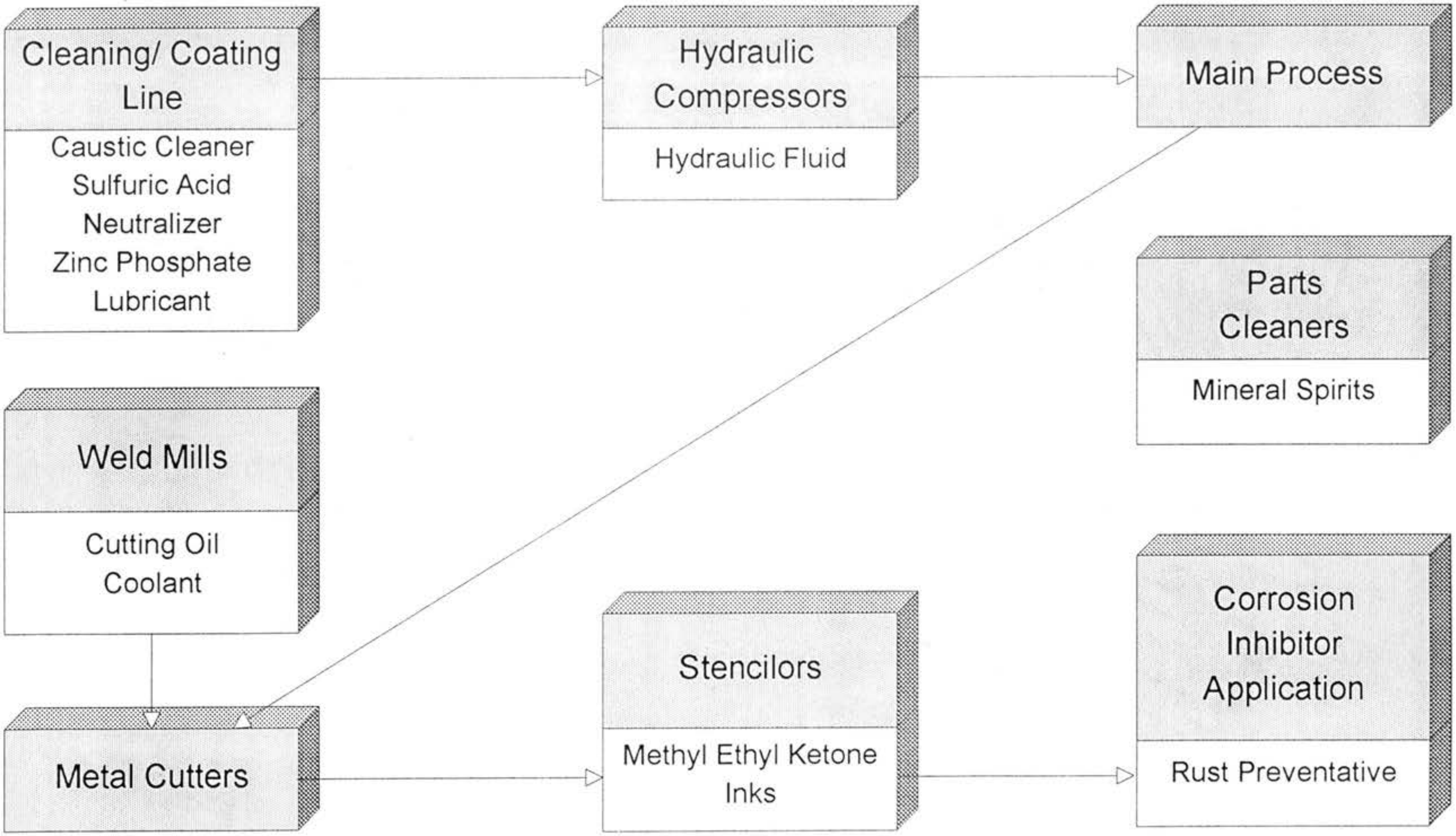

**Figure 3.1. Manufacturing and Chemical Flow Diagram**

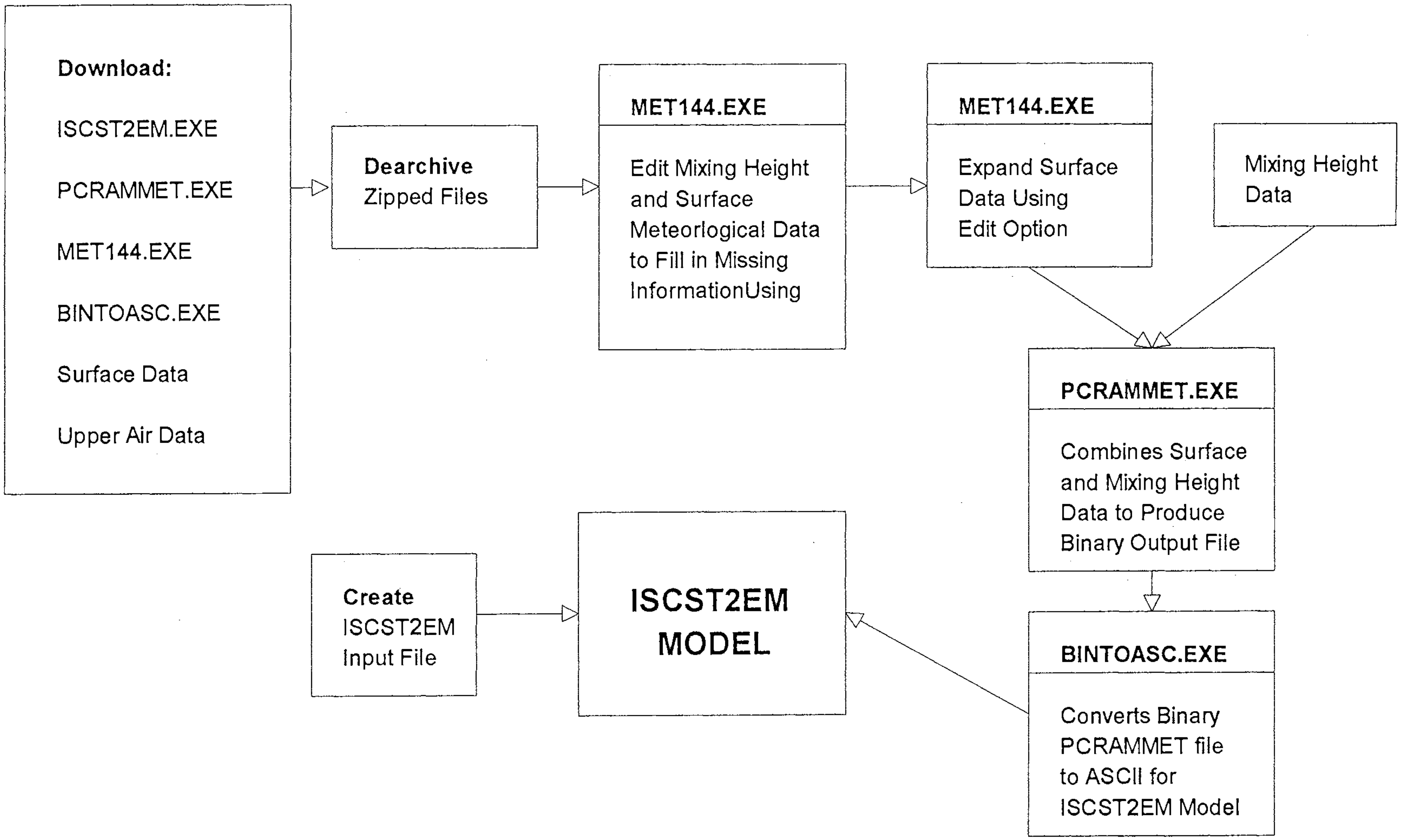

Figure 3.2. Input Flow Diagram for ISCST2EM Model

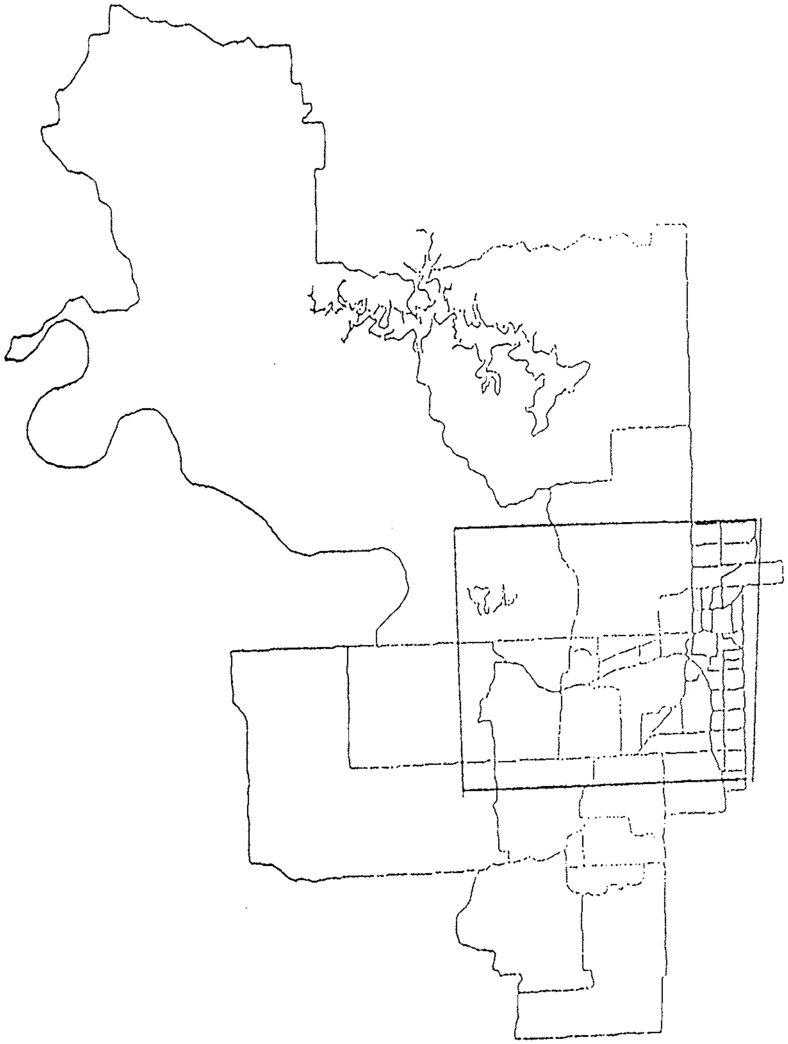

Figure 3.3a. Affected Census Tracts

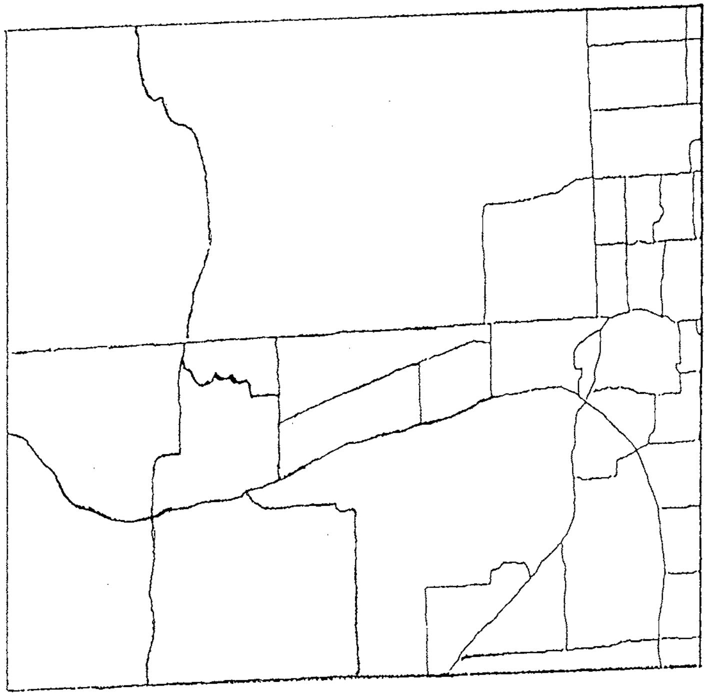

Figure 3.3b. Extracted Study Site Area

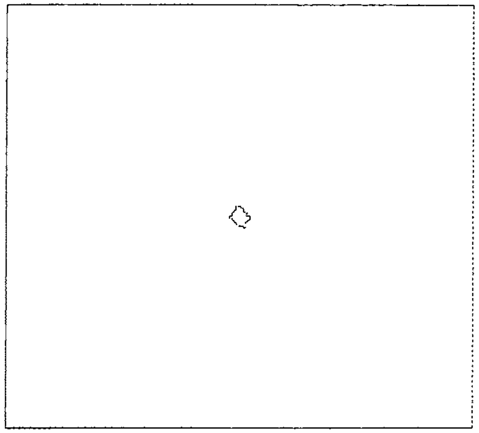

Figure 3.4a. Concentrations >1 ug/m3

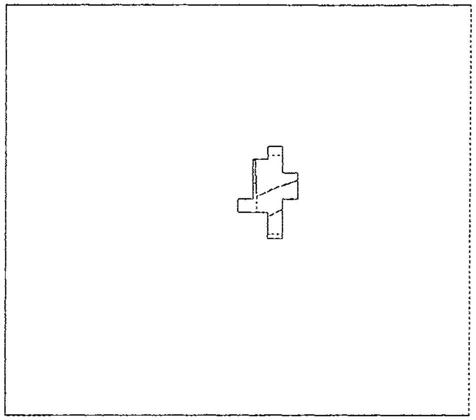

Figure 3.4b. Concentrations >.1 ug/m3

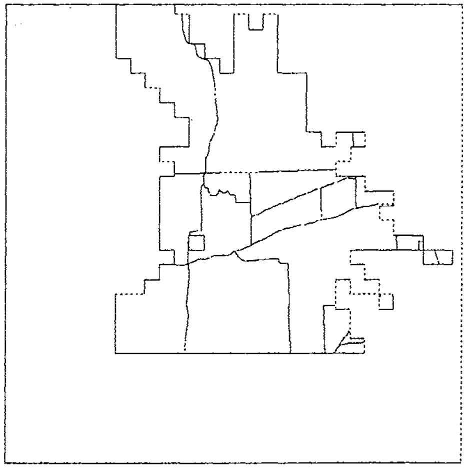

Figure 3.4c. Concentrations >.01 ug/m3

Figure 3.4. GRASS Generated Rust Preventative Concentration Maps

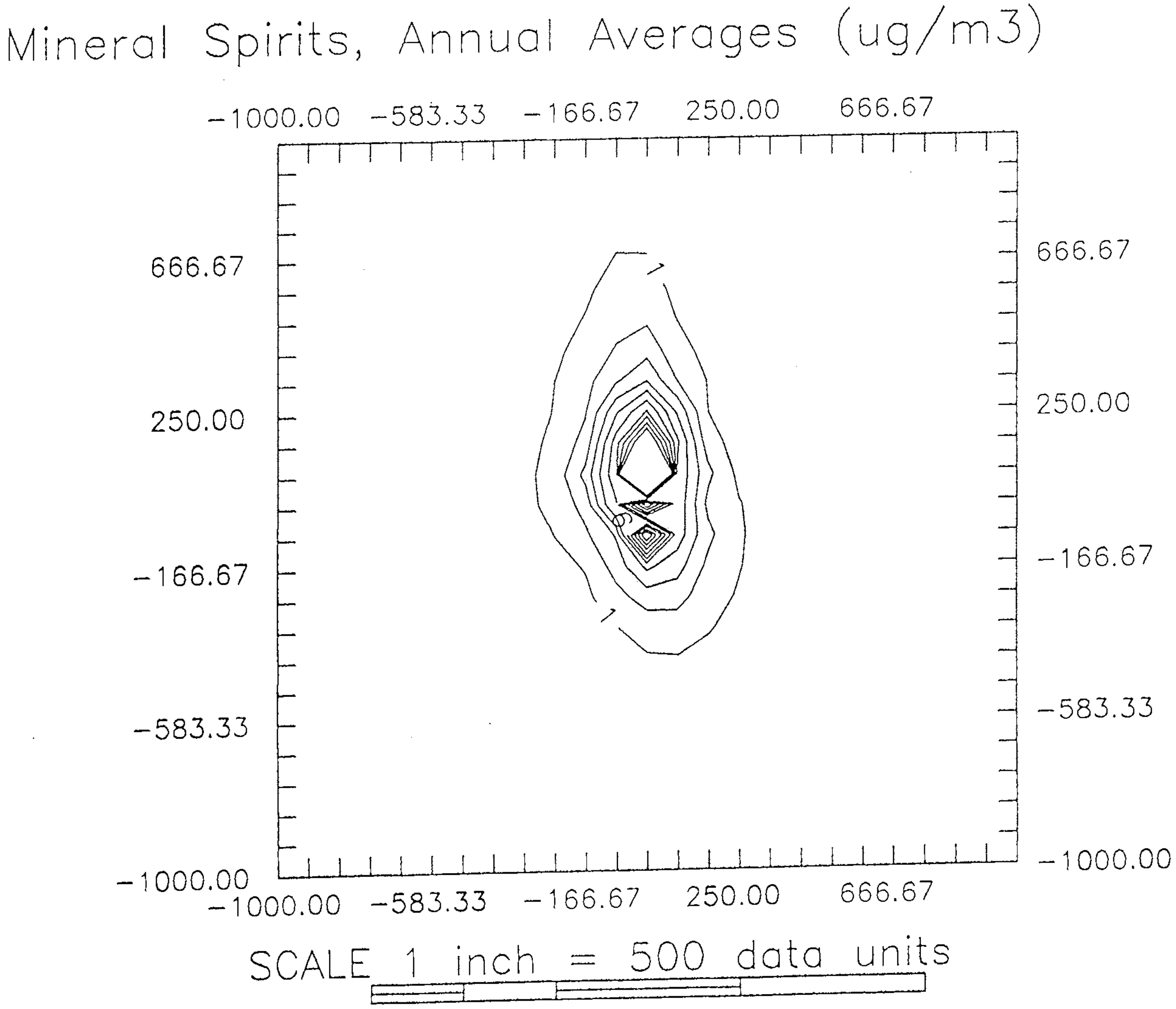

Figure 3.5. Surfer Generated Concentration Contour Map

# CHAPTER IV

# RESULTS

The MAA produced three lists: chemical and raw material inputs to the manufacturing process (Table 4.1), product output (Table 4.2) and environmental losses (Table 4.3). A database of environmental losses was created that consists of 67 entries. Each entry represents a chemical entering the environment from the firm. The following information is included for each entry: environmental loss (chemical entering the environment), environmental entrance point, wastestream the chemical is contained in, the input chemical from which the loss originated and the pounds per year released via this route.

The results of the IRIS are displayed in Table 4.4. Individual criteria used to calculate IRIS are explained in Appendix A. All index values for input chemicals and their constituents, as well as all environmental losses are included. The outcome from the MAA are combined with, and sorted by, the Risk Index and displayed in Tables 4.5, 4.6, and 4.7. From the prioritized list of environmental losses in Table 4.7, chemicals of concern for inclusion in the final risk assessment were further narrowed down by comparing routes of toxicity to potential routes of exposure. Table 4.8 lists environmental losses by their Risk Index (RI), along with the routes of exposure by which they are toxic to humans. Table 4.9 expresses the likelihood of human exposure to the environmental losses via those routes. Table 4.10 eliminates all but those exposures most likely to occur.

Environmental concentrations of the rust preventative, mineral spirits and methyl ethyl ketone were estimated using the ISCST2EM air quality model. Concentrations were modeled at the fenceline, the nearest neighbor to the north, south, east and west, and over an area of 20,000 by 20,000 meters. Results from several model runs can be found in Appendix F and Appendix G.

The outcome of the air quality modeling was used to estimate risk to human health from the chemicals of concern. Hazard Indexes for non-carcinogenic effects were estimated for the MEI and at the fenceline (Table 4.11), the REI for the nearest neighbor in to the north, south, east and west (Table 4.12) and HEI or the most highly exposed person off-site (Table 4.13). Results for the modeling runs on the Rust Preventative were used to calculate cancer incidence (Table 4.14) and a HI for reproductive effects (Table 4.15).

The final report for each chemical of concern is presented at the end of this chapter.

- Chemical Data Sheet -

**Chemical:** Methyl Ethyl Ketone

**Quantity Emitted:** 128 lbs/year

**Emission Factor:** .00184 gr/m$^2$/sec

*Release Description:* MEK is a primary component of the stenciling inks. It is a steady state release while the stencilers are running. The emission factor is an average value, assuming the stencilers run throughout the year.

**Half Life:** 2.3 Days

*Environmental Fate:* MEK combines with atmospheric hydroxyl radicals to form acetaldehyde.

**Health Effects:** At high doses, MEK has the potential to cause reproductive effects. It is non-irritating, and acute and subchronic effects are not expressed at low concentrations.

**RfC:** .037 mg/kg-d

**Risk Characterization:**

| | | | | |
|---|---|---|---|---|
| MEI: | 7.93E-03 | | | |
| HEI: | 6.77E-05 | | | |
| REI: | 3.58E-05 | North | 1.05E-05 | East |
| | 5.80E-06 | South | 7.30E-06 | West |

- Chemical Data Sheet -

**Chemical:** Mineral Spirits (Aliphatic Hydrocarbons)

**Quantity Emitted:** 3,116 lbs/year

**Emission Factor:** .02307 gr/m$^2$/sec

*Release Description:* Releases occur from the three parts cleaners when cleaners are opened to submerge or remove parts and from evaporation off cleaned parts. This is a yearly average value.

**Half Life:** Unknown

*Environmental Fate:* Combine with hydroxyl radicals and contribute to ozone formation. Hydrocarbons can persist for a long time in the atmosphere.

**Health Effects:** Atmospheric mineral spirits can cause eye and skin irritation. Greatest potential for harm is from secondary ozone formation.

**RfC:** 0.1 mg/kg-d (Annual Average Exposure)

1.0 mg/kg-d (Short Term Exposure)

**Risk Characterization:**

MEI: 1.31E-02

HEI: 4.96E-03

REI:

| Direction | Short Term | Annual Average |
|---|---|---|
| North | 5.78E-05 | 5.78E-04 |
| South | 9.37E-06 | 9.37E-05 |
| East | 1.69E-05 | 1.69E-04 |
| West | 1.18E-05 | 1.18E-04 |

- Chemical Data Sheet -

**Chemical:** Rust Preventative (Barium Soap and Mineral Oil)

**Quantity Emitted:** 866 lbs/year

**Emission Factor:** .00053 gr/m$^2$/sec

*Release Description:* The rust preventative is applied by spraying and dipping. These are enclosed processes with little evaporation. Evaporation can happen while forms are stored and waiting to be shipped. The lighter gaseous carbon molecules can evaporate at this time. Heavier mineral oil aerosols may form during handling. This is a yearly average.

**Half Life:** Unknown

*Environmental Fate:* Combine with hydroxyl radicals and contribute to ozone formation. Hydrocarbons can persist for a long time in the atmosphere.

**Health Effects:** Barium can be acutely hazardous. Mineral Oil may be mutagenic and potentially cause reproductive and teratogenic effects.

**RfC:** .007 mg/kg-d

**Risk Characterization:**

| | | | | |
|---|---|---|---|---|
| MEI: | 2.73E-01 | | | |
| HEI: | 1.25E-02 | | | |
| REI: | 9.02E-04 | North | 3.30E-04 | East |
| | 1.84E-04 | South | 2.32E-04 | West |
| CI: | 1E-06 (3 people) | | 1E-07 (13 people) | |
| | (calculated with hypothetical slope factor) | | | |
| Repro: | 1.02E-02 (1 person) | | | |
| | (Highest calculated HI) | | | |

## Table 4.1. Chemical and Raw Material Input To the Manufacturing Process

| Chemical and Raw Material Inputs And Constituents | Constituent Percent | Constituent Pounds/Yr | Ordered Pounds/Yr |
|---|---|---|---|
| Metal Parts | | | 52,000,000 |
| Sheet Metal | | | 83,200,000 |
| Sulfuric Acid (93%) | | | 367,229 |
| Magnesium Hydroxide | | | 218,236 |
| *Magnesium Hydroxide* | *50* | *118,156* | |
| Zinc Phosphate Replenisher | | | 183,540 |
| *Zinc Dihydrogen Phosphate* | *30-40* | *73,416* | |
| *Nitric Acid* | *1-10* | *18,354* | |
| *Zinc Nitrate* | *1-10* | *18,354* | |
| Preservative | | | 86,578 |
| *Barium Soap* | *1-5* | *4,329* | |
| *Mineral Oil* | *>95* | *82,250* | |
| Sodium Stearate Soap | | | 76,120 |
| Kitty Liter | | | 62,500 |
| Coolant | | | 49,273 |
| *Diethanolamine* | *5-10* | *4,927* | |
| Cutting Oil | | | 39,675 |
| *Naphthenic Mineral Oil* | *Unknown* | | |
| *Paraffinic Petroleum Distillate* | *Unknown* | | |

## Table 4.1. Chemical and Raw Material Input To the Manufacturing Process

| **Chemical or Raw Material** | **Percent Constituent** | **Constituent Pounds/Yr** | **Ordered Pounds/Yr** |
|---|---|---|---|
| Hydraulic Oil | | | 31,805 |
| Mineral Spirits | | | 16,609 |
| *Alphatic Hydrocarbons* | *Unknown* | | |
| Caustic Cleaner | | | 14,450 |
| *Sodium Hydroxide* | *60-70* | *10,115* | |
| *Potassium Hydroxide* | *3-7* | *1,012* | |
| *Resin(Rosin) Acids* | *3-7* | *1,012* | |
| Ferrous Sulfate | | | 10,000 |
| Soda Ash - Anhydrous Sodium Carbonate | | | 7,000 |
| Neutralizer | | | 3,594 |
| *Sodium Nitrite* | *10-30* | *1,078* | |
| *Sodium Borate* | *>60* | *2,156* | |
| Zinc Phosphate Makeup | | | 1,900 |
| *Zinc Dihydrogen Phosphate* | *5-10* | *190* | |
| *Nitric Acid* | *1-3* | *57* | |
| *Zinc Nitrate* | *30-40* | *760* | |
| Methyl Ethyl Ketone | | | 148 |
| Stencil Inks | | | 177 |
| *Methyl Ethyl Ketone* | | *127.66* | |
| *1-Methoxy-2-Propanol* | | *16.05* | |
| *Ethyl Alcohol* | | *7.32* | |
| *Isopropyl Alcohol* | | *5.46* | |

## Table 4.2. Product Output

| Material and Chemical Output | Exit Points | Manufacturing Process | Original Chemical | lbs/yr Exiting |
|---|---|---|---|---|
| Sheet Metal | Product | | | 72,384,000 |
| Metal Forms | Product | | | 44,088,013 |
| Zinc Phosphate Coating | Product Coating | Cleaning/Coating (Zinc Phosphate) | Zinc Phosphate Coating Soln | 75,988 |
| Preservative | Product Coating | Corrosion Inhibitor Application | Preservative | 85,713 |

## Table 4.3. Environmental Losses

| Environmental Loss | Environmental Entrance Points | Wastestream | Manufacturing Process | Original Chemical | Exiting lbs/yr |
|---|---|---|---|---|---|
| Sheet Metal | Scrap | Scrap | | Sheet Metal | 10,816,000 |
| Metal Forms | Scrap | Scrap | | Metal Forms | 7,780,238 |
| Iron II Sulfate | HWIW | Spent Pickle Liquor | Cleaning/Coating (Pickling) | Sulfuric Acid/Metal Forms | 310,050 |
| Sulfate Ion | HWIW | Spent Pickle Liquor | Cleaning/Coating (Pickling) | Sulfuric Acid | 130,783 |
| Magnesium | SWLF | IWTF Sludge | Internal Water Treatment Facility | Magnesium Hydroxide | 62,563 |
| Kitty Liter | SWLF | Sorbant for Hydraulic Oil | Compressors | Kitty Litter | 62,500 |
| Carbon Dioxide | Air | Sodium Stearate Incineration | Cleaning/Coating (Sodium Stearate) | Sodium Stearate | 59,027 |
| Coolant | Recycled on site | None | Weldmills | Coolant | 49,273 |
| Iron (Free) | HWIW | Spent Pickle Liquor | Cleaning/Coating (Pickling) | Metal Forms | 38,011 |
| Cutting Oil | Energy Reuse | Energy Reuse | Weldmills | Cutting Oil | 30,849 |
| Hydraulic Oil | Energy Recovery | Used Hydraulic Oil | Compressors | Hydraulic Oil | 30,040 |
| Sodium Stearate | SWLF | Flakes off metal parts | Cleaning/Coating (Sodium Stearate) | Sodium Stearate | 22,836 |
| Sodium Stearate | SWLF | IWTF Sludge-Dragout (Caustic) | Cleaning/Coating (Sodium Stearate) | Sodium Stearate | 21,694 |
| HSO4- | HWIW | Spent Pickle Liquor | Cleaning/Coating (Pickling) | Sulfuric Acid | 18,953 |
| Sulfate | POTW | IWTF-Dragout (Pickling) | Cleaning/Coating (Pickling) | Sulfuric Acid | 14,006 |
| Mineral Spirits | Recycled off site | Parts Cleaning | Parts Cleaners | Mineral Spirits | 13,493 |
| Tramp Oil | SWLF | Tramp Oil | Weldmills | Sheet Metal | 11,249 |
| Iron II Sulfate | SWLF | Spent Caustic Solution | Neutralization of Spent Caustic Soln | Sulfuric Acid/Metal Forms | 10,000 |
| Iron III Phosphate | SWLF | Zinc Phosphate Sludge | Cleaning/Coating (Zinc Phosphate) | ZnH2PO4/ Metal Forms | 8,597 |
| Nitrate | SWLF | Zinc Phosphate Sludge | Cleaning/Coating (Zinc Phosphate) | Zinc Nitrate/Nitric Acid | 7,689 |
| Sodium Stearate | SWLF | Sodium Stearate Sludge | Cleaning/Coating (Sodium Stearate) | Sodium Stearate | 7,612 |
| Magnesium | POTW | IWTF Effluent | Internal Water Treatment Facility | Magnesium Hydroxide | 6,951 |
| Iron Oxides | SWLF | Tramp Oil | Weldmills | Sheet Metal | 6,842 |
| Carbon Dioxide | Air | Carryover burned off in furnace | Weldmills | Cutting Oil | 6,557 |
| Na/K/Rosin Acid Salts | SWLF | Spent Caustic Solution | Cleaning/Coating (Caustic Cleaner) | NaOH/KOH/Rosin Acids | 6,462 |
| Iron (Free) | SWLF | IWTF Sludge-Dragout (Pickling) | Cleaning/Coating (Pickling) | Metal Forms | 5,900 |
| Carbonic Acid | SWLF | Zinc Phosphate Sludge | Cleaning/Coating (Zinc Phosphate) | Sodium Carbonate | 4,092 |

## Table 4.3. Environmental Losses

| Environmental Loss | Environmental Entrance Points | Wastestream | Manufacturing Process | Original Chemical | Exiting lbs/yr |
|---|---|---|---|---|---|
| Sheet Metal | Scrap | Scrap | | Sheet Metal | 10,816,000 |
| Metal Forms | Scrap | Scrap | | Metal Forms | 7,780,238 |
| Iron II Sulfate | HWIW | Spent Pickle Liquor | Cleaning/Coating (Pickling) | Sulfuric Acid/Metal Forms | 310,050 |
| Sulfate Ion | HWIW | Spent Pickle Liquor | Cleaning/Coating (Pickling) | Sulfuric Acid | 130,783 |
| Magnesium | SWLF | IWTF Sludge | Internal Water Treatment Facility | Magnesium Hydroxide | 62,563 |
| Kitty Liter | SWLF | Sorbant for Hydraulic Oil | Compressors | Kitty Litter | 62,500 |
| Carbon Dioxide | Air | Sodium Stearate Incineration | Cleaning/Coating (Sodium Stearate) | Sodium Stearate | 59,027 |
| Coolant | Recycled on site | None | Weldmills | Coolant | 49,273 |
| Iron (Free) | HWIW | Spent Pickle Liquor | Cleaning/Coating (Pickling) | Metal Forms | 38,011 |
| Cutting Oil | Energy Reuse | Energy Reuse | Weldmills | Cutting Oil | 30,849 |
| Hydraulic Oil | Energy Recovery | Used Hydraulic Oil | Compressors | Hydraulic Oil | 30,040 |
| Sodium Stearate | SWLF | Flakes off metal parts | Cleaning/Coating (Sodium Stearate) | Sodium Stearate | 22,836 |
| Sodium Stearate | SWLF | IWTF Sludge-Dragout (Caustic) | Cleaning/Coating (Sodium Stearate) | Sodium Stearate | 21,694 |
| $HSO_4^-$ | HWIW | Spent Pickle Liquor | Cleaning/Coating (Pickling) | Sulfuric Acid | 18,953 |
| Sulfate | POTW | IWTF-Dragout (Pickling) | Cleaning/Coating (Pickling) | Sulfuric Acid | 14,006 |
| Mineral Spirits | Recycled off site | Parts Cleaning | Parts Cleaners | Mineral Spirits | 13,493 |
| Tramp Oil | SWLF | Tramp Oil | Weldmills | Sheet Metal | 11,249 |
| Iron II Sulfate | SWLF | Spent Caustic Solution | Neutralization of Spent Caustic Soln | Sulfuric Acid/Metal Forms | 10,000 |
| Iron III Phosphate | SWLF | Zinc Phosphate Sludge | Cleaning/Coating (Zinc Phosphate) | $ZnH_2PO_4$/ Metal Forms | 8,597 |
| Nitrate | SWLF | Zinc Phosphate Sludge | Cleaning/Coating (Zinc Phosphate) | Zinc Nitrate/Nitric Acid | 7,689 |
| Sodium Stearate | SWLF | Sodium Stearate Sludge | Cleaning/Coating (Sodium Stearate) | Sodium Stearate | 7,612 |
| Magnesium | POTW | IWTF Effluent | Internal Water Treatment Facility | Magnesium Hydroxide | 6,951 |
| Iron Oxides | SWLF | Tramp Oil | Weldmills | Sheet Metal | 6,842 |
| Carbon Dioxide | Air | Carryover burned off in furnace | Weldmills | Cutting Oil | 6,557 |
| Na/K/Rosin Acid Salts | SWLF | Spent Caustic Solution | Cleaning/Coating (Caustic Cleaner) | NaOH/KOH/Rosin Acids | 6,462 |
| Iron (Free) | SWLF | IWTF Sludge-Dragout (Pickling) | Cleaning/Coating (Pickling) | Metal Forms | 5,900 |
| Carbonic Acid | SWLF | Zinc Phosphate Sludge | Cleaning/Coating (Zinc Phosphate) | Sodium Carbonate | 4,092 |

## Table 4.3. Environmental Losses

| Environmental Loss | Exit Points | Wastestream | Process | Original Chemical | lbs/yr |
|---|---|---|---|---|---|
| Mineral Spirits | Air Emissions | Evaporation | Parts Cleaners | Mineral Spirits | 3,116 |
| Sodium Ion | SWLF | Zinc Phosphate Sludge | Cleaning/Coating (Zinc Phosphate) | Sodium Carbonate | 3,037 |
| Hydrogen Ion | HWIW | Spent Pickle Liquor | Cleaning/Coating (Pickling) | Sulfuric Acid | 2,929 |
| Borate Ions | SWLF | IWTF-Neutralizer Tank | Cleaning/Coating (Neutralizer) | Sodium Borate (Borax) | 1,941 |
| Zinc | SWLF | Sodium Stearate Sludge | Cleaning/Coating (Dragout ZnPO4) | Zinc Phosphate Coating Soln | 1,513 |
| Cutting Oil | SWLF | Tramp Oil | Weldmills | Cutting Oil | 1,406 |
| Sodium Stearate | POTW | IWTF-Carryover to Caustic | Cleaning/Coating (Sodium Stearate) | Sodium Stearate | 1,142 |
| Zinc | SWLF | Zinc Phosphate Sludge | Cleaning/Coating (Zinc Phosphate) | Zinc Phosphate Coating Soln | 1,003 |
| Sodium Ion | POTW | IWTF-Neutralizer Tank | Cleaning/Coating (Neutralizer) | Sodium Borate/Sodium Nitrite | 934 |
| Hydraulic Oil | NHWIW | Empty Drums | Compressors | Hydraulic Oil | 922 |
| Nitrate | POTW | IWTF-Dragout (Zinc Phosphate) | Cleaning/Coating (Zinc Phosphate) | Zinc Nitrate/Nitric Acid | 919 |
| Preservative | Air Emissions | Evaporation | Corrosion Inhibitor Application | Preservative | 866 |
| Hydraulic Oil | SWLF | Sorbed to Kitty Litter | Compressors | Hydraulic Oil | 843 |
| Sulfate Ion | SWLF | Spent Caustic Solution | Neutralization of Spent Caustic Soln | Sulfuric Acid | 435 |
| Nitrate | POTW | IWTF-Neutralizer Tank | Cleaning/Coating (Neutralizer) | Sodium Nitrite | 329 |
| Nitric Oxide NO | Air | Neutralizer Tank | Cleaning/Coating (Neutralizer) | Sodium Nitrite | 318 |
| Surfactants | POTW | IWTF-Dragout (Caustic) | Cleaning/Coating (Caustic Cleaner) | Sodium&Potassium Hydroxide | 303 |
| Hydrogen Gas | Air | Sulfuric Acid Pickling Tank | Cleaning/Coating (Pickling) | Sulfuric Acid | 253 |
| Sodium Ion | SWLF | Spent Caustic Solution | Cleaning/Coating (Caustic Cleaner) | Sodium Hydroxide | 221 |
| Methyl Ethyl Ketone | Recycled off site | Stenciling Process | Stencilors | Methyl Ethyl Ketone | 148 |
| Methyl Ethyl Ketone | Air Emissions | Evaporation | Stencilors | Stenciling Inks and Makeup | 128 |
| Zinc | POTW | Zinc Phosphate Sludge | Cleaning/Coating (Zinc Phosphate) | Zinc Phosphate Coating Soln | 25 |
| Potassium Ion | SWLF | Spent Caustic Solution | Cleaning/Coating (Caustic Cleaner) | Potassium Hydroxide | 19 |
| 1-Methoxy-2-Propanol | Air Emissions | Evaporation | Stencilors | Stenciling Inks and Makeup | 16 |
| Sodium Ion | POTW | IWTF-Dragout (Caustic) | Cleaning/Coating (Caustic Cleaner) | Sodium Hydroxide | 12 |
| Ethyl Alcohol | Air Emissions | Evaporation | Stencilors | Stenciling Inks and Makeup | 7 |
| Isopropyl Alcohol | Air Emissions | Evaporation | Stencilors | Stenciling Inks and Makeup | 5 |
| Potassium Ion | POTW | IWTF-Dragout (Caustic) | Cleaning/Coating (Caustic Cleaner) | Potassium Hydroxide | 1 |

## Table 4.4. All Chemicals Sorted by Risk Index

| | | | **P** | | | **PH** | | | **EH** | | | | | | | **HH** | **Risk** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Chemical** | N(ap) | N(pe) | **Index** | N(f) | N(x) | **Index** | N(b) | N(e) | **Index** | N(a) | N(s) | N(c) | N(m) | N(t) | N(r) | **Index** | **Index** |
| Zn Phosphate Coating | 3.00 | 3.00 | **6.00** | 0.00 | 1.00 | **3.50** | 3.00 | 6.00 | **7.00** | 7.00 | 7.00 | 1.00 | 2.00 | 3.00 | 3.00 | **6.29** | ***159.54*** |
| Mineral Oil (Preserv) | 2.00 | 3.00 | **5.00** | 1.00 | 3.00 | **7.25** | 2.00 | 3.00 | **4.25** | 1.00 | 1.00 | 5.00 | 2.00 | 5.00 | 2.00 | **5.18** | ***145.59*** |
| Preservative | 2.00 | 3.00 | **5.00** | 1.00 | 3.00 | **7.25** | 2.00 | 4.00 | **4.25** | 7.00 | 3.00 | 1.00 | 2.00 | 2.00 | 3.00 | **4.94** | ***143.12*** |
| Sulfuric Acid (93%) | 3.00 | 2.00 | **5.00** | 0.00 | 2.00 | **6.00** | 0.00 | 6.00 | **5.25** | 7.00 | 2.00 | 2.00 | 0.00 | 3.00 | 1.00 | **4.44** | ***130.68*** |
| Zinc Dihydrogen Phos. | 2.00 | 3.00 | **5.00** | 0.00 | 1.00 | **3.50** | 3.00 | 6.00 | **7.00** | 5.00 | 7.00 | 1.00 | 2.00 | 1.00 | 2.00 | **4.69** | ***116.90*** |
| Zinc Nitrate | 2.00 | 3.00 | **5.00** | 0.00 | 1.00 | **3.50** | 3.00 | 6.00 | **7.00** | 5.00 | 7.00 | 1.00 | 2.00 | 1.00 | 2.00 | **4.69** | ***116.90*** |
| Cutting oil | 2.00 | 2.00 | **4.00** | 1.00 | 3.00 | **7.25** | 2.00 | 3.00 | **4.25** | 3.00 | 2.00 | 5.00 | 3.00 | 2.00 | 2.00 | **4.94** | ***114.50*** |
| Nitrosamines | 2.00 | 3.00 | **5.00** | 0.00 | 1.00 | **3.50** | 0.00 | 4.00 | **2.50** | 3.00 | 3.00 | 6.00 | 4.00 | 3.00 | 3.00 | **6.42** | ***111.68*** |
| Mineral Spirits | 2.00 | 2.00 | **4.00** | 1.00 | 4.00 | **10.00** | 1.00 | 3.00 | **3.50** | 3.00 | 2.00 | 0.00 | 0.00 | 1.00 | 1.00 | **1.97** | ***109.80*** |
| Naphthenic Min. Oil | 2.00 | 2.00 | **4.00** | 1.00 | 3.00 | **7.25** | 3.00 | 3.00 | **6.50** | 2.00 | 0.00 | 5.00 | 1.00 | 1.00 | 1.00 | **3.21** | ***109.67*** |
| Paraffinic Petr. Distillate | 2.00 | 2.00 | **4.00** | 1.00 | 3.00 | **7.25** | 2.00 | 2.00 | **4.00** | 2.00 | 6.00 | 3.00 | 3.00 | 1.00 | 1.00 | **4.20** | ***107.57*** |
| Zn Phosphate Makeup | 1.00 | 3.00 | **4.00** | 0.00 | 1.00 | **3.50** | 3.00 | 6.00 | **7.00** | 7.00 | 7.00 | 1.00 | 2.00 | 3.00 | 3.00 | **6.29** | ***106.36*** |
| Caustic Cleaner | 2.00 | 2.00 | **4.00** | 0.00 | 2.00 | **6.00** | 1.00 | 6.00 | **5.50** | 7.00 | 4.00 | 1.00 | 2.00 | 1.00 | 2.00 | **4.44** | ***105.55*** |
| Tramp Oil | 2.00 | 2.00 | **4.00** | 1.00 | 3.00 | **7.25** | 2.00 | 3.00 | **4.25** | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | **3.46** | ***102.65*** |
| Hydraulic Oil | 2.00 | 2.00 | **4.00** | 1.00 | 3.00 | **7.25** | 2.00 | 3.00 | **4.25** | 1.00 | 1.00 | 2.00 | 2.00 | 2.00 | 2.00 | **2.96** | ***98.70*** |
| Sodium Hydroxide | 2.00 | 2.00 | **4.00** | 0.00 | 2.00 | **6.00** | 1.00 | 3.00 | **3.50** | 7.00 | 4.00 | 1.00 | 2.00 | 1.00 | 2.00 | **4.44** | ***97.55*** |
| Iron (II) Sulfate | 3.00 | 2.00 | **5.00** | 0.00 | 0.00 | **1.00** | 1.00 | 6.00 | **5.50** | 7.00 | 2.00 | 3.00 | 2.00 | 3.00 | 3.00 | **5.80** | ***95.51*** |
| Hydrogen Ion | 2.00 | 2.00 | **4.00** | 0.00 | 2.00 | **6.00** | 0.00 | 3.00 | **2.50** | 7.00 | 2.00 | 2.00 | 1.00 | 3.00 | 1.00 | **4.57** | ***94.53*** |
| Zinc | 2.00 | 3.00 | **5.00** | 0.00 | 0.00 | **1.00** | 3.00 | 6.00 | **7.00** | 5.00 | 7.00 | 1.00 | 2.00 | 1.00 | 2.00 | **4.69** | ***91.90*** |
| Nitric Acid | 2.00 | 2.00 | **4.00** | 1.00 | 2.00 | **3.50** | 0.00 | 6.00 | **5.25** | 7.00 | 5.00 | 0.00 | 0.00 | 3.00 | 3.00 | **5.18** | ***90.47*** |
| Sodium Nitrite | 1.00 | 2.00 | **3.00** | 1.00 | 2.00 | **6.00** | 0.00 | 6.00 | **5.25** | 5.00 | 4.00 | 3.00 | 4.00 | 3.00 | 3.00 | **6.05** | ***88.04*** |
| Sodium Carbonate | 2.00 | 2.00 | **4.00** | 0.00 | 2.00 | **6.00** | 1.00 | 3.00 | **3.50** | 5.00 | 2.00 | 0.00 | 0.00 | 1.00 | 3.00 | **3.21** | ***87.67*** |
| Isopropyl Alcohol | 1.00 | 2.00 | **3.00** | 3.00 | 4.00 | **10.00** | 0.00 | 2.00 | **1.00** | 1.00 | 1.00 | 2.00 | 3.00 | 3.00 | 2.00 | **3.46** | ***83.74*** |
| Neutralizer | 1.00 | 2.00 | **3.00** | 3.00 | 1.00 | **4.00** | 3.00 | 6.00 | **7.00** | 5.00 | 4.00 | 3.00 | 4.00 | 3.00 | 4.00 | **6.42** | ***83.51*** |
| Iron | 3.00 | 2.00 | **5.00** | 0.00 | 0.00 | **1.00** | 2.00 | 3.00 | **4.25** | 2.00 | 7.00 | 3.00 | 2.00 | 2.00 | 2.00 | **5.06** | ***81.86*** |
| 1-Methoxy-2-Propanol | 1.00 | 2.00 | **3.00** | 3.00 | 4.00 | **10.00** | 1.00 | 1.00 | **2.25** | 3.00 | 2.00 | 0.00 | 0.00 | 1.00 | 1.00 | **1.97** | ***78.60*** |
| Nitrate | 2.00 | 3.00 | **5.00** | 1.00 | 1.00 | **3.50** | 0.00 | 4.00 | **2.50** | 3.00 | 3.00 | 2.00 | 1.00 | 1.00 | 1.00 | **3.09** | ***78.36*** |

## Table 4.4. All Chemicals Sorted by Risk Index

| | | | **P** | | | **PH** | | | **EH** | | | | | | | **HH** | **Risk** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Chemical** | N(ap) | N(pe) | **Index** | N(f) | N(x) | **Index** | N(b) | N(e) | **Index** | N(a) | N(s) | N(c) | N(m) | N(t) | N(r) | **Index** | **Index** |
| | | | | | | | | | | | | | | | | | |
| Methyl Ethyl Ketone | 1.00 | 2.00 | **3.00** | 3.00 | 4.00 | **10.00** | 0.00 | 2.00 | **1.00** | 3.00 | 1.00 | 0.00 | 0.00 | 3.00 | 1.00 | **2.47** | *77.81* |
| Potassium Hydroxide | 1.00 | 2.00 | **3.00** | 0.00 | 2.00 | **6.00** | 0.00 | 6.00 | **5.25** | 5.00 | 4.00 | 1.00 | 2.00 | 1.00 | 2.00 | **3.95** | *75.45* |
| Phosphate | 2.00 | 3.00 | **5.00** | 0.00 | 1.00 | **3.50** | 0.00 | 4.00 | **2.50** | 3.00 | 3.00 | 0.00 | 0.00 | 1.00 | 1.00 | **2.22** | *69.72* |
| Barium Soap of Ox. Hydr | 1.00 | 3.00 | **4.00** | 1.00 | 0.00 | **1.00** | 1.00 | 4.00 | **3.50** | 7.00 | 3.00 | 0.00 | 1.00 | 3.00 | 3.00 | **4.81** | *60.51* |
| Iron Oxide | 1.00 | 2.00 | **3.00** | 0.00 | 0.00 | **1.00** | 2.00 | 3.00 | **4.25** | 3.00 | 7.00 | 3.00 | 2.00 | 2.00 | 2.00 | **5.31** | *50.59* |
| Iron III Phophate | 1.00 | 2.00 | **3.00** | 0.00 | 0.00 | **1.00** | 2.00 | 3.00 | **4.25** | 3.00 | 7.00 | 3.00 | 2.00 | 2.00 | 2.00 | **5.31** | *50.59* |
| Ethyl Alcohol | 1.00 | 1.00 | **2.00** | 3.00 | 4.00 | **10.00** | 0.00 | 2.00 | **1.00** | 1.00 | 2.00 | 1.00 | 0.00 | 1.00 | 1.00 | **1.85** | *49.41* |
| Sodium Metaborate | 1.00 | 2.00 | **3.00** | 0.00 | 0.00 | **1.00** | 3.00 | 3.00 | **6.50** | 3.00 | 3.00 | 1.00 | 2.00 | 1.00 | 4.00 | **3.95** | *49.20* |
| Iron II Hydroxide | 1.00 | 2.00 | **3.00** | 0.00 | 0.00 | **1.00** | 2.00 | 3.00 | **4.25** | 2.00 | 7.00 | 3.00 | 2.00 | 2.00 | 2.00 | **5.06** | *49.11* |
| Sodium Borate | 1.00 | 2.00 | **3.00** | 0.00 | 0.00 | **1.00** | 3.00 | 3.00 | **6.50** | 3.00 | 3.00 | 1.00 | 0.00 | 1.00 | 4.00 | **3.70** | *47.72* |
| Borate Ion | 1.00 | 2.00 | **3.00** | 0.00 | 0.00 | **1.00** | 3.00 | 3.00 | **6.50** | 3.00 | 3.00 | 1.00 | 0.00 | 1.00 | 4.00 | **3.70** | *47.72* |
| Carbon Dioxide | 2.00 | 2.00 | **4.00** | 0.00 | 0.00 | **1.00** | 1.00 | 4.00 | **3.50** | 1.00 | 0.00 | 0.00 | 0.00 | 3.00 | 3.00 | **2.47** | *41.75* |
| Resin (Rosin) Acids | 1.00 | 2.00 | **3.00** | 1.00 | 0.00 | **1.00** | 1.00 | 6.00 | **5.50** | 5.00 | 2.00 | 0.00 | 0.00 | 1.00 | 1.00 | **2.47** | *37.31* |
| Coolant | 2.00 | 1.00 | **3.00** | 0.00 | 0.00 | **1.00** | 3.00 | 3.00 | **6.50** | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 | 3.00 | **1.60** | *35.13* |
| Magnesium Sulfate | 2.00 | 2.00 | **4.00** | 0.00 | 0.00 | **1.00** | 1.00 | 1.00 | **2.25** | 1.00 | 1.00 | 0.00 | 2.00 | 3.00 | 1.00 | **2.22** | *34.77* |
| Sodium Stearate Soap | 2.00 | 2.00 | **4.00** | 1.00 | 0.00 | **1.00** | 1.00 | 4.00 | **3.50** | 1.00 | 1.00 | 0.00 | 1.00 | 1.00 | 1.00 | **1.36** | *32.86* |
| Na/K/Rosin Acid Soaps | 2.00 | 2.00 | **4.00** | 1.00 | 0.00 | **1.00** | 1.00 | 4.00 | **3.50** | 1.00 | 1.00 | 0.00 | 1.00 | 1.00 | 1.00 | **1.36** | *32.86* |
| Diethanolamine (Cool.) | 1.00 | 1.00 | **2.00** | 1.00 | 0.00 | **1.00** | 3.00 | 3.00 | **6.50** | 3.00 | 1.00 | 2.00 | 0.00 | 1.00 | 3.00 | **3.21** | *29.84* |
| Magnesium Hydroxide | 2.00 | 2.00 | **4.00** | 0.00 | 0.00 | **1.00** | 1.00 | 1.00 | **2.25** | 2.00 | 1.00 | 0.00 | 0.00 | 1.00 | 1.00 | **1.48** | *28.85* |
| Hydrogen Gas | 1.00 | 2.00 | **3.00** | 1.00 | 1.00 | **3.50** | 0.00 | 0.00 | **1.00** | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 | **0.74** | *28.44* |
| Potassium Ion | 1.00 | 2.00 | **3.00** | 0.00 | 0.00 | **1.00** | 0.00 | 4.00 | **2.50** | 3.00 | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 | **1.48** | *22.39* |
| Nitric Oxide (NO) | 1.00 | 2.00 | **3.00** | 0.00 | 0.00 | **1.00** | 0.00 | 1.00 | **1.00** | 3.00 | 2.00 | 0.00 | 2.00 | 1.00 | 1.00 | **2.22** | *22.33* |
| Sulfate Ion | 1.00 | 2.00 | **3.00** | 0.00 | 0.00 | **1.00** | 0.00 | 1.00 | **1.00** | 3.00 | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 | **1.48** | *17.89* |
| Sodium Ion | 1.00 | 2.00 | **3.00** | 0.00 | 0.00 | **1.00** | 0.00 | 2.00 | **1.00** | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 | **0.74** | *13.44* |
| Carbonic Acid | 1.00 | 2.00 | **3.00** | 0.00 | 0.00 | **1.00** | 0.00 | 0.00 | **1.00** | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 | **0.74** | *13.44* |

## Table 4.5. Chemical and Raw Material Inputs Sorted by Risk Index

| Chemical and Raw Material Inputs and Constituents | Constituent Pounds/Yr | Constituent IRIS Index | Input Pounds/Yr | Input IRIS Index |
|---|---|---|---|---|
| Zinc Phosphate Coating | | | 183,540 | 159.54 |
| *Zinc Dihydrogen Phosphate* | *73,416* | *116.90* | | |
| *Nitric Acid* | *18,354* | *90.47* | | |
| *Zinc Nitrate* | *18,354* | *116.90* | | |
| Preservative | | | 86,578 | 143.12 |
| *Barium Soap* | *4,329* | *60.51* | | |
| *Mineral Oil* | *82,250* | *145.59* | | |
| Sulfuric Acid (93%) | | | 367,229 | 130.68 |
| Cutting Oil | | | 39,675 | 114.50 |
| *Naphthenic Mineral Oil* | *Unknown* | *109.67* | | |
| *Paraffinic Petroleum Distillate* | *Unknown* | *107.57* | | |
| Mineral Spirits | | | 16,609 | 109.80 |
| Zinc Phosphate Makeup | | | 1,900 | 106.36 |
| *Zinc Dihydrogen Phosphate* | *190* | *116.90* | | |
| *Nitric Acid* | *57* | *90.47* | | |
| *Zinc Nitrate* | *760* | *116.90* | | |
| Caustic Cleaner | | | 14,450 | 105.55 |
| *Sodium Hydroxide* | *10,115* | *97.55* | | |
| *Potassium Hydroxide* | *1,012* | *75.45* | | |
| *Resin (Rosin) Acids* | *1,012* | *37.31* | | |
| Hydraulic Oil | | | 31,805 | 98.70 |

## Table 4.5. Chemical and Raw Material Inputs Sorted by Risk Index

| Input Chemical or Raw Material | Constituent Pounds/Yr | Constituent IRIS Index | Input Pounds/Yr | Input IRIS Index |
|---|---|---|---|---|
| Ferrous Sulfate | | | 10,000 | 95.51 |
| Soda Ash (Anhydrous Na Carbonate) | | | 7,000 | 87.67 |
| Isopropyl Alcohol | | | 5 | 83.74 |
| Neutralizer | | | 3,594 | 83.51 |
| *Sodium Nitrite* | *1,078* | *88.04* | | |
| *Sodium Borate* | *2,156* | *47.72* | | |
| 1-Methoxy-2-Propanol | | | 16 | 78.60 |
| Methyl Ethyl Ketone | | | 276 | 77.81 |
| Ethyl Alcohol | | | 7 | 49.41 |
| Coolant | | | 49,273 | 35.13 |
| *Diethanolamine* | *4,927* | *29.84* | | |
| Sodium Stearate Soap | | | 76,120 | 32.86 |
| Magnesium Hydroxide | | | 218,236 | 28.85 |
| *Magnesium Hydroxide* | *118,156* | *28.85* | | |
| Metal Parts | | | 52,000,000 | |
| Sheet Metal | | | 83,200,000 | |
| Kitty Liter | | | 62,500 | |

## Table 4.6. Product Output Sorted by Risk Index

| Material and Chemical Output | Exit Points | Manufacturing Process | Original Chemical | lbs/yr Exiting | Risk Index |
|---|---|---|---|---|---|
| Preservative | Product Coating | Corrosion Inhibitor Application | Preservative | 85,713 | 143.12 |
| Zinc Phosphate Coating | Product Coating | Cleaning/Coating (Zinc Phosphate) | Zinc Phosphate Coating Soln | 75,988 | 91.90 |
| Sheet Metal | Product | | | 72,384,000 | |
| Metal Forms | Product | | | 44,088,013 | |

## Table 4.7. Environmental Losses Sorted by Risk Index

| Environmental Loss | Environmental Entrance Points | lbs/yr | Risk Index |
|---|---|---|---|
| Preservative | Air Emissions | 866 | 143.12 |
| HSO4- | HWIW | 18,953 | 130.68 |
| Cutting Oil | Energy Reuse | 30,849 | 114.50 |
| Cutting Oil | SWLF | 1,406 | 114.50 |
| Mineral Spirits | Recycled off site | 13,493 | 109.80 |
| Mineral Spirits | Air Emissions | 3,116 | 109.80 |
| Tramp Oil | SWLF | 11,249 | 102.65 |
| Hydraulic Oil | Energy Recovery | 30,040 | 98.70 |
| Hydraulic Oil | SWLF | 843 | 98.70 |
| Hydraulic Oil | NHWIW | 922 | 98.70 |
| Iron II Sulfate | HWIW | 310,050 | 95.51 |
| Iron II Sulfate | SWLF | 10,000 | 95.51 |
| Hydrogen Ion | HWIW | 2,929 | 94.53 |
| Zinc | SWLF | 2,516 | 91.90 |
| Zinc | POTW | 25 | 91.90 |
| Isopropyl Alcohol | Air Emissions | 5 | 83.74 |
| Iron (Free) | HWIW | 38,011 | 81.86 |
| Iron II | SWLF | 5,900 | 81.86 |
| 1-Methoxy-2-Propanol | Air Emissions | 16 | 78.60 |
| Nitrate | SWLF | 7,689 | 78.36 |
| Nitrate | POTW | 1,248 | 78.36 |
| Methyl Ethyl Ketone | Recycled off site | 148 | 77.81 |
| Methyl Ethyl Ketone | Air Emissions | 128 | 77.81 |
| Iron III Phosphate | SWLF | 8,597 | 50.59 |
| Iron Oxides | SWLF | 6,842 | 50.59 |
| Ethyl Alcohol | Air Emissions | 7 | 49.41 |
| Borate Ions | SWLF | 1,941 | 47.72 |
| Carbon Dioxide | Air | 65,584 | 41.75 |
| Coolant | Recycled on site | 49,273 | 35.13 |
| Sodium Stearate | SWLF | 52,142 | 32.86 |
| Na/K/Rosin Acid Salts | SWLF | 6,462 | 32.86 |
| Sodium Stearate | POTW | 1,142 | 32.86 |
| Surfactants | POTW | 303 | 32.86 |
| Magnesium | SWLF | 62,563 | 28.85 |
| Magnesium | POTW | 6,951 | 28.85 |
| Hydrogen Gas | Air | 253 | 28.44 |
| Potassium Ion | SWLF | 19 | 22.39 |
| Potassium Ion | POTW | 1 | 22.39 |
| Nitric Oxide NO | Air | 318 | 22.33 |
| Sulfate Ion | HWIW | 130,783 | 17.89 |
| Sulfate Ion | POTW | 14,006 | 17.89 |
| Sulfate Ion | SWLF | 435 | 17.89 |
| Carbonic Acid | SWLF | 4,092 | 13.44 |
| Sodium Ion | SWLF | 3,258 | 13.44 |
| Sodium Ion | POTW | 946 | 13.44 |

SWLF: Solid Waste Landfill
HWIW: Hazardous Waste Injection Well
NHWIW: Non-hazardous Waste Injection Well
POTW: Publicly Owned Treatment Works

## Table 4.8. Routes of Toxicity

| Environmental Loss | IRIS Index | Ingestion | Dermal | Inhalation | Intravenous | Intraperitoneal | Irritant | Subcutaneous | Based On |
|---|---|---|---|---|---|---|---|---|---|
| Preservative | 143.12 | Carcinogenic | Carcinogenic | Teratogenic | | | Eye | | MO/Barium |
| HSO4- | 130.68 | Moderately | Unspecified | Experimental | Unspecified | Unspecified | Corrosive | | Sulfuric Acid |
| Cutting Oil | 114.50 | | Yes | | | | | | Cutting Oil |
| Mineral Spirits | 109.80 | Mild | | Mild | | Mild | | | Mineral Spirits |
| Tramp Oil | 102.65 | Carcinogenic | Carcinogenic | Teratogenic | | | Eye | Poison | MO/Iron |
| Hydraulic Oil | 98.70 | Carcinogenic | Carcinogenic | Teratogenic | | | Eye | | Mineral Oil |
| Iron II Sulfate | 95.51 | Poison | Unspecified | Unspecified | Unspecified | Unspecified | Unspecified | Unspecified | Iron II Sulfate |
| Hydrogen Ion | 94.53 | Moderately | Unspecified | Experimental | Unspecified | Unspecified | Corrosive | | Sulfuric Acid |
| Zinc | 91.90 | Yes | | Yes | | | | | Zinc |
| Isopropyl Alcohol | 83.74 | Poison | Mild | | Moderately | Moderately | | Poison | Isopropyl Alcohol |
| Iron (Free) | 81.86 | Yes | | | | | | Yes | Iron |
| 1-Methoxy-2-Propanol | 78.60 | Mild | Mild | | | | Skin | | 1-Methoxy-2-Prop. |
| Nitrate | 78.36 | Yes | | | | | | | Nitrate |
| Methyl Ethyl Ketone | 77.81 | Moderately | Moderately | | | Moderately | Strong | | MEK |
| Iron III Phosphate | 50.59 | Yes | | | | | | Yes | Iron |
| Iron Oxides | 50.59 | | | | | | | Poison | Iron Oxides |
| Ethyl Alcohol | 49.41 | Carcinogenic | Mild | Mild | Moderately | Moderately | | | Ethyl Alcohol |
| Borate Ions | 47.72 | Poison | Moderately | | | | | Moderately | Boron Compounds |
| Carbon Dioxide | 41.75 | | | Asphyxiant | | | | | Carbon Dioxide |
| Coolant | 35.13 | | Yes | | | | | | Diethanolamine |
| Sodium Stearate | 32.86 | | | | Poison | | Unspecified | | Sodium Stearate |
| Magnesium | 28.85 | Poison | | Moderately | | | | | Mg Hydroxide |
| Hydrogen Gas | 28.44 | | | Innocuous | | | | | Hydrogen Gas |
| Potassium Ion | 22.39 | | Injection | | | | | | K Hydroxide |
| Nitric Oxide | 22.33 | | | Poison | | | | | Nitric Oxide |
| Sulfate Ion | 17.89 | | | | | | | | Non-toxic |
| Carbonic Acid | 13.44 | | | | | | | | Unknown |
| Sodium Ion | 13.44 | | | | | | | | Non-toxic |

## Table 4.9. Liklihood of Exposure Via Specified Routes

| Environmental Loss | IRIS Index | Ingestion | Dermal | Inhalation | Intravenous | Intraperitoneal | Irritant | Subcutaneous |
|---|---|---|---|---|---|---|---|---|
| Preservative | 143.12 | Medium | High | High | | | High | |
| HSO4- | 130.68 | Medium | Medium | Medium | Low | Low | Medium | |
| Cutting Oil | 114.50 | | Low | | | | | |
| Mineral Spirits | 109.80 | Medium | | High | | Low | | |
| Tramp Oil | 102.65 | Low | Low | Low | | | Low | Low |
| Hydraulic Oil | 98.70 | Low | Medium | Medium | | | | |
| Iron II Sulfate | 95.51 | Low | Low | Low | Low | Low | Low | Low |
| Hydrogen Ion | 94.53 | Medium | Medium | Medium | Low | Low | Medium | |
| Zinc | 91.90 | Low | | | | | | |
| Isopropyl Alcohol | 83.74 | Medium | Medium | | Low | Low | | Low |
| Iron (Free) | 81.86 | Medium | | | | | | Low |
| 1-Methoxy-2-Propanol | 78.60 | Low | High | | | | High | |
| Nitrate | 78.36 | Medium | | | | | | |
| Methyl Ethyl Ketone | 77.81 | Medium | High | | Low | Low | | |
| Iron III Phosphate | 50.59 | Low | | | | | | Low |
| Iron Oxides | 50.59 | Low | | | | | | Low |
| Ethyl Alcohol | 49.41 | Low | High | High | | Low | | |
| Borate Ions | 47.72 | Medium | Medium | | | | | Low |
| Carbon Dioxide | 41.75 | | | Low | | | | |
| Coolant | 35.13 | | Low | | | | | |
| Sodium Stearate | 32.86 | | | | Low | | Medium | |
| Magnesium | 28.85 | Low | | Low | | | | |
| Hydrogen Gas | 28.44 | | | Low | | | | |
| Potassium Ion | 22.39 | | Low | | | | | |
| Nitric Oxide | 22.33 | | | High | | | | |
| Sulfate Ion | 17.89 | | | | | | | |
| Carbonic Acid | 13.44 | | | | | | | |
| Sodium Ion | 13.44 | | | | | | | |

## Table 4.10. High Exposure Potentials Combined With Routes of Toxicity

| Environmental Loss | IRIS Index | Ingestion | Dermal | Inhalation | Intravenous | Intraperitoneal | Irritant | Subcutaneous |
|---|---|---|---|---|---|---|---|---|
| Preservative | 143.12 | | High | High | | | High | |
| HSO4- | 130.68 | | | | | | | |
| Cutting Oil | 114.50 | | | | | | | |
| Mineral Spirits | 109.80 | | | High | | | | |
| Tramp Oil | 102.65 | | | | | | | |
| Hydraulic Oil | 98.70 | | | | | | | |
| Iron II Sulfate | 95.51 | | | | | | | |
| Hydrogen Ion | 94.53 | | | | | | | |
| Zinc | 91.90 | | | | | | | |
| Isopropyl Alcohol | 83.74 | | | | | | | |
| Iron (Free) | 81.86 | | | | | | | |
| 1-Methoxy-2-Propanol | 78.60 | | High | | | | High | |
| Nitrate | 78.36 | | | | | | | |
| Methyl Ethyl Ketone | 77.81 | | High | | | | | |
| Iron III Phosphate | 50.59 | | | | | | | |
| Iron Oxides | 50.59 | | | | | | | |
| Ethyl Alcohol | 49.41 | | High | High | | | | |
| Borate Ions | 47.72 | | | | | | | |
| Carbon Dioxide | 41.75 | | | | | | | |
| Coolant | 35.13 | | | | | | | |
| Sodium Stearate | 32.86 | | | | | | | |
| Magnesium | 28.85 | | | | | | | |
| Hydrogen Gas | 28.44 | | | | | | | |
| Potassium Ion | 22.39 | | | | | | | |
| Nitric Oxide | 22.33 | | | High | | | | |
| Sulfate Ion | 17.89 | | | | | | | |
| Carbonic Acid | 13.44 | | | | | | | |
| Sodium Ion | 13.44 | | | | | | | |

Table 4.11. Hazard Index for Maximum Exposed Individual

| Chemical | Location | Maximum Hazard Index | Average Hazard Index |
|---|---|---|---|
| **Mineral Spirits** | Fenceline | 1.31E-02 | 2.94E-02 |
| **Rust Preventative** | Fenceline | 2.73E-01 | 5.98E-02 |
| **Methyl Ethyl Ketone** | Fenceline | 2.26E-03 | 5.11E-04 |

Table 4.12. Most Hightly Exposed Individual (HEI)

| Chemical | Maximum Hazard Index |
|---|---|
| **Mineral Spirits** | 4.96E-03 |
| **Rust Preventative** | 1.25E-02 |
| **Methyl Ethyl Ketone** | 6.77E-05 |

Table 4.13. Hazard Index for Reasonably Exposed Individual

| Chemical | Location | Maximum Hazard Index | Average Hazard Index |
|---|---|---|---|
| Mineral Spirits | North | 5.78E-05 | 1.14E-04 |
| | South | 9.37E-06 | 1.96E-06 |
| | East | 1.69E-05 | 9.94E-06 |
| | West | 1.18E-05 | 9.17E-06 |
| Rust Preventative | North | 9.02E-04 | 2.24E-04 |
| | South | 1.84E-04 | 3.85E-06 |
| | East | 3.30E-04 | 1.94E-05 |
| | West | 2.32E-04 | 1.80E-05 |
| Methyl Ethyl Ketone | North | 3.58E-05 | 7.02E-06 |
| | South | 5.80E-06 | 1.21E-07 |
| | East | 1.05E-05 | 6.18E-07 |
| | West | 7.30E-06 | 5.68E-07 |

## Table 4.14. Cancer Incidence from Rust Preventative

| *Yearly Average Conc. in Air ug/m3* | *Cancer Incidence* | *Number of People Exposed at the Average Value* | *Yearly Maximum Conc. in Air ug/m3* | *Cancer Incidence* | *Number of People Exposed at the Maximum Value* |
|---|---|---|---|---|---|
| 250 | 3.64E-05 | 0 | 250 | 3.64E-05 | 3 |
| 100 | 1.46E-05 | 0 | 100 | 1.46E-05 | 0 |
| 10 | 1.46E-06 | 3 | 10 | 1.46E-06 | 17 |
| 1 | 1.46E-07 | 13 | 1 | 1.46E-07 | 177 |
| 0.1 | 1.46E-08 | 171 | 0.1 | 1.46E-08 | 2,907 |
| 0.01 | 1.46E-09 | 198 | 0.01 | 1.46E-09 | 27,087 |
| 0.001 | 1.46E-10 | 9,759 | 0.001 | 1.46E-10 | 82,113 |

## Table 4.15. Reproductive Effects from Rust Preventative

| *Yearly Maximum Conc. in Air ug/m3* | *Hazard Index* | *Maximum Number of Adults* |
|---|---|---|
| 250 | 1.02E-02 | 1 |
| 100 | 4.08E-03 | 0 |
| 10 | 4.08E-04 | 7 |
| 1 | 4.08E-05 | 70 |
| 0.1 | 4.08E-06 | 1,165 |
| 0.01 | 4.08E-07 | 11,724 |
| 0.001 | 4.08E-08 | 36,835 |

# CHAPTER V

# DISCUSSION

## Exposure Assessment

### Materials Accounting

The initial Materials Accounting Analysis MAA step of diagraming the manufacturing process, assigning chemical usage to each process and identifying wastestreams proved to be the easiest step. The analysis was expedited by the fact that at this plant few chemicals were used in more than one process. This eliminated the problem of splitting usage between two areas. Product output was also well quantified and documented. The most difficult aspect of the MAA was quantitatively estimating the composition of each wastestream. As stated previously, little test data was available, so assumptions were made using knowledge of process and stoichiometric relationships. A drawback to the MAA procedure is that when indirect measures are used, the outcome provides only estimated release quantities.

Overcoming this problem would require additional expenditures on laboratory tests. Certain test could be run on-site without further investment in equipment, such as extra pH readings and gravimetric analyses to convert volumes of waste to pounds. At this site, the cost of performing the necessary outside testing is approximately $800, excluding those done on-site. Table 5.1 lists the needed tests. The need for extra testing can be seen as a problem, as the MAA is intended to be completed with information already available in a manufacturer's records and through knowledge of process. However, this is not necessarily the case. Ultimately, it is up to the plant engineer or decision maker to determine how comfortable s/he is with the results of the MAA. The MAA can provide a framework, where the decisionmaker can decide which areas, if any, need more information and how much s/he is willing to spend to overcome uncertainties.

A major problem with the MAA process was time involved. It took approximately 80 hours to complete the first MAA that went through Procedure #2 described in Chapter III. Looking at process reactions increased the time taken by at least another 80 to 100 hours. This was due partly to the research time needed to find appropriate process equations and descriptions. This information may be more available to working professionals, depending on their knowledge of process. Regardless of whether they are used to estimate releases, it is important to include a discussion of these equations in the final MAA because they give an insight into the manufacturing processes. For example, identifying $H_2$ gas emissions from the sulfuric acid dip tank. In the case of the caustic cleaner, though, understanding the physical processes involved did little to overcome a lack of data and only a very rough estimate of the quantity of chemical available to react could be made.

## Integrated Risk Index System (IRIS)

The advantage of using the IRIS system for prioritizing chemicals of concern is that it comprehensively includes exposure potential, physical and environmental effects and a range of toxic endpoints for human health. Exposure potential was based on the number of populations exposed (occupational, public or consumer) and the quantity of chemical released into the environment. Once the MAA was completed, this information was readily available.

Physical hazards posed by these chemicals could be found in reference books, such as the CRC Handbook of Chemistry and Physics (Weast, 1981). However, a problem that surfaced in the physical hazard area concerned chemicals or compounds which did not meet a particular criterion on their own, but were mixed with compounds that did. For example, on its own barium soap is not explosive, but when mixed with the more volatile mineral oil base to form the rust preventative it becomes part of a compound that does meet the explosivity criteria. It therefore exists at the site in a mixture that has explosive characteristics. For consistency, it was decided that individual components of a compound would be ranked on their own characteristics and not on those of the compound.

The Environmental Index (EI) had only two criteria, but it was the most arduous part of IRIS. Owing to nature's diversity, there are no comprehensive manuals, similar to those for humans, listing species and test data for different chemicals. Also, little data was available for terrestrial effects. This made finding environmental effects data for non-human species difficult and time consuming. One reference manual, Weiss's (1986) Hazardous Chemical Data Book, had a brief section on environmental effects, but was mostly confined to the aquatic environment and had a limited number of listed chemicals. In certain instance (i.e. mineral oil) the potential for adverse non-human species effects were based on test data for human effects.

Also, for the effort expended to find accurate data for the EI, the EI is not heavily weighted in the overall Risk Index (RI). The RI calculation weighs human health effects and physical risks twice as heavily as the EI. For example, changing the EI from 7.0 to 5.0 for the top ranked Zinc Phosphate Coating (Table 4.4) does not lower the compounds overall ranking, whereas decreasing any of the other indexes will.

Information could also be a problem for the Human Health Index (HH). Human health effects can be found in several comprehensive references. Early access to these would have expedited completing the health effects section of IRIS. Additionally, for some environmental losses conflicting information existed, as in the case of cutting oil. The MSDS made no mention of the potential for carcinogenicity, yet other sources (Lewis, 1991a) claimed components of cutting oil can be carcinogenic so a compromise score was selected. In other instances, there is was abundance (Iron, Zinc, MEK) of information, while for still others there was no information - the combination of sodium and potassium soaps found in the spent caustic solution or the tramp oil.

To overcome a lack of data, information for closely related chemicals was used. Sodium stearate values were used to rank the sodium/potassium soaps and mineral oil and iron oxides were used to rank tramp oil. Subchronic values were seldom available, so listed systemic effects were used. Mineral oil values were used for certain rust preventative, cutting oil, hydraulic oil and mineral spirits criteria. When data was conflicting, a compromise value was used.

The HH's for chemical compounds are based on risk posed by their individual components. Each component was scored individually on the IRIS scale, then the highest values applied to the compound. For example, mutagenic and reproductive effects for the caustic cleaner were based on hydroxide, which scored higher in these two categories than the other components of the cleaner. Occasionally, a chemical scored high for an endpoint, such as reproductive and teratogenic effects from high doses of ethyl alcohol, but the release quantity from the site was low. The IRIS scale for these endpoints did not include dose levels, so again a compromise lower score was given.

Toxicological experience makes chemical of concern selection easier, but in the absence of that experience IRIS was selected to aid in that decision making process. But are the numbers meaningful? The numbers are qualitative and in this instance the spread between values is not large. The difference in RI between the first and second ranked chemical is 13 and from highest to lowest is 130 points. Although Rosenblum (1987) states that IRIS has been applied successfully in the chemical production industry, Delpire (1995) found, while working on a similar computerized system, that due to the default values the spread between numbers was not great enough to provide a useful ranking system. Additionally, in this project, the chemicals of concern could have selected by comparing routes of toxicity and pathways of exposure.

The IRIS may not be a necessary step for a quantitative risk assessment, but it does have value. It provides an understanding of the impact of chemicals released from a site. Information required for the HH was subsequently used in the toxicology assessment. This portion of the IRIS had value to the final risk assessment. As an example of how this information can be used, Table 5.2 lists the environmental losses by HH. Also, the IRIS in combination with an MAA has great potential for those companies not wanting to perform a full risk assessment, but that want or need to prioritize emissions for reduction. The MAA procedure provides a comprehensive list of chemicals entering the environment, but gives not indication of the risks posed by those emissions. The IRIS can provide that missing step.

An alternative procedure to the IRIS for selecting chemicals of concern to be included in a risk assessment, would be to include only regulated chemicals. None of the chemicals used at this site are appear on the SARA list of Extremely Hazardous Substances. The following are environmental losses that can be found on the RCRA list of regulated wastes and/or the CERCLA list of reportable chemicals:

| **Environmental Loss** | **IRIS Rank** | **lbs/yr Emitted** | **RCRA Waste** | **CERCLA List** |
|---|---|---|---|---|
| HSO- | 2 | 18,953 | K062 | X |
| Mineral Spirits | 4 | 16,609 | D001 | RCRA |
| Hydrogen Ion | 8 | 2,929 | K062 | X |
| Zinc | 9 | 1,758 | | X |
| Isopropyl Alcohol | 10 | 5 | D001 | RCRA |
| 1-Methoxy-2-Propanol | 13 | 16 | D001 | RCRA |
| Methyl Ethyl Ketone | 15 | 276 | F005 | X |
| Ethyl Alcohol | 18 | 7 | D001 | RCRA |
| Nitric Oxide | 29 | 318 | | X |
| Sodium Ion | 32 | 4,225 | | X |

The by-products of sulfuric acid (HSO- and hydrogen ion) and MEK are listed by name as RCRA wastes, while the others are listed due to their flammable characteristic (D001). RCRA wastes are automatically included on the CERCLA list. Chemicals listed by name on the CERCLA list are those with X's in the above list. In general, the environmental losses from this industry included on these lists are those presenting a physical hazard - flammability, corrosivity and reactivity and do not account for health hazards such as carcinogenicity, teratogenicity, etc... Environmental losses, such as the rust preventative that has the potential to cause teratogenic effects and cutting oil with its potential carcinogenicity are not on the above lists. For this reason, selecting chemicals of concern based on their regulated status was not used.

## Environmental Fate and Transport - ISCST2EM Model

Once chemicals of concern were selected, their environmental concentrations were estimated using the ISCST2EM air quality model. To run this model, a 386 computer with extended memory is require, but it runs faster on a 486. The model was downloaded off the SCRAM bulletin board free of charge, but access to the internet or a modem is required. Also, downloading the model was time consuming, the 250,000 byte zipped ISCST2EM file took four hours to download. A larger faster version of the model is available (ISCST2), but due to the size of the program and longer download time the connection was consistently interrupted. A problem with the ISCST2EM model was variations in input file between the ISCST2 model and the extended model that were not reflected in the documentation. Also, the instructions were vague concerning the processing and input of meteorological data. The advantages, however, to using the models on the SCRAM bulletin board, in addition to being EPA approved and free, is that help is only a phone call or an e-mail message away. Technical support personnel are knowledgeable and very helpful.

## Population Exposure - Geographic Information System (GIS)

A Geographic Information Systems (GIS) was useful in combining the number and location of different populations (adult, children, elderly) from the Census Bureau's TIGER database with output from the ISCST2EM model. Census data, including population and census tract maps can be found on CD-ROM's or in hard copy at many libraries, both public and academic. However, neither the hardcopy maps nor the CD-ROM's are in a form easily accessed by the novice user. Originally, this part of the project was to be contracted out. However, due to difficulty in finding an expert who could lay population data over area using the CD-ROM generated maps, the census tracts of interest had to be digitized and the population data input to an EXCEL3.0 file for import into GRASS4.0.

GRASS4.0 can also be difficult to use for the neophyte, so from this point on it was necessary to work with a technical person to extract the needed information. For the environmental manager of a smaller company this type of help may be hard to come by and expensive. There are several alternatives for overcoming this problem. Data in XYZ files generated by the ISCST2EM model can be contoured with a program such as SURFER. This inexpensive, easy to use program runs under Windows or MS-DOS. SURFER provides a spatially correct representation of the data. The problem is combining the SURFER generated chemical concentration contour map with the Census Bureau information. Census Bureau information is by county and there may be several large and unwieldy maps for each county of interest. The case study site study area was located in three counties, each having maps in different scales. By digitizing the maps in GRASS4.0, the program could snap the maps together even though they were drawn to different scales.

It is possible to get the counties of interest put together to a useable scale through a local library. In that case, SURFER can create a contour map to the same scale which can be laid over the census bureau map. The areas of different concentration can be measured or estimated to determine the number of exposed people at each concentration level. It is crude but effective. For a small company, estimating the number of people exposed may not even be necessary. Initially, the MEI and REI might be more important to them. If interested they could look up the maps and number of people per tract and make a qualitative judgement.

### Risk Characterization

A question rose at the beginning of the risk characterization phase, over whether to use the yearly maximum concentrations values to calculate risk or the yearly averages. The yearly average values were lower and perhaps more representative of the day to day exposure of the local population, but they failed to consider those times when populations were exposed at higher levels. The possibility exists that the daily exposure levels are often higher than the average, but several days of extremely low concentrations caused the overall average to be lower. For this reason, although the risk values are presented for both average and maximum concentrations, maximum concentrations are used to characterize risk. For the mineral spirits both short and long term ACL's existed, so the maximum and average intake concentrations had RfC's to be compared to.

Risk was characterized for the MEI using fenceline concentrations, REI using concentrations at the nearest neighbor to the north, south, east and west, and population risk using data from the 20,000 meter by 20,000 meter areal grid. The

MEI was calculated by making standard assumptions about intake and body weight. At the fenceline, none of the chemical's Hazard Index (HI) exceeded the standard of one when divided by the RfC. The rust preventative was closest with a HI of .273 when calculated with the maximum yearly high (Table 4.12). However, considering the ISCST2EM modeled concentrations can be off by ten to forty percent (51 CFR 51) the potential exists for an exceedence. An HI in this range should prompt an environmental manager to review the uncertainties associated with the value and determine if more information is needed. Using the MEI HI to rank chemical emissions, has the advantage of using the worst case scenario at a point where the chemical immediately leaves the industry's property. It is easily modeled and calculated. As an internal policy, it is a quick and dirty means of ranking emissions without looking at exposed populations. But the MEI gives little information about what happens beyond this point. If the MEI exceeds one, the next step would be to look at risk beyond the fenceline.

The next step in this project was to determine the most highly exposed person off-site (HEI). In this case, the highest concentrations were close to the facility boundary, where other industries are located. The HEI is assumed to be a worker at one of these industries who works a 40 hour week for 50 weeks of the year for 25 years. For Table 4.13, it can be seen that the HI is not exceeded for this individual, but if it had been, the next step would be to look at the nearest residential neighbor, which may in some cases be the HEI.

Hazard Indexes for the REI are presented in Table 4.14. None of these values exceeds one. The REI assumes a shorter exposure time, four hours over a thirty year period, but uses standard assumptions about body weight and intake. For this industry, the nearest neighbor was located over 1,000 meters away. The REI represents a more reasonable exposure to those persons living closest to the industry. Once a chemical leaves the property boundaries, it may become more or less toxic depending on environmental interactions. This is the value to determining the REI, to understand the delivered dose and its potential effect on an industry's neighbors. A second ranking is done with the REI as the main criteria.

When REI's are exceeded or the CI is greater than one in a million, the populations at risk can be determined through a GIS by setting a concentration level and having the GRASS4.0 program determine the number of people exposed at that level. This has the value of indicating the potential scale of a problem. Cancer incidence, calculated with a hypothetical slope factor and displayed in Table 4.15, compares the number of people exposed at various incidence levels. This is important, for example, if the cancer standard is 1 in a million but only 20 people are exposed at or above with level. Another example of why including the number of exposed person is important, can be seen in Table 5.3. This table shows a hypothetical number of people exposed at the following concentrations: Mineral Spirits 10 ug/m$^3$, Rust Preventative 25 ug/m$^3$ and MEK 3 ug/m$^3$ and ranked by HI. All three HI's are very close to one, but the lowest HI has the greatest number of people exposed.

The GIS using census data also has the added benefit of identifying the type of population exposed. This project used reproductive effects as an example by looking only at adult populations (ages 14 to 44) exposed to a potential reproductive toxicant (rust preventative). Table 4.15 and Diagram 4.2 are examples of how this data can be displayed. Table 4.15 lists the number of people exposed at each level and Diagram 4.2 gives a spatial display of exposures at various levels. Other populations and information can be extracted from the TIGER files -- children under the age of 5 or between the ages of 5 and 14 or the locations of schools or hospitals.

## Uncertainties

The uncertainties associated with this project stemmed from assumptions made during the following phases: MAA, air modeling, dose-response, risk characterization and population identification. Uncertainties were handled in a descriptive manner. Diagram 5.1 displays qualitatively the level of certainty that was felt to exists between several of the quantitative portions of the risk assessment for each chemical. They were compared against having perfect knowledge for each step of the process.

### Materials Accounting

MEK: It was assumed that all of the MEK emissions came from evaporation of the stenciling inks and that none of the MEK used in clean up evaporated. In reality there would be some evaporation of MEK during cleanup, but the amount used on site is small and probably not worth the time to determine that quantity.

Mineral Spirits: The estimated quantity of mineral spirits released was found by subtracting the quantity recycled from the quantity purchased. As recycling and evaporation are the only two known wastestreams from the parts cleaning process, this is a good estimate. Evaporation may be greater though, because mineral spirits sent to be recycled contain dirt and grease from the cleaning process and it was assumed that all of the recycled material was mineral spirits.

Rust Preventative: The one percent evaporation of applied rust preventative was a guess. This is a difficult problem to overcome, because the mineral oil base is composed of carbon molecules of varying shapes and sizes with varying degrees of volatility, so applying an volatility equations or emission rates is difficult. The rust preventative could be put in a pan of known area and the weight taken before and after being allowed to evaporate over a specific length of time. There are some different forces at work in the lab, then in practice, but it would be in indication of evaporation rate that could be turned into pounds per year loss by multiplying by exposed surface area. This is a more uncertain value.

## IRIS

MEK: MEK is a well studied chemical and most of the values needed were readily available.

Mineral Spirits: Qualitative information concerning acute, subchronic and cancer potential came from the MSDS and Grosselin's. There was also a brief description of mineral spirits' health effects in Lewis (1991b) which gave no mention of teratogenicity or mutagenicity, so these endpoints were scored low. Mutagenicity information was found through a literature search (Conway et al, 1984). The EI was based on mineral oil.

Rust Preventative: Because this is a compound, RI numbers came from its two known components -- barium and mineral oil. Barium is well studied and several sources contained information on mineral oil (Lewis, 1991a and 1991b). There was a conflict over cancer though. The MSDS said that no component of the preservative could cause cancer, but Lewis (1991a) says there is a potential for mineral oil to cause cancer.

## Air Quality Modeling (ISCST2EM)

Modeled concentrations of chemicals at any site may off by ten to 40 percent (51 CFR Pt 51) and dispersion algorithms can account for twenty to thirty percent of the uncertainties associated with risk assessments (Gratt, 1989). EPA recommends longer averaging times to overcome the first problem, so for this project 24 hour averaging times were used over three hour averaging times to estimate daily maximums and annual averages. The great source of uncertainty in this project was the emission rates.

There was also a problem with the meteorological data. Surface data existed for the study site in 1992, but upper air data was not available. Normally, the

SCRAM operators suggest using upper air data from the next downstream station, but a closer station existed upwind. Upper air data was only available for 1991, so to make the files match, surface data from 1991 for the case study site was used and it was assumed that emissions were the same for 1991 and 1992.

MEK: MEK was estimated as a steady state release, but the stencilers do not run constantly or use the same ink each time. The actual MEK release would be larger but for a shorter period of time.

Mineral Spirits: This too was modeled as a steady state release, whereas in reality it would be intermittent throughout the day. For the MEK and mineral spirits, a higher release rate to determine the daily high would be the best estimate.

Rust Preventative: This is actually a steady state release from forms stored for several days, waiting to be shipped. The problem is calculating surface area. This could be overcome by recording for several weeks, quantities in storage and potential exposed surface area.

### Population Exposure - Geographic Information System (GIS)

The same problems are present for all the chemicals. An average number of people per square meter in each census tract was used, but in reality people would be more concentrated in cities or townships. This could be overcome by looking up the number of people in a township, assigning them to that area and subtracting them off of the rest of the tract. Those people not included in townships or cities could be averaged out over the remaining area in the census tract.

### Toxicity Assessment

According to Gratt (1989), dose response relationships may be off by factors ranging from 100 to 1,000. Exploring the uncertainties associated with animal test data and derivation of dose-response curves is beyond the scope of this paper, so it is assumed that published ambient air levels (AAL's) are protective of the most sensitive individuals in a population. The uncertainties associated with this part of the project, are the use of a standard weight and intake value to derive RfC's from AAL's. Also, mineral oil's AAL was used to calculate the RfC for the rust preventative. This AAL more than likely is for a level that prevents a common problem from mineral oil, lipophilic pneumonia, and may not be set low enough to prevent reproductive effects. However, as stated earlier, mineral oil is a combination of carbon atoms, short and long chained, ringed and straight. The smaller lighter carbon atoms are more volatile, but the literature said nothing about which portion of the mineral oil caused the reproductive effects. If it is the less volatile portion, then potential exposure would be lessened.

Also, there was not way to estimate the CSF. If an industry did have suspected carcinogenic emissions, but no CSF existed, how could this be overcome? Available through the SCRAM is the National Air Toxics Clearinghouse (NATICH) which contains raw data and standards used by different states and regulatory institutions. It was too large of a file to be downloaded with the equipment available for this, but it may contain data to estimate better CSF's and RfC's.

## Risk Characterization

Standard assumptions about body weight, resident time and intake rate were used to calculate the MEI, but no one lives that close to the plant. The nearest neighbor is over 1,000 meters away. Some of the same assumptions were used in calculating the REI. Also, it was assumed that 100 percent of the delivered chemical concentration was effective. This is not very likely. Cumulative effects were not considered from exposure in the home, workplace or from ambient concentrations from other sources, to the same chemical or ones with a similar endpoint. Nor were potential synergistic or antagonistic effects considered. This information was not available. Of equal importance to the health effects caused by the chemicals themselves are the secondary effects caused by by-products of atmospheric reactions involving these chemicals. For example, in the atmosphere MEK reacts to form acetaldehyde, a suspected carcinogen and irritant. Hydrocarbons such as the mineral oil in the rust preventative and mineral spirits play a role in ozone formation. Ozone is poison by inhalation and a powerful irritant. Secondary effects were not considered.

Although uncertainties were handled qualitatively, more quantitative means could have been used too. Worst case/best case scenarios for chemical release and exposure could have been developed as an upper and lower bound of uncertainty. The rust preventative would have a greater range, because there was more uncertainty associated with the environmental loss quantity, release rate used for modeling and actual health effects from the compound. Probability distributions could be created for each of the variables (emission rate and human uptake rate) to create a distribution of potential effects.

### Risk Management

The first step is to decide which numbers have meaning and how they will be used. Initially, those that exceed a HI of one or have a CI greater than $10^{-6}$ would be higher than those chemicals whose risk values below the HI and CI standards. Any of the decision aids chosen must begin by answering the question: What is the value of knowledge? With each risk estimate comes an associated set of uncertainties as to how it was derived. Before money is to be spent reducing a risk, there must be some level of comfort in the fact that the greatest risk is actually being reduced.

Table 5.5 looks at the degree of uncertainties associated with various quantitative steps of the risk assessment and how those uncertainties could be reduced. The rust preventative, which had a higher risk ranking than the other two, also had the greatest amount of uncertainty associated with each step. Contributing to the uncertainties was the fact that less specific data was available for this chemical than for the other two. Rust preventative is a mixture of barium soap and mineral oil and the type of mineral oil present is unknown. Ranking areas of uncertainty and listing potential solutions, can assist the environmental manager in choosing the least costly, most beneficial areas of uncertainty to reduce.

In certain instances, this may be easily done. For example, the CI calculated for rust preventative, showed that 20 people were exposed at levels that may increase their lifetime risk of contracting cancer by one in a million. The company must decide the cost of gaining better knowledge. For this site, this step is not too expensive. Because the GIS spread people evenly over the census tract, a windshield tour may reveal that there are no residential dwellings in the high incidence area.

However, uncertainty reduction strategies are not always that obvious. Table 5.3 presents a hypothetical situation where the three chemicals of concern have HI's in the range of .714, 1.31, 7.29. The range of exposed populations is: 912, 506, 424 respectively. The populations are large enough that they can not be attributed to an improper distribution of people within a census tract. The rust preventative obviously has the highest HI (7.29), but also has the greatest degree of uncertainty and least number of potentially exposed people. If the endpoints for these two chemicals are the same and the cost to decrease the uncertainty about the 7.29 value greater than the cost of completely eliminating risk from the 1.31 value. Then protecting the larger population by decreasing the 1.31 may be the best economic policy as it protects a greater number of people. This may, though, raise ethical considerations.

Assuming a comfortable degree of certainty is found, and chemicals can be ranked, as stated earlier, based on those that exceed the standards. For non-cancerous effects, if the MEI HI exceeds one, the HEI and REI would be considered next. If these values are all over one, the chemical can be included on list of chemicals to reduce. The same is true for cancer. If the CI exceeds one in a millions ($10^{-6}$) for a chemical, it too stays on the reduction list. Reduction strategies include compensating at-risk populations, end-of-pipe controls and process modification.

Economic decision aids such as total cost benefit analysis (TCA), decision analysis (DA) and cost effectiveness analysis (CEA), have applications to this process. TCA is the step child of Cost Benefit Analysis, that seeks to increase payback time and focus the more blurred benefits associated with waste minimization. By placing values on the potential health effects associated with chemical releases (HEI's and CI's), a firm can look at long term effects and clearly see some of the potential costs and benefits and place a dollar value on them. DA also fits in well with the risk management scheme, as both are cyclic -- gathering information, determining the outcome, and then the need for more information. Once potential solutions have been enumerated, CEA has applications, however, areas where more information is needed.

## Hypothetical Economic Application

Suppose that all uncertainties associated with the HI's have been explored and the firm is confident in the values obtained. None of the HI numbers exceed one, but two of the chemicals (Mineral Spirits and Rust Preventative) with the same endpoint, reproductive effects, exceed one when their HI's are added, as shown below:

| | HI | Quantity Released |
|---|---|---|
| Rust Preventative | .9 | 866 |
| Mineral Spirits | .5 | 3,116 |
| *Total* | *1.4* | |

The Rust Preventative is emitted in smaller quantities, but has a higher HI than the Mineral Spirits.

The firm explores possible reduction schemes and comes up with the options listed in Table 5.6. For the Mineral Spirits, the existing cleaners can be modified to capture, condense and return the emissions to the cleaner or new cleaners can be purchased. Also two alternate types of cleaners are available, one that would employ detergent and water and reduce emissions to zero, or one that replaced the mineral spirits with a heavier solvent and added a water blanket to reduce emissions. Rust preventative alternatives include, enclosing the shipping area and filtering the air through a recyclable carbon filter, product substitution or shipping the parts faster to reduce the quantity of emissions release during storage. Optionally, the firm can do nothing with either of the chemicals. Table 5.6 also shows two ways of looking at cost of installation for each of these alternatives, total cost of installation and cost per reducing the HI by one tenth.

The firm feels that a margin of safety will be met if the cumulative HI is reduced to .9. To meet this criteria and looking only at total cost of implementation, several combination of solutions exists. Eliminating mineral spirits (Option 4 + 5), enclosing the shipping area (Option 7 + 1), and a combination of modifying the cleaners and shipping parts faster (Option 3 + 6) each cost $50,000 but these would be more expensive than implementing (Option 2 + 6) purchasing new cleaners and shipping parts faster ($45,000). Option 8 of materials substitution is the most expensive. However, if the cost per .1 HI reduced is used as a criteria, (Option 3 + 6) would give the company more risk reduction per dollar spent.

## Risk Analysis as a Management Tool

The value for prioritizing chemical emissions to target for reduction can be seen in Table 5.4, which compares the results when the three chemicals of concern are ranked by four different criteria. When prioritized by quantity emitted into the environment (MAA and environmental concentration), mineral spirits ranks number one. But when ranked by risk (IRIS and MEI) the rust preventative moves to the top. It is interesting to note that the more heavily regulated MEK consistently ranks third. This is due in part to the small quantity released. MEK is regulated because of its abundant use, high volatility and environmental reactions. However, at this site it may not be of primary concern.

**TABLE 5.1. Laboratory Analyses Needed to Improve Accuracy of MAA**

**pH:**
Spent caustic solution
Caustic rinse tank effluent
Caustic sludge
Spent pickle liquor
Cold rinse tank effluent
Hot rinse tank effluent
Zinc Phosphate rinse tank effluent
Zinc Phosphate sludge

**Anionic Surfactants:**
Spent caustic solution
Caustic rinse tank effluent
Caustic sludge
Sodium Stearate in sodium stearate sludge
Sodium Stearate in spent caustic solution

**Borate:**
Neutralizer tank when emptied
IWTF effluent
IWTF sludge

**Iron (Total):**
Spent pickle liquor
Cold water rinse tank effluent
Hot water rinse tank effluent
Tramp Oil

**Phosphate:**
Zinc Phosphate sludge
Zinc Phosphate rinse tank
IWTF effluent
IWTF sludge

**Oil in Water:**
Oil in effluent from IWTF

**Sulfate:**
Spent pickle liquor
Cold water rinse tank effluent
Hot water rinse tank effluent

**Measurements:**
Quantity of caustic sludge
Quantity of recycled cutting oil
Estimation preservative of evaporation
Estimation of cutting oil carry over
on product

**Gravimetric Analysis:**
Density of the spent solution
Density of the caustic sludge
Density of Cutting Oil
Density Gravity of Tramp Oil
Density of Hydraulic Oil
Density of Preservative

**Sodium:**
Spent caustic solution
Caustic rinse tank effluent
Caustic sludge
Neutralizer tank when emptied
IWTF effluent & sludge

**Nitrate:**
Zinc Phosphate sludge
Zinc Phosphate rinse tank
IWTF effluent
Neutralizer tank when emptied

**Iron (Ferrous):**
Spent pickle liquor
Cold water rinse tank effluent
Hot water rinse tank effluent
Tramp Oil

**Potassium:**
Spent caustic solution
Caustic rinse tank effluent
Caustic sludge

**Zinc:**
Zinc Phosphate rinse tank effluent

**Magnesium:**
ITWF effluent
IWTF sludge

**Additional Information:**
MSDS of Hydraulic Oil

## Table 5.2. Environmental Losses Sorted by Health Index

| Environmental Losses | Health Index |
|---|---|
| Iron II Sulfate | 5.80 |
| Iron III Phosphate | 5.31 |
| Iron Oxides | 5.31 |
| Iron (Free) | 5.06 |
| Cutting Oil | 4.94 |
| Preservative | 4.94 |
| Zinc | 4.69 |
| Hydrogen Ion | 4.57 |
| HSO4- | 4.44 |
| Borate Ions | 3.70 |
| Tramp Oil | 3.46 |
| Isopropyl Alcohol | 3.46 |
| Nitrate | 3.09 |
| Hydraulic Oil | 2.96 |
| Carbon Dioxide | 2.47 |
| Methyl Ethyl Ketone | 2.47 |
| Nitric Oxide NO | 2.22 |
| Mineral Spirits | 1.97 |
| 1-Methoxy-2-Propanol | 1.97 |
| Ethyl Alcohol | 1.85 |
| Coolant | 1.60 |
| Sulfate Ion | 1.48 |
| Magnesium | 1.48 |
| Potassium Ion | 1.48 |
| Sodium Stearate/Surfactants | 1.36 |
| Carbonic Acid | 0.74 |
| Sodium Ion | 0.74 |
| Hydrogen Gas | 0.74 |
| Sodium Ion | 0.74 |

## Table 5.3. Comparison of HI's and Number of Exposed Persons

| *Chemical* | *Average or Maximum* | *Concent. in Air mg/m3* | *Intake mg/kg-d* | *Hazard Index* | *Total People* |
|---|---|---|---|---|---|
| Mineral Spirits | Maximum | 35 | 7.14E-01 | 7.14E-01 | 424 |
| Rust Preventative | Maximum | 25 | 5.10E-01 | 7.29E+01 | 912 |
| MEK | Maximum | 6 | 1.22E-01 | 1.31E+00 | 605 |

## Table 5.4. Chemicals of Concern Ranked by Different Criteria

| | **Environmental Losses from MAA (lbs/year)** | **IRIS Risk Index Ranking** | **Maximum Conc. (ug/m3)** | **Maximum Hazard Index** |
|---|---|---|---|---|
| **First** | Mineral Spirits<br>13,493 | Rust Preventative<br>143 | Mineral Spirits<br>46,067 | Rust Preventative<br>2.73E-01 |
| **Second** | Rust Preventative<br>866 | Mineral Spirits<br>110 | Rust Preventative<br>6,718 | Mineral Spirits<br>1.31E-02 |
| **Third** | Methyl Ethyl Ketone<br>128 | Methyl Ethyl Ketone<br>78 | Methyl Ethyl Ketone<br>1,031 | Methyl Ethyl Ketone<br>2.26E-03 |

## Diagram 5.5. Degrees of Uncertainty and Potential Solutions

| Area of Uncertainty | Methyl Ethyl Ketone | Mineral Spirits | Rust Preventative |
|---|---|---|---|
| **Materials Accounting Analysis** | *Low* | *Low* | *High*<br>Volatility Testing and/or Surface Area Measurements of Stored Bundles |
| **Emission Factors (ISCST2EM)** | *Medium*<br>Record times and length of MEK ink usage | *Low* | *High*<br>Same as MAA |
| **Population Estimations** | *Medium*<br>Collect more data from local sources | *Medium*<br>Collect more data from local sources | *Medium*<br>Collect more data from local sources |
| **Toxicology Assessment** | *Low* | *Medium*<br>Search for better data and/or Create Dose Response Curves | *High*<br>Create Dose Respone Curves and/or Determine Portion of Preventative That is Most Hazardous |

## Table 5.6 Comparison of Risk Reduction Alternatives

| | Alternative | Comments | Costs | | HI After Installation | Cost per .1 HI Reduced |
|---|---|---|---|---|---|---|
| **Mineral Spirits** | | | | | | |
| 1 | Do Nothing | Does not solve the problem | Inexpensive | $0 | 0.5 | $0 |
| 2 | Purchase new cleaners that use a heavier solvent and water blanket | Water may increase rust buildup on parts over time | Moderately Expensive | $20,000 | 0.3 | $10,000 |
| 3 | Modify equipment to return emissions back to the cleaner | Increased energy consumption and some extra maintenance | Moderately Expensive | $25,000 | 0.2 | $8,333 |
| 4 | Purchase detergent and water based cleaners | Eliminates Problem | Expensive to purchase and potentially to maintain, increased energy costs | $50,000 | 0.0 | $10,000 |
| **Rust Preventative** | | | | | | |
| 5 | Do Nothing | Does not solve the problem | Inexpensive | $0 | 0.9 | $0 |
| 6 | Ship parts faster | Problems with scheduling workers and potential increase in shipping costs | Nothing to purchase or maintain | $25,000 | 0.6 | $8,333 |
| 7 | Enclose shipping area | Eliminates most of the problem | Expensive startup costs and maintenance of recyclable filters, increased energy costs | $60,000 | 0.4 | $12,000 |
| 8 | Materials Substitution | Eliminates problem | Expensive startup costs | $90,000 | 0.0 | $10,000 |

# CHAPTER VI

# CONCLUSIONS

The objectives of this research project were to: "develop a risk based management tool to identify industrial chemical emissions that pose a potential risk to HHE, rank them based on that risk and determine the most cost effective method to reduce the risk. A sub-objective is to evaluate individual management tools that can be used to expedite a risk analysis in a private industry." This objective was met by quantifying environmental releases through a MAA, selecting chemicals of concern using routes or toxicity and pathways of exposure, estimating environmental concentrations using the ISCST2EM air quality model, characterizing risk to the MEI, HEI and REI from non-carcinogens and CI for carcinogens and tying exposure levels to human populations using a GIS and census tract data. The management tools used in this project were: MAA, IRIS, ISCST2EM, GRASS4.0 (GIS) and the NAS risk analysis paradigm. The NAS risk paradigm provided a framework that the others fit into. Using this paradigm allows the risk manager to focus on the health and environmental outcomes of chemical emissions, which was the original intent of environmental legislation. The MAA played a significant role in identifying environmental emissions and the ISCST2EM, as a recommended EPA model, supplied environmental concentrations. IRIS, although not necessary to complete a successful risk analysis, does provided a comprehensive insight into the risks posed by a chemical. An understanding of what populations are exposed is an important step in the risk analysis, but a GIS using GRASS4.0 as performed in this project may be beyond the budgetary means of most environmental managers. It did, however, perform the defined task of population identification successfully. The project fell short of including all environmental releases (water and soil) because information was scarce in these areas.

Carrying out a project similar to this one would require the following steps:

1) Identify chemical and raw material inputs, product output and wastestreams for each manufacturing process
2) Identify and quantify wastestream constituents or environmental losses
3) Prioritize environmental losses based on physical and toxicological characteristics
4) Select chemicals of concern to be included in the risk assessment from the prioritized list
5) Determine emission rates for selected chemicals and estimate delivered dose to target populations
6) Characterize risk to the MEI, REI and HEI
7) Examine uncertainties
8) Select emissions to be reduced and re-iterate from step 5 based on estimated emission rates after reduction strategy is implemented

There is a need to streamline the process before it can be worked into an industry's environmental program. Further research in this area would include developing a procedure by which risks from chemicals disposed of in a solid waste landfill or treated and sent to a POTW could be included in the risk assessment. A complete listing of where pertinent data can be found and how emission factors can be developed is needed. Two very important areas of research are uncertainties and risk characterization. As discussed in the literature review, there are a number of ways to assess uncertainties. Developing probability distributions through Monte Carlo modeling may be the most accurate, but could be difficult for first time modeler. On the other end of the spectrum are qualitative descriptions. These can be lengthy, making it difficult to assess what they mean to the bottom line risk numbers. Qualitative descriptions are important, though, and need to be included in the final report, but a simpler method to assign a value to the uncertainties needs to be developed.

How to characterize risk is another area of needed research. As stated earlier, secondary effects from by-products of atmospheric reactions with the chemicals of concern were not considered and may have greater health effects. Future research would include deciding how and where to include these in the final risk assessment. Other areas of risk characterization were not included - synergistic and antagonistic effects and cumulative risk. Without knowing what other industries are emitting into the atmosphere, looking at synergistic and antagonistic effects and cumulative risk can be difficult. Some of this information is available through SARA 313 reporting and via state and local environmental agencies that track air quality. Research to determine how an industry can decide their contribution to the overall risk is needed as well.

To implement a risk based environmental program, or any environmental program, requires time and commitment. Before starting a project similar to this it is important to set boundaries on how risk is to be characterized, because it is impossible to look at the total risk posed by chemical emissions at all times and in all places. People move in and out of affected areas throughout the day and throughout their lifetimes, emissions fluctuate, the wind changes direction, all of these affect the nature of risk. Internally, key elements of the risk analysis must be flagged, so that personnel in the appropriate departments can track important data needed to complete and maintain the program.

Overall the application of environmental risk analysis to prioritizing industrial emissions for the purpose of reducing those that cause the greatest risk was successful, but is it necessary? The cost of impaired health from industrial releases, once considered a social cost, is more and more viewed as a corporate responsibility. Complying with regulations is not always protective of the human health and the environment, as seen in the Yorktown Project. A procedure similar to this can pinpoint potential problem areas, allowing a firm to reduce its liabilities and be a good corporate neighbor.

A final note on the use of risk assessment and risk analysis to set environmental policy. These are important data collection tools for problem definition and alternative policy evaluation, but due to the many uncertainties associated with assigning quantitative numbers to chemical and biological processes that are difficult to measure and sometimes not well defined, it should be remembered that results of these assessments can only be used as an indicator of where potential problems may or may not be occurring. Other factors should play into the final decision, including not only social and economic concerns, but the long term consequences of the policy adopted.

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# APPENDIX A

# CALCULATING THE INTEGRATED RISK INDEX

# APPENDIX A

# CALCULATING THE INTEGRATED RISK INDEX

## POTENTIAL EXPOSURE CRITERIA:

The Potential Exposure Criteria is based on the annual weight of the chemical produced ($N_{ap}$) and the number of populations potentially exposed ($N_{pe}$). Each of these is scored as follows and then the two values added: $P = N_{ap} + N_{pe}$.

### Annual Production ($N_{ap}$)

| Score | Criteria |
|---|---|
| 1 | Less than 10,000 lbs |
| 2 | 10,000 to 1 million lbs |
| 3 | Greater than 1 million lbs |

### Exposed Populations ($N_{pe}$)

| Score | Criteria |
|---|---|
| 1 | One Population or Limited Environmental |
| 2 | Two Populations or Moderate Environmental |
| 3 | Three Populations or Widespread Environmental |

## HAZARD CRITERIA:

### Physical Hazard

The Physical Hazard (PH) is based on the flammable ($N_f$ ) and explosive properties ($N_e$ ) of a chemical. The scores from these individual properties are applied to a Physical Hazard Matrix (PHM) and the matrix value is used in the Risk Index. The flammability and reactivity criteria and Physical Hazard Matrix follow.

**Flammability ($N_f$)**

| Score | Criteria |
|---|---|
| 0 | Materials that will not burn in air when exposed to a temperature of 1500°F for a period of five (5) minutes |
| 1 | Materials that must be preheated before ignition can occur (F.P. > 140°F) |
| 2 | Materials that must be moderately heated or exposed to relatively high ambient temperatures before ignition can occur (F.P. > 100°F < 140°F) |
| 3 | Liquids and solids that can be ignited under almost all ambient temperature conditions (F.P. < 100°F; B.P. < 100°F) |
| 4 | Materials which will rapidly or completely vaporize at atmospheric pressure and normal ambient temperature, or which are readily dispersed in air and which will burn readily (F.P. < 100°F; B.P. < 100°F) |

**Reactivity ($N_x$)**

| Score | Criteria |
|---|---|
| 0 | Materials which are normally stable, even under fire exposure conditions, and which are not reactive with water |
| 1 | Materials which are normally stable, but which can become unstable at elevated temperatures and pressures or which may react with water with some release of energy but not violently |

2 Materials which are normally unstable and readily undergo violent chemical change but do not detonate. Also materials which may react violently with water or which may form potentially explosive mixtures with water

3 Materials which are capable of detonation or explosive reaction but require a strong initiating source or which must be heated under confinement before initiation or which react explosively with water

4 Materials which are readily capable of detonation or of explosive decomposition or reaction at normal temperatures and pressures

## PHYSICAL HAZARD MATRIX

### A) Flammable Liquids and Gases

| | $N_x = 0$ | $N_x = 1$ | $N_x = 2$ | $N_x = 3$ | $N_x = 4$ |
|---|---|---|---|---|---|
| $N_f = 0$ | 1.00 | 3.50 | 6.00 | 7.25 | 10.00 |
| $N_f = 1$ | 1.00 | 3.50 | 6.00 | 7.25 | 10.00 |
| $N_f = 2$ | 2.50 | 3.50 | 6.75 | 7.75 | 10.00 |
| $N_f = 3$ | 4.00 | 4.00 | 7.50 | 8.50 | 10.00 |
| $N_f = 4$ | 5.25 | 5.25 | 8.00 | 9.00 | 10.00 |

### B) Combustible Dust or Mist

Course Particles

| | | | | |
|---|---|---|---|---|
| 4.00 | 4.00 | 6.00 | 7.25 | 10.00 |

Fine Particles

| | | | | |
|---|---|---|---|---|
| 6.00 | 6.00 | 7.25 | 8.50 | 10.00 |

### C) Combustible Solids

Dense Solids, e.g., wood, metals

| | | | | |
|---|---|---|---|---|
| 1.00 | 3.50 | 6.00 | 7.25 | 10.00 |
| Open Solids, e.g., pellets, rolls, bags | | | | |
| 2.50 | 5.00 | 8.00 | 8.50 | 10.00 |
| Rubber Goods | | | | |
| 5.25 | | | | |

Environmental Hazard

The environmental hazard is found by applying results from persistence/ bioaccumulation and adverse effects criteria to an Environmental Hazard Index (EHI). This number is used in the RI.

## CHEMICAL PERSISTENCE/BIOACCUMULATION POTENTIAL (Nb)

| **Score** | **Criteria** |
|---|---|
| 0 | Experimental evidence showing non-persistence and non-accumulation |
| 1 | No data; bioaccumulation not expected |
| 2 | Persistence and bioaccumulation is low |
| 3 | Testing needed; bioaccumulation judged to be appreciable |
| 4 | Persistence and bioaccumulation is appreciable |
| 5 | Testing needed; bioaccumulation judged to be high or no known information |
| 6 | Persistence and bioaccumulation is high |

## ENVIRONMENTAL HAZARD CRITERIA

| Score | Criteria |
|---|---|
| 0 | Experimental evidence with negative results |
| 1 | No test data; low probability for adverse effects |
| 2 | Adverse effects at high concentrations |
| 3 | Testing needed; probability of minor or local adverse effects at moderate concentrations |
| 4 | Adverse effects at moderate concentrations |
| 5 | Testing needed; probability of major or widespread adverse effects or no known information |
| 6 | Adverse effects at low concentrations |

These criteria are based on "a hypothetical accidental spill of 100 lbs of product into a flowing stream."

## ENVIRONMENTAL HAZARD MATRIX (EH)

| | $N_b = 0$ | $N_b = 1$ | $N_b = 2$ | $N_b = 3$ | $N_b = 4$ | $N_b = 5$ | $N_b = 6$ |
|---|---|---|---|---|---|---|---|
| $N_e = 0$ | 1.00 | 2.25 | 3.50 | 6.00 | 6.25 | 7.50 | 10.00 |
| $N_e = 1$ | 1.00 | 2.25 | 3.75 | 6.00 | 6.25 | 7.50 | 10.00 |
| $N_e = 2$ | 1.00 | 2.25 | 4.00 | 6.25 | 6.75 | 7.75 | 10.00 |
| $N_e = 3$ | 2.50 | 3.50 | 4.25 | 6.50 | 7.00 | 8.00 | 10.00 |
| $N_e = 4$ | 2.50 | 3.50 | 4.25 | 6.50 | 7.00 | 8.00 | 10.00 |
| $N_e = 5$ | 4.00 | 4.25 | 4.75 | 6.75 | 7.75 | 8.50 | 10.00 |
| $N_e = 6$ | 5.25 | 5.50 | 5.75 | 7.00 | 8.00 | 9.00 | 10.00 |

Human Health Hazard

Acute, chronic/subchronic, carcinogenic, mutagenic and reproductive effects endpoints is scored separately, and these scores weighted based on the "severity of effects and societal concern." The authors admit that this part of the IRI is subjective. The weighting scheme and Health Hazard formula are as follows:

**Health Hazard (HH) Index Calculation**

| Factor | Weighting | Score |
|---|---|---|
| Acute Toxicity | 2x | = ($N_a$ ) |
| Subchronic Toxicity | 2x | = ($N_s$ ) |
| Carcinogenicity | 3x | = ($N_c$ ) |
| Mutagenicity | 1x | = ($N_m$ ) |
| Teratogenicity | 3x | = ($N_t$ ) |
| Reproductive Effects | 3x | = ($N_r$ ) |

$$\text{HH Index} = \frac{4.32\,(N_a + N_s + N_c + N_m + N_t + N_r)}{35} \quad ;\ \textit{where,}$$

35 = the maximum number of health hazard factors and

4.32 = a constant which keeps the HH index in the same 1.00 - 10.00 scale as the physical and environmental factors

## ACUTE TOXICITY ($N_a$)

| Score | Criteria |
|---|---|
| 0 | No test data, suspected to be minimally toxic, non-irritating or non-sensitizing |
| 1 | Minimally toxic, irritating or sensitizing<br>Acute oral $LD_{50}$: > 5 g/kg<br>Acute dermal $LD_{50}$: > 500 mg/kg<br>Acute inhalation $LC_{50}$: > 500 ppm<br>Skin irritation Draize: < 0.9<br>Skin sensitivity: minimal<br>Eye irritation Draize: < 24.9 |
| 2 | No test data, suspected to be slightly toxic, irritating or sensitizing |
| 3 | Slightly toxic, irritating or sensitizing<br>Acute oral $LD_{50}$: 0.5 - 5 g/kg<br>Acute dermal $LD_{50}$: 50 - 500 mg/kg<br>Acute inhalation $LC_{50}$: 50 - 500 ppm<br>Skin irritation Draize: 1.0 - 1.9<br>Skin sensitivity: slight<br>Eye irritation Draize: 25 - 44.9 |
| 4 | No test data, suspected to moderately toxic, irrigating or sensitizing |
| 5 | Moderately toxic, irritating or sensitizing<br>Acute oral $LD_{50}$: 50 - 499 mg/kg<br>Acute dermal $LD_{50}$: 1 - 49 mg/kg<br>Acute inhalation $LC_{50}$: 5 ppm<br>Skin irritation Draize: 6.0 - 8.0<br>Skin sensitivity: moderate<br>Eye irritation Draize: 45 - 64.9 |
| 6 | No test data, suspected to be extremely toxic, irritating or sensitizing or cannot judge probable toxicity |
| 7 | Extremely toxic, irritating or sensitizing<br>Acute oral $LD_{50}$: ≤ 50 mg/kg<br>Acute dermal $LD_{50}$: ≤ 1 mg/kg<br>Acute inhalation $LC_{50}$: < 5 ppm<br>Skin irritation Draize: 6.0 - 8.0<br>Skin sensitivity: extreme<br>Eye irritation Draize: > 65 |

## SUBCHRONIC/CHRONIC TOXICITY ($N_s$ )

| Score | Criteria |
|---|---|
| 0 | No test data, suspected to be minimally toxic |
| 1 | Minimally toxic<br>NOEL oral: > 100 mg/kg-day<br>NOEL dermal: > 10 mg/kg-day<br>NOEL inhalation: > 10 ppm -day |
| 2 | No test data, suspected to be slightly toxic |
| 3 | Slightly toxic<br>NOEL oral: 10 - 100 mg/kg-day<br>NOEL dermal: 1 - 10 mg/kg-day<br>NOEL inhalation: 1 - 10 ppm -day |
| 4 | No test data, suspected to be moderately toxic |
| 5 | Moderately toxic<br>NOEL oral: 1 - 9 mg/kg-day<br>NOEL dermal: .02 - .9 mg/kg-day<br>NOEL inhalation: 0.1 - 0.9 ppm-day |
| 6 | No test data, suspected to be extremely toxic or cannot judge probable toxicity |
| 7 | Extremely toxic<br>NOEL oral: < 1 mg/kg-day<br>NOEL dermal: < .02 mg/kg-day<br>NOEL inhalation: < .1 ppm -day |

## CARCINOGENICITY ($N_c$)

| Score | Criteria |
|---|---|
| 0 | Adequately tested, with negative results in two animal species |
| 1 | Insufficient test data; no suspicion |
| 2 | Insufficient test data; equivocal as to positive or negative based on structure or biological activity |
| 3 | Insufficient animal test data; positive mutagenicity tests (3 or higher on Mutagenicity Score) |
| 4 | Positive in one animal species |
| 5 | Insufficient test data; strong suspicion as human carcinogen or cannot judge probable carcinogenicity |
| 6 | Known human carcinogen or positive in two animal tests |

## MUTAGENICITY ($N_m$)

| Score | Criteria |
|---|---|
| 0 | Adequately tested with negative results |
| 1 | Inadequately tested; no suspicion of mutagenicity |
| 2 | Inadequately tested; suspicion of mutagenicity |
| 3 | Tested in multiple systems with mixed (positive and negative) results |
| 4 | Positive in one mutagen system |
| 5 | Tested in multiple systems with all positive results |

## TERATOGENICITY ($N_t$)

| Score | Criteria |
|---|---|
| 0 | Adequately tested, with negative results in at least two animal species |
| 1 | No test data; no suspicion |
| 2 | No test data; suspected or cannot judge probable teratogenicity |
| 3 | Confirmed teratogen in one animal species |
| 4 | Confirmed teratogen in two animal species |
| 5 | Confirmed or strongly suspected human teratogen |

## REPRODUCTIVE EFFECTS ($N_r$)

| Score | Criteria |
|---|---|
| 0 | Adequately tested with negative results in at least two animal species |
| 1 | No test data; no suspicion |
| 2 | No test data; suspected or cannot judge reproductive effects |
| 3 | Positive for reproductive effects in one animal species |
| 4 | Positive for reproductive effects in two animal species |
| 5 | Confirmed or strongly suspected human reproductive effect |

### Final Risk Index Number

The final Risk Index Number is calculated using the formula:

$$RI = (2PH + 2HH + EH)$$

# APPENDIX B

# MATERIALS ACCOUNTING WORKSHEETS

## Caustic Cleaner

*A) Quantity ordered* 14,450 lbs

*B) Constituents*

| Caustic Cleaner | % | lbs | MW | Moles | lbs Na or K | lbs OH | |
|---|---|---|---|---|---|---|---|
| Sodium Hydroxide | 60-70 | 10,115 | 40 | 253 | 5,816 | 4,299 | |
| Potassium Hydroxid | 3-7 | 708 | 56 | 13 | 493 | 215 | |
| Resin(Rosin) Acids | 3-7 | 708 | 276 | 3 | | | |
| | | 11,531 | | | 6,309 | 4,514 | = Total |

*C) Waste Streams*

### 1) Caustic Sludge

Quantity and constituents unknown.

### 2) Spent Caustic Solution

(129 cubic yards of spent caustic are produced)

*a) Sodium Stearate* (See Section on Sodium Stearate)

*b) Hydroxide*

i) Excess hydroxide ion

Caustic cleaners are usually spent when the pH reaches 10 (Niven, 1955). The potential quantity of free hydroxide ions can be estimated based on the pH. The free hydroxide is neutralized with sulfuric acid.

| | | moles/l | yd3 | liters/yd3 | liters | moles OH | lbs OH |
|---|---|---|---|---|---|---|---|
| pH = | 10 | 0.0001 | 129 | 765 | 98,628 | 10 | **168** |

ii) Hydroxide consumed in cleaning process:

Hydroxide combines with free acids and is neutralized.

| lbs purchased | | excess lbs | | Hydroxide available for reactions | |
|---|---|---|---|---|---|
| 4,514 | - | 168 | = | **4,346** | lbs |

*c) Sodium, Potassium and Rosin Acids*

This is a more difficult estimation as neither sodium nor potassium concentrations are measured. The assumption will be made that similar to hydroxide, all but 4% of the sodium and potassium ions will be used in the cleaning process and 96% are free to join with fatty acids to make surfactants and sapponify oils. The rosin acids are assumed to be completely used, as the small quantity present acts to begin the process.

| | % used | lbs purchased | lbs used | lbs not used |
|---|---|---|---|---|
| Sodium | 96 | 5,816 | 5,583 | 233 |
| Potassium | 96 | 493 | 473 | 20 |
| Rosin Acids | 100 | 708 | 708 | |
| | | | 6,765 | |

*d) Sulfuric Acid*

The estimation of sulfuric acid is based on the presence of about 10 moles of free hydroxide and is calculated assuming that the 9 moles of hydrogen ion is needed to neutralize the tank to pH 7. Sulfuric acid is a strong acid. The first hydrogen completely ionizes and $HSO_4^-$ has a Ka of .012. Therefore approximately 4.5 moles or 440 lbs of sulfuric acid is needed. The hydrogen neutralizes the hydroxide and approximately 435 lbs of sulfate ions remain.

*e) Ferrous Sulfate* $Fe_2(SO_4)_3$

The tank is emptied every nine months and each nine months two 80 lb pallets of ferrous sulfate are used to treat this wastestream.

| For nine months: | | For twelve months: | |
|---|---|---|---|
| Pallets | 2 | Pallets | 2.5 |
| 80 lb/bag | 40 | 80 lb/bag | 50 |
| Total | 6,400 | Total | 10,000 lbs |

### 3) Dragout from the Caustic Tank to the rinse tank

An estimation of chemical concentration must be made in the rinse tanks, as these are not measured. Five percent is used. The contaminants listed below are soluble and will eventually overflow to the IWTF and then to the POTW.

| *Chemical* | % | lbs in Spent Soln | lbs dragout | | Final lbs in Spent Soln | Plus Rosin Acids | |
|---|---|---|---|---|---|---|---|
| *Na/K in Surfactant* | 5 | 6,057 | **303** | = | 5,754 | 708 | **6,462** |
| *Hydroxide* | 5 | 168 | **8** | = | **159** | | |
| *Sodium* | 5 | 233 | **12** | = | **221** | | |
| *Potassium* | 5 | 20 | **1** | = | **19** | | |

## *D) Summary of Pounds of Chemicals at each Exit Point*

| Chemical | Exit Points | lbs/yr |
|---|---|---|
| Na/K/Rosin Acid Salt | SWLF-Spent Caustic | 6,462 |
| Sodium | SWLF-Spent Caustic | 221 |
| Potassium | SWLF-Spent Caustic | 19 |
| Sulfate | SWLF-Spent Caustic from neutralization | 435 |
| Ferrous Sulfate | SWLF-Spent Caustic from treatment | 10,000 |
| Na/K in Surfactant | POTW - IWTF - Dragout-Caustic | 303 |
| Sodium | POTW - IWTF - Dragout-Caustic | 12 |
| Potassium | POTW - IWTF - Dragout-Caustic | 1 |

## Sulfuric Acid (93%)

*A) Quantity Ordered* 394,870 lbs

*B) Constituents*

| | % | lbs | MW | Moles |
|---|---|---|---|---|
| H2SO4 | 93 | 367,229 | 98.0734 | 3,744 |
| Hydrogen | | 7,548 | 1.0079 | 7,489 |
| Sulfate | | 359,681 | 96.0576 | 3,744 |
| Water | 7 | 27,641 | | |

*C) Waste Streams:*

### 1) Spent Pickle Liquor

*a) H+, HSO4-, and SO4*

The waste is 10% by volume total acid or H2SO4, so the amount of H+, HSO4-, and SO4 can be calculated.

| lbs waste | | gal/lbs | | gal waste |
|---|---|---|---|---|
| 1,689,358 | x | 0.0654 | = | 110,416 |

| gal waste | | % | | gal H2SO4 |
|---|---|---|---|---|
| 110,416 | x | 0.09 | = | 9,937 |

| gal H2SO4 | sp.g. (gr/ml) | ml/gal | lb/gr | lb H2SO4 |
|---|---|---|---|---|
| 9,937 | 1.841 | 3,785.412 | 0.002 | **152,677** |

Formula and Molecular Weights:

| H2SO4 | H2 | H | HSO4- | SO4-2 |
|---|---|---|---|---|
| 98.0734 | 2.0158 | 1.0079 | 97.0655 | 96.0576 |

Pounds and moles of Sulfuric Acid and Hydrogen available:

| H2SO4 lbs | H2SO4 moles | H lbs | H moles |
|---|---|---|---|
| 152,677 | 1,557 | 3,138 | 3,114 |

The first hydrogen or 1/2 of the total hydrogen will dissociate completely:

| Total lbs H | Total moles H | First H lbs | First H moles |
|---|---|---|---|
| 3,114 | 3,089 | 1,557 | 1,545 |

The second hydrogen will dissociate according to:

$$.012 = \frac{[H]\;[SO4-2]}{[HSO4-]}$$

| Second H lbs | Second H moles | SO4 -2 lbs | SO4 -2 moles | HSO4- lbs | H in HSO4 lbs | SO4 in HSO4 lbs | H in HSO4 lbs |
|---|---|---|---|---|---|---|---|
| **1,372** | 1,362 | **130,783** | 1,362 | **18,953** | 193 | 18,756 | 193 |

*b) Total Iron*

The waste is 9% by volume total iron.

| | Iron | Sulfate | Iron II Sulfate |
|---|---|---|---|
| Formula and Molecular Weights: | 55.8470 | 96.0576 | 151.9046 |

| | lbs waste | | % | | lbs of Iron | moles |
|---|---|---|---|---|---|---|
| Weight of Iron = | 1,689,358 | x | 0.09 | = | 152,042 | 2,722 |

This 2,722 moles of iron represents both free iron and iron bound to sulfate to form Iron II Sulfate, making it difficult to estimate the quantity of each. Therefore it will be assumed that at least 25% is free and the rest is bound to sulfate.

| | moles | | MW | | lbs |
|---|---|---|---|---|---|
| Free Fe | 681 | x | 55.85 | = | **38,011** |
| FeSO4 | 2,042 | x | 151.85 | = | **310,050** |
| Fe | 2,042 | x | 55.85 | = | 114,032 |
| SO4 | 2,042 | x | 96.06 | = | 196,136 |

## 2) Loss of Hydrogen as Hydrogen gas (H2) and Water

*a) Hydrogen gas and water*

For every mole of iron removed in the pickling process, approximately two moles of hydrogen are released and converted to either hydrogen gas or combine with oxygen to form water. Approximately one in eight hydrogen molecules (or 12.5%) becomes hydrogen gas. If 2,042 moles of FeSO4 are produced, then 4,094 moles of hydrogen are needed. Of these, 12.5% or 511 moles become hydrogen gas and 3,602 combine with oxygen to form water.

| | Moles | MW | lbs |
|---|---|---|---|
| Hydrogen as Gas (H2 | 511 | 2.016 | **515** |
| Hydrogen in Water | 3,602 | 1.008 | **3,631** |

## 3) Dragout

Sulfuric acid that is not used in the pickling process or present in the spent pickle liquor is assumed to be lost as dragout and can be determined through subtraction. The quantity of iron in drag out is estimated using lab results of tests on the IWTF filter press sludge. It is assumed that most of the iron in the sludge comes from the pickling process and that the iron is preciptated out in the IWTF.

*a) Iron*

| | | |
|---|---|---|
| Quantity of Filter Press Sludge | 755 | cubic yds |
| Quantity of Iron in Sludge | 4,636 | mg/l |
| Liters/cubic yard | 765 | |

| | cubic yds | l/cubic yd | mg/l | lb/mg | | lbs | Moles |
|---|---|---|---|---|---|---|---|
| lbs iron = | 755 | 765 | 4,636 | 2.20E-06 | = | 5,900 | 106 |

This is the estimated quantity of iron in the sludge. It is assumed that little of the iron goes over the wiers to the POTW. This assumption is made because even if .25 mg/l escaped, this quantity would represent less than one mole per year. In the IWTF the iron will precipitate out as Fe(OH)2:

| MW of Fe(OH)2 | | moles | | lbs |
|---|---|---|---|---|
| 89.8616 | x | 106 | = | 9,493 |

*b) Hydrogen and Sulfate*

The following table is an accounting of the hydrogen, sulfate and iron in each waste stream.

| | Iron moles | Iron lbs | Sulfate moles | Sulfate lbs | Hydrogen moles | Hydrogen lbs |
|---|---|---|---|---|---|---|
| Available* | | | 3,746 | 359,681 | 7,489 | 7,548 |
| Pickle Liquor FeSO4 | 2,042 | 114,032 | 2,042 | 196,136 | | |
| Pickle Liquor HSO4 | | | 195 | 18,756 | 195 | 193 |
| Pickle Liquor Free | 681 | 38,011 | 1,361 | 130,783 | 2,907 | 2,929 |
| Hydrogen to Gas | | | | | 511 | 515 |
| Hydrogen (Pickling) | | | | | 3,602 | 3,630 |
| Dragout | 106 | **5,900** | 146 | **14,006** | 274 | 280 |
| Total Used | 2,829 | 157,943 | 3,744 | 359,681 | 7,489 | 7,548 |

* These quantities represent the amount ordered.

In the IWTF hydrogen will combine with hydroxide to form water and sulfate will react with magnesium to form magnesium sulfate. The solubility of this compound is between 26 gr/100cc (0 C) and 73.8 (100 C). The potential concentration of Magnesium Sulfate in solution if the sulfate reacts mole for mole with magnesium is .022 gr/100cc. The temperature of the solution is close to ambient (20 - 35 C), so the magnesium sulfate will probably stay in solution and exit to the POTW.

| lbs Sulfate | | MW SO4 | | Moles SO4 |
|---|---|---|---|---|
| 19,320 | x | 96.06 | = | 201 |

| Moles SO4 | | MW MgSO4 | | lbs of MgSO4 | | mg/lb | mg MgSO4 |
|---|---|---|---|---|---|---|---|
| 201 | x | 120.37 | = | 24,210 | x | 453,600 | 10,981,815,551 |

| mg MgSO4 | | Liters of Effluent | | mg/l MgSO4 |
|---|---|---|---|---|
| 10,981,815,551 | / | 3.98E+07 | = | 275.978747 |

| mg/l MgSO4 | gr/mg | l/100ml | | gr/100cc |
|---|---|---|---|---|
| 275.98 | 0.001 | 0.1 | = | 0.02759787 |

### D) *Summary of Pounds of Chemicals at each Exit Point*

| Chemical | Exit | lbs |
|---|---|---|
| | | |
| $H^+$ (free) | HWIW - Spent Pickle Liquor | 2,929 |
| Sulfate (free) | HWIW - Spent Pickle Liquor | 130,783 |
| $HSO_4^-$ | HWIW - Spent Pickle Liquor | 18,953 |
| Iron (free) | HWIW - Pickle Liquor | 38,011 |
| $FeSO_4$ | HWIW - Pickle Liquor | 310,050 |
| $H_2$ | Air - Pickling Tank | 253 |
| Fe II | SWLF - IWTF Sludge -Dragout pickle liquor | 5,900 |
| Sulfate | POTW - Dragout Sulfate in Pickle Liquor | 14,006 |

## Zinc Phosphate Coating Solution and Makeup Solution

### *A) Quantity Ordered*

| | |
|---|---|
| Coating Solution | 183,540 lbs |
| Makeup Solution | 1,900 lbs |

### *B) Constituents*

| Coating Solution | % | lbs |
|---|---|---|
| Zinc Dihydrogen Phosphate | 30-40 | 73,416 |
| Nitric Acid | 1-10 | 18,354 |
| Zinc Nitrate | 1-10 | 18,354 |
| Water & Others | | 73,416 |

| Make-up Solution | % | lbs |
|---|---|---|
| Zinc Dihydrogen Phosphate | 5-10 | 190 |
| Nitric Acid | 1-3 | 57 |
| Zinc Nitrate | 10-40 | 760 |
| Water & Others | | 893 |

Total pounds of each constituent (see next page for calculations):

| | lbs | MW | Moles |
|---|---|---|---|
| Zinc | 25,154 | 65.38 | 385 |
| Phosphate | 53,907 | 94.97 | 568 |
| Nitrate | 30,632 | 62.00 | 494 |
| Hydrogen | 1,439 | 1.01 | 1,427 |

**Coating Solution:**

| | lbs | MW | Molecules | MW in Formula | % of FW |
|---|---|---|---|---|---|
| Zinc Dihydrogen Pho | 73,416 | | | | |
| Zinc | 18,507 | 65.38 | 1 | 65.38 | 0.2521 |
| Phosphate (PO4) | 53,768 | 94.97 | 2 | 189.94 | 0.7324 |
| Hydrogen | 1,141 | 1.01 | 4 | 4.03 | 0.0155 |
| | | 162.37 | | 259.35 | 1.0000 |
| Nitric Acid | 18,354 | | | | |
| Nitrate | 18,060 | 62.00 | 1 | 62.00 | 0.9840 |
| Hydrogen | 294 | 1.01 | 1 | 1.01 | 0.0160 |
| | | | | 63.01 | 1.0000 |
| Zinc Nitrate | 18,354 | | | | |
| Zinc | 6,336 | 65.38 | 1 | 65.38 | 0.3452 |
| Nitrate | 12,018 | 62.00 | 2 | 124.01 | 0.6548 |
| | | | | 189.39 | 1.0000 |

**Make-up Solution:**

| | lbs | MW | Molecules | MW in Formula | % of FW |
|---|---|---|---|---|---|
| Zinc Dihydrogen Pho | 190 | | | | |
| Zinc | 48 | 65.38 | 1 | 65.38 | 0.2521 |
| Phosphate (PO4) | 139 | 94.97 | 2 | 189.94 | 0.7324 |
| Hydrogen | 3 | 1.01 | 4 | 4.03 | 0.0155 |
| | | 162.37 | | 259.35 | 1.0000 |
| Nitric Acid | 57 | | | | |
| Nitrate | 56 | 62.00 | 1 | 62.00 | 0.9840 |
| Hydrogen | 1 | 1.01 | 1 | 1.01 | 0.0160 |
| | | | | 63.01 | 1.0000 |
| Zinc Nitrate | 760 | | | | |
| Zinc | 262 | 65.38 | 1 | 65.38 | 0.3452 |
| Nitrate | 498 | 62.00 | 2 | 124.01 | 0.6548 |
| | | | | 189.39 | 1.0000 |

**Zinc Phosphate Coating and Makeup Solution** (cont...):

### *C) Wastestreams:*

### 1) Zinc Phosphate Coating

Zinc and phosphate are incorporated into the coating on the forms. Additionally, iron can also play a role in coating formation. A estimated ratios of these three chemicals, based on the zinc phosphate coating equations is: 4 moles zinc to 5 moles phosphate to 1 mole iron. The table below shows the moles available to react if the process is 90% efficient. The actual ratio is 4 moles zinc to 6 moles phosphate. The extra phosphate may be used in the coating process or be incorporated in the phosphate sludge or dragout. For the purpose of this paper, the extra phosphate will be accounted for in the coating process. Hydrogen and nitrate are not incorporated into the zinc phosphate coating, but act to initiate and accelerate reactions.

| | lbs Purchase | MW | Moles Ordered | % Efficiency | Moles Available | lbs Available |
|---|---|---|---|---|---|---|
| Zinc | 25,154 | 65.38 | 385 | 90 | **346** | 22,638 |
| Phosphate | 53,907 | 94.97 | 568 | 90 | **511** | 48,516 |
| Iron* | | | | | **87** | 4,834 |

* The moles of iron are based on a ratio of 1 mole iron to 4 moles of zinc.

### 2) Sludge Formation

A by-product of the coating process is sludge. 118 drums of phosphate sludge are disposed of at a SWLF. A lab report shows there are 8-9 pounds per gallon. The total weight is calculated below:

| Drums | gal/drum | lbs/gal | lbs sludge |
|---|---|---|---|
| **118** | 50 | 8.50 | 50,150 |

From the sludge formation equation, it can be seen that Iron III Phosphate is a substantial portion of the sludge. In addition, water, elemental iron, unused zinc, nitrate and hydrogen are also present.

*a) Iron III Phosphate:*

Iron (III) Phosphate is composed of one mole of iron for every mole of phosphate. From the information in the previous step, it was shown that 57 moles of phosphate are not used in the coating process and are therefore available to combine with iron and precipitate out as sludge.

|  | Moles | lbs |
|---|---|---|
| Phosphate | 57 | 5,413 |
| Iron | 57 | 3,183 |
| Iron III Phosphate |  | **8,597** |

*b) Hydrogen Ion:*

To neutralize the hydrogen ions in the sludge, 7,000 lbs of soda ash is added. The approximate quantity of acid present can be estimated by the amount of sodaash added. Sodium carbonate reacts with water to form sodium hydroxide and carbonic acid. Sodium hydroxide dissociates and hydroxide ions combine with excess hydrogen ions to form water.

|  | lbs | MW | Moles |
|---|---|---|---|
| Na2CO3 (anhydrous) | 7,000 | 105.97 | 66 |
| Sodium (Na) | **3,037** | 22.99 | 132 |
| Carbonate | 3,963 | 59.99 | 66 |

At a minimum, 132 moles of Sodium are available to react with 132 moles of Hydrogen ion. In addition, 66 moles of carbonic acid are produced.

|  | moles | MW | lbs |
|---|---|---|---|
| Hydrogen | 132 | 1.0079 | **133** |
| Carbonic Acid | 66 | 62.006 | **4,092** |

*c) Zinc:*

| | |
|---|---|
| Weight of Sludge | 50,150 lbs |
| Zinc Content | 2 % |

| | lbs sludge | % | lbs | moles |
|---|---|---|---|---|
| Weight of Zn: | 50,150 | 0.02 | 1,003 | 15.34 |

*d) Nitrate:*

No lab tests are made to determine the concentration of Nitrate in the sludge. It is assumed that some nitrate will adhere to settling sludge and be precipitated out. It is estimated that over a year one quarter of the nitrate will settle this way into the sludge.

| | moles | MW | lbs |
|---|---|---|---|
| Nitrate | 124 | 62.00 | 7,689 |

*e) Estimation of Water Content:*

| Weight in lbs of: | | | | |
|---|---|---|---|---|
| Sludge | 50,150 | lbs or | 5,900 | gallons |
| FePO4 | 8,597 | | | |
| Hydrogen ion | 133 | | | |
| Sodium | 3,037 | | | |
| Carbonic Acid | 4,092 | | | |
| Zinc | 1,003 | | | |
| Nitrate Ion | 7,689 | | | |
| Water = | 25,599 | lbs or | 3,069 | gallons |

## 3) Dragout

### *a) Zinc*

An estimation of the amount of Zinc lost to dragout can be made by determining the quantity of zinc in the IWTF sludge, the effluent to the POTW, and in the sodium stearate sludge. Although a certain percentage of Zn found in the sodium stearate sludge has actually flaked off of the zinc coated forms, it will be assumed here that the zinc found in the sodium stearate is dragout.

#### i) Zinc in IWTF Sludge

| | | |
|---|---|---|
| Quantity of Filter Press Sludge | 755 | cubic yds |
| Quantity of Zinc in Sludge | 0.661 | mg/l |
| Liters/cubic yard | 764.555 | |
| Lbs/mg | 2.20E-06 | |

| | cubic yds | l/cubic yd | mg/l | lb/mg | | | |
|---|---|---|---|---|---|---|---|
| lbs zinc = | 755 | 764.5549 | 0.6610 | 2.20E-06 | = | **0.841** | lbs |

#### ii) Zinc in Effluent to POTW

| | |
|---|---|
| MG of effluent | 10.512 |
| lbs/gal | 8.340 |
| ppm zinc | 0.280 |

| | MG | lbs/gal | ppm | | | |
|---|---|---|---|---|---|---|
| lbs zinc = | 10.5120 | 8.3400 | 0.2800 | = | **24.5476** | lbs |

#### iii) Zinc in Sodium Stearate Sludge

| | |
|---|---|
| Lbs of Na St. Sludge | 72,975 |
| Percent Zinc (BFI) | 1 |
| Lbs Zinc | **730** |

| | | | | |
|---|---|---|---|---|
| Moles of Zinc | 11 | | | |
| Total Zinc in Dragout: | | lbs | moles | % of amount ordered |
| i) Zinc in IWTF Sludge | | 0.8412 | | |
| ii) Zinc in Effluent to POTW | | 24.5476 | | |
| iii) Zinc in Sodium Stearate Sludge | | 729.7500 | | |
| | | **755** | 12 | 3.00 |

*b) Hydrogen, Phosphate and Nitrate*

The 12 moles of zinc in this waste stream represents 3% of the total amount of zinc ordered, so it will be assumed that 3% of the hydrogen and nitrate ions are also found in the dragout. Note that 82 moles of Hydrogen Ion are carried over to the Borax tank (see explanation under borax). It is assumed that the most of the phosphate is either incorporated into the zinc phosphate coating or the phosphate sludge and that only a minimal amount would be found in dragout.

| | Moles Purchased | % in Dragout | Moles in Dragout | Moles to Borax Tank | Total |
|---|---|---|---|---|---|
| Hydrogen | 1,427 | 3 | 43 | 82 | 125 |
| Nitrate | 494 | 3 | 15 | | |

### D) *Summary of Moles and Pounds of Chemical in Each Wastestream*

| | Coating Moles | Coating Lbs | Sludge Moles | Sludge Lbs | Dragout Moles | Dragout Lbs | Total Moles Used | Moles Ordered |
|---|---|---|---|---|---|---|---|---|
| Hydrogen | 0 | | **133** | 134 | **125** | 126 | *258* | *1,427* |
| Zinc | **346** | 22,638 | **15** | 1,003 | **23** | 1,513 | *373* | *385* |
| Phosphate | **511** | 48,516 | **57** | 5,413 | 0 | 0 | *568* | *568* |
| Nitrate | 0 | | **124** | 7,689 | **15** | 919 | *139* | *494* |
| Iron | **87** | 4,834 | **57** | 3,183 | | 0 | *144* | |
| Sodium Carbonate | | | | **7,000** | | | | |

The number of moles used should equal the number of moles ordered. The moles of phosphate balance, but the others do not. The discrepancy for zinc is minor. The hydrogen and nitrate can not be balanced because these ions are not used up, but are recycled and reused in the process.

### *E) Summary of Pounds of Chemicals at each Exit Point*

| Chemical | Exit Points | lbs |
|---|---|---|
| Hydrogen | Neutralized - Dragout Zn PO4 Tank | 126 |
| Zinc, Iron, Phosphate | Zinc Phosphate Coating | 75,988 |
| Hydrogen | Neutralized - Phosphate Sludge | 134 |
| Iron III Phosphate | SWLF - Phosphate Sludge | 8,597 |
| Zinc | SWLF - Phosphate Sludge | 1,003 |
| Nitrate | SWLF - Phosphate Sludge | 7,689 |
| Sodium | SWLF - Phosphate Sludge | 3,037 |
| Carbonic Acid | SWLF - Phosphate Sludge | 4,092 |
| Zinc | Dragout to Na Stearate Tank | 1,513 |
| Zinc | POTW - Zinc Phosphate Tank | 25 |
| Nitrate | POTW - IWTF - Dragout Zn PO4 Tan | 919 |

## Neutralizer

*A) Quantity Ordered =* 3,594 lbs

*B) Constituents*

| | % | lbs | MW | FW | % | Moles |
|---|---|---|---|---|---|---|
| Sodium Nitrite | 10-30 | 1,078 | | | | |
| Sodium | | 359 | 22.99 | 22.99 | 0.3332 | 16 |
| Nitrite | | 719 | 46.01 | 46.01 | 0.6668 | 16 |
| | | | | 69.00 | | |
| Sodium Borate | >60 | 2,516 | | | | |
| Sodium | | 575 | 22.99 | 45.98 | 0.2285 | 25 |
| Borate (Borax) | | 1,941 | 155.24 | 155.24 | 0.7715 | 13 |
| | | | | 201.22 | | |

*C) Waste Streams:*

**1) Overflow to IWTF**

*a) Sodium*

The potential exists for 41 moles of sodium to react with water to form sodium hydroxide. Sodium hydroxide ionizes and the hydroxide neutralizes hydrogen ions, forming water. For every sodium ion formed the potential exists for a minimum of 2 hydrogen ions to be neutralized. In this case it would be 82 moles of hydrogen. However, once sodium hydroxide ionizes, the potential exists for the sodium to form more sodium hydroxide for further acid neutralization. It will be assumed that 82 moles of hydrogen ion are carried over to the rinse tank and then to the IWTF. Sodium ions will also eventually overflow to the IWTF.

| | MW | Moles | lbs |
|---|---|---|---|
| Sodium ions | 22.9900 | 41 | 934 |
| Hydrogen ions | 1.0079 | 82 | 83 |

### *b) Borate*

The reaction of sodium borate with water produces tetraborate acid. Tetraborate acid overflows to the IWTF and is neutralized. The borate ions are fairly insoluble and settle out in the IWTF sludge. The potential exists for the formation of 13 moles of borate ions after neutralization.

| | MW | Moles | lbs | |
|---|---|---|---|---|
| Borate ions | 155.24 | 13 | 1,941 | Quantity Purchased |

### *c) Nitrate*

The sodium nitrate reacts to form nitric oxide, nitrate ions, and sodium ions. For every three nitrite ions, 2 react to form nitric oxide and the other nitrate ion.

| | MW | Moles | lbs |
|---|---|---|---|
| Nitrate | 62.00 | 5 | 329 |
| Nitrogen Oxide NO | 30.01 | 11 | 318 |

## *D) Summary of Pounds of Chemicals at each Exit Point*

| Chemical | Exit Point | lbs |
|---|---|---|
| Borate Ions | SWLF - via IWTF sludge & Neutralizer Tank | 1,941 |
| Sodium Ion | POTW - via IWTF & Neutralizer Tank | 934 |
| Nitrate | POTW - via IWTF & Neutralizer Tank | 329 |
| Nitric Oxide NO | Air - Neutralizer Tank | 318 |

## Sodium Stearate

*A) Quantity Ordered* 76,120 lbs

*B) Constituents*

| | |
|---|---|
| Sodium Stearate | 100% |

*C) Wastestreams*

**1) Lubrication Process**

At 90% efficiency, the following calculations show the quantity of sodium stearate carried over on the forms:

| lbs Ordered | Efficiency | | lbs on Forms |
|---|---|---|---|
| 76,120 | 90 | = | 68,508 |

Of this quantity, it is assumed that 1/3 falls off after processing and is disposed of in the SWLF and another third is burned off in the furnaces. One third is removed in the caustic cleaning tank when forms are re-coated for further processing.

Amount of Sodium Stearate that:

| | |
|---|---|
| a) flakes off and is taken to the SWLF: | **22,836** lbs |
| b) is burned off in the furnaces to carbon dioxide and water: | 22,836 lbs |
| c) is removed in the caustic tank: | 22,836 lbs |

*Estimated quantity of carbon dioxide:*

| lbs Sodium Stearate | % C Carbon | lbs Carbon | Moles Carbon | Moles CO2 | MW CO2 | lbs CO2 |
|---|---|---|---|---|---|---|
| 22,836 | 70.54 | 16,110 | 1,341 | 1,341 | 44.01 | 59,027 |

*Fate of sodium stearate in caustic tank:*

It is assumed 5 percent of the sodium stearate in the caustic tank is dragged out and the other 95 percent is disposed of along with the spent caustic tank solution. Dragout eventually enters the IWTF. Because the IWTF is alkaline, the sodium stearate will not precipitate and will go to the POTW

| | % | lbs |
|---|---|---|
| Spent caustic solution | 95 | **21,694** |
| POTW | 5 | **1,142** |

## 2) Sodium Stearate Sludge

Pounds of Sodium Stearate Sludge:

Because the specific gravity of the sludge is unknown, the specific gravity of water is used to convert gallons to pounds.

| Drums | gal/drum | lb/gal | | lbs |
|---|---|---|---|---|
| 175 | 50 | 8.34 | = | 72,975 |

*a) Sodium Stearate*

Ten percent of the sludge is estimated to be sodium stearate.

| lbs of Sodium Stearate Ordered | % | lbs in Sludge |
|---|---|---|
| 76,120 | 10 | **7,612** |

*b) Zinc*

From plant records it was found that 1 percent of the sodium stearate sludge is zinc.

| lbs of sludge | % Zinc | lbs Zinc |
|---|---|---|
| 72,975 | 1 | **730** |

*c) Other metals (from laboratory analyses)*

| | | mg/l | Liters of Waste | lb/mg | lbs |
|---|---|---|---|---|---|
| Silver | < | 0.05 | 33,111 | 2.21E-06 | 0.0037 |
| Arsenic | | 0.13 | 33,111 | 2.21E-06 | 0.0095 |
| Barium | < | 0.1 | 33,111 | 2.21E-06 | 0.0073 |
| Cadmium | < | 0.05 | 33,111 | 2.21E-06 | 0.0037 |
| Chromium | < | 0.05 | 33,111 | 2.21E-06 | 0.0037 |
| Lead | < | 0.1 | 33,111 | 2.21E-06 | 0.0073 |
| Mercury | < | 0.0036 | 33,111 | 2.21E-06 | 0.0003 |
| Selenium | < | 0.1 | 33,111 | 2.21E-06 | 0.0073 |
| | | | | | 0.0426 Total lbs |

*d) Water*

| | |
|---|---|
| Zinc | 730 |
| Sodium Stearate | 7612 |
| Water | 64,633 lbs |

### *D) Summary of Pounds of Chemicals at each Exit Point*

| Chemical | Exit Point | lbs |
|---|---|---|
| Sodium Stearate | SWLF - Flakes off forms | 22,836 |
| Carbon Dioxide | Air - Sodium Stearate incineration | 59,027 |
| Sodium Stearate | SWLF - Spent Caustic Solution | 21,694 |
| Sodium Stearate | POTW - Caustic Tank | 1,142 |
| Sodium Stearate | SWLF - Sodium Stearate Sludge | 7,612 |
| Zinc | SWLF - Sodium Stearate Sludge | 730 |

## Metal Parts and Sheet Metal

### *A) Quantity Ordered*

| | tons | lbs |
|---|---|---|
| Metal Parts | 26,000 | 5.20E+07 |
| Sheet Metal | 41,600 | 8.32E+07 |

### *B) Constituents*

### *C) Wastestreams*

*Iron Removed in Processing of Metal Parts:*

| | | Total (lbs) | Total (tons) |
|---|---|---|---|
| Pickling | 123,733 | | |
| Phosphate Coating | 8,017 | 131,750 | 66 |

| Quantity of Parts Available for Main Process - | Ordered | | Iron Removed | | Available Parts |
|---|---|---|---|---|---|
| | 5.20E+07 | - | 131,750 | = | 5.19E+07 |

### 1) Product and Scrap

| Process | Material | lbs | % Efficiency | lbs used | lbs scrap |
|---|---|---|---|---|---|
| Main Process | Metal Parts | 5.19E+07 | 85 | 44,088,013 | 7,780,238 |
| Weld Mill | Sheet Metal | 8.32E+07 | 87 | 72,384,000 | 10,816,000 |

### *D) Summary of Pounds of Chemicals at each Exit Point*

| Chemical | Exit Point | lbs |
|---|---|---|
| Metal Parts | Product | 44,088,013 |
| Metal Parts | Scrap | 7,780,238 |
| Sheet Metal | Product | 72,384,000 |
| Sheet Metal | Scrap | 10,816,000 |

## Hydraulic Oil

|  | 55 gal-drum | lbs |  |
|---|---|---|---|
| A) *Quantity Ordered* | 77 | 31,808 | (Specific gravity = 0.9) |

B) ***Constituents***

C) ***Wastestreams***

1) **Blended and Resold** (Approximately 4,000 gallons are blended and resold)

|  | gal | ml/gal | gr/ml | lb/gr | lbs/year |
|---|---|---|---|---|---|
| lbs/year = | 4,000 | 3,785 | 0.90 | 0.0022 | 30,040 |

2) **Non-hazardous Waste Injection Well (NHWIW)**

Of the 12,280 gallons of oily water sent to a non-hazardous injection well, one percent is hydraulic oil.

|  | Percent | gal | ml/gal | gr/ml | lb/grams | lbs/year |
|---|---|---|---|---|---|---|
| lbs/year = | 1 | 12,280 | 3,785 | 0.9 | 0.0022 | 922 |

3) **Solid Waste Landfill**

Spills of Hydraulic Oil are sorbed to kitty liter and disposed of in the SWLF in 55 gallon drums. Approximately 27 drums are produced in a year. The quantity of oil can be found by subtracting the amount of hydraulic oil resold and the amount sent to the non-hazardous injection well from the amount purchased.

| lbs/year<br>Purchased | lbs/year<br>Resold | lbs/year<br>NHWIW |  | lbs/year<br>SWLF |
|---|---|---|---|---|
| 31,805 | 30,040 | 922 | = | 843 |

Kitty Liter is used as an absorbent. Approximately 1,250-50 lb bags or 62,500lbs are ordered each year.

### D) *Summary of Pounds of Chemicals at each Exit Point*

| Chemical | Exit Point | lbs |
|---|---|---|
| Hydraulic Oil | Energy Recovery | 30,040 |
| Hydraulic Oil | NHWIW - Hydraulic Oil | 922 |
| Water | NHWIW - with Hydraulic Oil | 91,300 |
| Hydraulic Oil | SWLF - Sorbed Hydraulic Oil | 843 |
| Kitty Liter | SWLF - Sorbant for Hydraulic Oil | 62,500 |

## Coolant

| | 55 gal-drum | lbs | |
|---|---|---|---|
| A) *Quantity Ordered* | 101 | 49,273 | (Specific gravity = 1.063) |

### B) *Constituents*

| | % | lbs |
|---|---|---|
| Diethanolamine | 5-10 | 4,927 |

### C) *Wastestreams*

**1) Recycled**

The coolant is recycled and reused on site.

### D) *Summary of Pounds of Chemicals at each Exit Point*

| Chemical | Exit Point | lbs |
|---|---|---|
| Coolant | Recycled on site | 44,346 |
| Diethanolamine | Recycled on site | 4,927 |

## Cutting Oil

| | 55 gal-drum | lbs | |
|---|---|---|---|
| *A)* ***Quantity Ordered*** | 95 | 35,839 | (Specific gravity = .822) |

*B)* ***Constituents***

| | % | Specific Gravity | |
|---|---|---|---|
| Naphthenic Mineral Oil | Not Given | 0.822 | (Specific Gravity of Mineral Oil) |
| Paraffinic Petroleum Distillate | Not Given | .71 - .75 | |

*C)* ***Wastestreams***

**1) Carryover on tubes**

The plant engineer estimates that up to 10% may be carried over on forms and eventually burned off in the furnaces to carbon dioxide (CO2) and water. Carbon dioxide emissions are based on the mineral oil being 50% carbon and assuming a 100% efficient furnace.

| lbs Purchased | % Carried Over | | lbs/year |
|---|---|---|---|
| 35,839 | 10 | = | 3,584 |

| lbs Cutting Oil Carried over | % Carbon | lbs Carbon | Moles Carbon | Moles CO2 | lbs CO2 |
|---|---|---|---|---|---|
| 3,584 | 50 | 1,792 | 149 | 149 | 6,557 |

**2) Solid Waste Landfill**

41 drums of tramp oil and iron oxides are generated in the cutting process. The tramp oil is mostly oil from the sheet metal. It is assumed that this wastestream is 10% cutting oil, 10% iron oxides and the rest is tramp oil of unknown origin (80%). The specific gravity of Tramp Oil is estimated to be .822, the same as mineral oil.

| | drums | gal/drum | ml/gal | gr/ml | lb/gr | % | lbs | Total |
|---|---|---|---|---|---|---|---|---|
| Cutting Oil | 41 | 50 | 3,785 | 0.822 | 0.0022 | 0.10 | **1,406** | |
| Tramp Oil | 41 | 50 | 3,785 | 0.822 | 0.0022 | 0.80 | **11,249** | |
| Iron Oxides | 41 | 50 | 3,785 | 4 | 0.0022 | 0.10 | **6,842** | 19,497 |

### 3) Energy Reuse

The amount of cutting oil that is taken off site for energy use can be found by subtraction.

| lbs Purchased | lbs Carried Ove | lbs Tramp oil | | lbs Energy Reuse |
|---|---|---|---|---|
| 35,839 | 3,584 | 1,406 | = | 30,849 |

## *D) Summary of Pounds of Chemicals at each Exit Point*

| Chemical | Exit Point | lbs |
|---|---|---|
| Carbon Dioxide | Air - Carry over of cutting oil on sheet | 6,557 |
| Cutting Oil | SWLF - In tramp oil | 1,406 |
| Cutting Oil | Energy Reuse | 30,849 |
| Sheet Metal Oil | SWLF - In tramp oil | 11,249 |
| Iron Oxides | SWLF - In tramp oil | 6,842 |

## Stenciling Inks and Cleaners

### *A) Quantity Ordered*

| | |
|---|---|
| Methyl Ethyl Ketone - pure (MEK | 22 gal |
| WT0906R White Ink | 5 gal |
| 1000Q Wash Solution | 45 quarts |
| Domino 090C Make-up | 18 600ml |
| Domino 0906C White Ink | 18 600ml |
| Domino BK070R Black Ink | 3 600ml |
| Domino BK0721C Make-up | 12 600ml |

### *B) Constituents*

| **Chemical** Constituents | % | Assumed Values | Quantity Ordered | Units | Specific Gravity | lbs Ordered |
|---|---|---|---|---|---|---|
| **MEK (pure)** | 100 | | 22 | gal | 0.8054 | 147.85 |
| **WT0906R White** | | 1 | 5 | gal | 0.9600 | 40.05 |
| Methyl Ethyl Ketone | >50 | 0.5 | | | 0.8054 | 16.80 |
| Ethyl Alcohol | | 0.1 | | | 0.7893 | 3.29 |
| Isopropyl Alcohol | | 0.1 | | | 0.7855 | 3.28 |
| 1-Methoxy-2-Propanol | | 0.2 | | | 0.9620 | 8.03 |
| **1000Q Wash Solution** | | 1 | 45 | quarts | 0.8060 | 75.66 |
| Methyl Ethyl Ketone | >95 | 0.96 | | | 0.8054 | 69.68 |
| **Domino 090C Make-up** | | 1 | 18 | 600ml | 0.8000 | 19.05 |
| Methyl Ethyl Ketone | >90 | 0.91 | | | 0.8054 | 17.33 |
| Ethyl Alcohol | | 0.09 | | | 0.7893 | 1.71 |

*B) Constituents (cont...)*

| **Chemical** Constituents | % | Assumed Values | Quantity Ordered | Units | Specific Gravity | lbs Ordered |
|---|---|---|---|---|---|---|
| **Domino 0906C White Ink** | | 1 | 18 | 600ml | 0.9600 | 22.86 |
| Methyl Ethyl Ketone | >50 | 0.5 | | | 0.8054 | 9.59 |
| Ethyl Alcohol | | 0.1 | | | 0.7893 | 1.88 |
| Isopropyl Alcohol | | 0.1 | | | 0.7855 | 1.87 |
| 1-Methoxy-2-Propanol | | 0.3 | | | 0.9620 | 6.87 |
| | | | | | | |
| **Domino BK070R Black Ink** | | 1 | 3 | 600ml | 0.9600 | 3.81 |
| Methyl Ethyl Ketone | >50 | 0.5 | | | 0.8054 | 1.60 |
| Ethyl Alcohol | | 0.1 | | | 0.7893 | 0.31 |
| Isopropyl Alcohol | | 0.1 | | | 0.7855 | 0.31 |
| 1-Methoxy-2-Propanol | | 0.3 | | | 0.9620 | 1.15 |
| | | | | | | |
| **Domino BK0721C Make-up** | | 1 | 12 | 600ml | 0.8000 | 15.24 |
| Methyl Ethyl Ketone | >90 | 0.99 | | | 0.8054 | 12.66 |
| Ethyl Alcohol | | 0.01 | | | 0.7893 | 0.13 |

*Quantity of Each Constituent Ordered*

| Chemical | Constituent | | lbs Ordered |
|---|---|---|---|
| Domino BK070R Black | 1-Methoxy-2-Propanol | | 1.15 |
| Domino 0906C White I | 1-Methoxy-2-Propanol | | 6.87 |
| WT0906R White | 1-Methoxy-2-Propanol | | 8.03 |
| | | Total = | 16.05 |

| Chemical | Constituent | | lbs Ordered |
|---|---|---|---|
| Domino 090C Make-up | Ethyl Alcohol | | 0.13 |
| Domino BK070R Black | Ethyl Alcohol | | 0.31 |
| Domino 090C Make-up | Ethyl Alcohol | | 1.71 |
| Domino 0906C White I | Ethyl Alcohol | | 1.88 |
| WT0906R White | Ethyl Alcohol | | 3.29 |
| | | Total = | 7.32 |
| Domino BK070R Black | Isopropyl Alcohol | | 0.31 |
| Domino 0906C White I | Isopropyl Alcohol | | 1.87 |
| WT0906R White | Isopropyl Alcohol | | 3.28 |
| | | Total = | 5.46 |
| Domino BK070R Black | Methyl Ethyl Ketone | | 1.60 |
| Domino 0906C White I | Methyl Ethyl Ketone | | 9.59 |
| Domino 090C Make-up | Methyl Ethyl Ketone | | 12.66 |
| WT0906R White | Methyl Ethyl Ketone | | 16.80 |
| Domino 090C Make-up | Methyl Ethyl Ketone | | 17.33 |
| 1000Q Wash Solution | Methyl Ethyl Ketone | | 69.68 |
| MEK (pure) | Methyl Ethyl Ketone | | 147.85 |
| | | Total = | 275.51 |

### C) *Wastestreams*

### 1) Recycling

Approximately one 50 gallon drum of waste containing a mixture of methyl ethyl ketone and ink sludge is produced and taken off site for recycling each year. This is assumed to be mostly the pure methyl ethyl ketone and the components of ink that do not evaporate.

MEK (pure) = 22 gallons o **148 lbs**

### 2) Air Emissions

Other than the drum of methyl ethyl ketone which is recycled, the other volatile compounds are assumed to evaporate.

| *Chemical* | *lbs* |
|---|---|
| 1-Methoxy-2-Propano | **16** |
| Methyl Ethyl Ketone | **128** |
| Isopropyl Alcohol | **5** |
| Ethyl Alcohol | **7** |
| Total = | **156** |

## *D) Summary of Pounds of Chemicals at each Exit Point*

| Chemical | Exit Point | lbs |
|---|---|---|
| 1-Methoxy-2-Propano | Air Emissions-Stenciling | 16 |
| Methyl Ethyl Ketone | Air Emissions-Stenciling | 128 |
| Isopropyl Alcohol | Air Emissions-Stenciling | 5 |
| Ethyl Alcohol | Air Emissions-Stenciling | 7 |
| Methyl Ethyl Ketone | Recycling-Stenciling | 148 |

## Preservative

| | gal | lbs | |
|---|---|---|---|
| A) *Quantity Ordered* | 11,645 | 86,578 | (Assumed specific gravity = .822) |

### B) *Constituents*

| | % | SG |
|---|---|---|
| Barium Soap of Oxygenated Hydrocarbons | Not Given | |
| Mineral Oil | Not Given | 0.822 |

### C) *Wastestreams*

### 1) Air Emissions

The possibility of evaporation exists due to the spraying, dipping and storing involved in the process. The plant engineer estimates this amount to be about one percent.

| lbs Purchased | % | | lbs Emitted |
|---|---|---|---|
| 86,578 | 1 | = | 866 |

### 2) Carryover on Product

The preservative that does not evaporate, carries over on the product.

| lbs Purchased | lbs Emitted | | lbs on Product |
|---|---|---|---|
| 86,578 | 866 | = | 85,713 |

### D) *Summary of Pounds of Chemicals at each Exit Point*

| Chemical | Exit Point | lbs |
|---|---|---|
| Preservative | Air Emissions | 866 |
| Preservative | Product - Carryover | 85,713 |

## Magnesium Hydroxide (50% Slurry)

| | Gallons | lbs |
|---|---|---|
| *A) Quantity Ordered* | 24,000 | 218,236 |

### *B) Constituents*

| | % | Gal | SG | | lbs | Moles |
|---|---|---|---|---|---|---|
| Magnesium Hydroxid | 50 | 24,000 | 2.36 | = | 118,156 | 2,860 |
| Magnesium | | | | | 69,514 | 2,860 |
| Hydroxide | | | | | 48,642 | 2,860 |
| Water | 50 | 24,000 | 1.00 | = | 100,080 | |

### *C) Wastestreams*

*i) Hydroxide*

Magnesium hydroxide ionizes in solution. Hydroxide ions neutralize hydrogen ions to form water and maintain effluent pH at 7.0. Additionally, hydroxide ions aid in precipitating metals, such as iron, to form sludge.

*ii) Magnesium*

Magnesium also aids in precipitating some anions. However, the quantity of magnesium in the sludge and effluent is unknown. It will be assumed that 10% is not precipitated out and goes to the POTW.

| Wastestream | bs Purchase | % | | lbs |
|---|---|---|---|---|
| POTW | 69,514 | 10 | = | 6,951 |
| SWLF as sludge | 69,514 | 90 | = | 62,563 |

## Magnesium **Hydroxide** (50% Slurry) cont...

### *D) Summary of Pounds of Chemicals at each Exit Point*

| Chemical | Exit Point | lbs |
|---|---|---|
| Magnesium | SWLF - IWTF sludge | 62,563 |
| Magnesium | POTW - IWTF | 6,951 |

## Mineral Spirits

| | 55gl-dr | lbs |
|---|---|---|
| *A) Quantity Ordered* | 47 | 16,609 |

*B) Constituents*

| | % |
|---|---|
| Alphatic Hydrocarbo | Not Given |

*C) Wastestreams*

**1) Recycled**

Safety Clean reported off site recycling of 13,493 pounds of mineral spirits.

| | |
|---|---|
| Recycled | **13,493** lbs |

**2) Evaporation**

The mineral spirits that are not recycled evaporate and are air emissions.

| lbs Purchased | lbs Recycled | | lbs Evaporated |
|---|---|---|---|
| 16,609 | 13,493 | = | **3,116** |

*D) Summary of Pounds of Chemicals at each Exit Point*

| Chemical | Exit Point | lbs |
|---|---|---|
| Mineral Spirits | Recycled - Parts Cleaning | 13,493 |
| Mineral Spirits | Air Emissions | 3,116 |

# APPENDIX C

# MATERIALS ACCOUNTING BALANCE

# Input and Output Materials Accounting Balance

| *Chemical* | | *Input Quantity lbs* | *Output Balance lbs* |
|---|---|---|---|
| **Input to Caustic Cleaning** | | | |
| Causitic Cleaner | 14,450 lbs | 24,890 | |
| Ferrous Sulfate | 10,000 lbs | | |
| Sulfuric Acid | 440 lbs | | |
| **Total =** | 24,890 lbs | | |

| **Outputs** | Sodium | Potassium | Hydroxide | Rosin Acid | FeSO4 | H+ | Sulfate | Other Ingredients in Cleaner | *Input Quantity lbs* | *Output Balance lbs* |
|---|---|---|---|---|---|---|---|---|---|---|
| Other Ingredients in Cleaner | | | | | | | | 2,919 | | |
| Na/K/Rosin Acid Salts | 5,304 | 449 | | 708 | | | | | | |
| Spent Solution | 221 | 19 | 162 | | | | | | | |
| Cleaning Reactions (Hydroxide) | | | 4,346 | | | | | | | |
| Neutralizing Spent Caustic Soln | | | | | | 9 | | | | |
| Excess Sulfate | | | | | | | 432 | | | |
| FeSO4 for Spent Solution | | | | | 10,000 | | | | | |
| Dragout (Free) | 12 | 1 | 8 | | | | | | | |
| Dragout (In Na/K Salts) | 279 | 24 | | | | | | | | |
| **Total =** | 5,816 | 493 | 4,516 | 708 | 10,000 | 9 | 432 | 2,919 | | 24,893 |

# Input and Output Materials Accounting Balance

| *Chemical* | | | | | *Input Quantity lbs* | *Output Balance lbs* |
|---|---|---|---|---|---|---|
| **Input to Pickling Process** | | | | | | |
| *Sulfuric Acid (93%)* | | | | | 394,870 | |
| **Outputs** | | | | | | |
| | H+ | SO4 | Water | Iron* | | |
| Water (7%) | | | 27,641 | | | |
| Spent Pickle Liquor | 2,929 | 130,783 | | 117,833 | | |
| Sulfate in FeSO4 (Spent Soln) | | 196,136 | | | | |
| HSO4- in Spent Soln | 193 | 18,756 | | | | |
| H+ as Hydrogen Gas | 515 | | | | | |
| H+ as Water | 3,631 | | | | | |
| Dragout | 280 | 14,006 | | 5,900 | | |
| | 7,548 | 359,681 | 27,641 | 123,733 | | 394,870 |

* Iron is included with Metal Forms

## Input and Output Materials Accounting Balance

| *Chemical* | | *Input Quantity lbs* | *Output Balance lbs* |
|---|---|---|---|
| **Input to Zinc Phosphate Coating Process** | | | |
| Coating Solution | 183,540 lbs | 192,440 | |
| Makeup Solution | 1,900 lbs | | |
| Sodium Carbonate | 7,000 lbs | | |
| Ordered | 192,440 lbs | | |

**Outputs**

| | Zinc | Hydrogen | Nitrate | Phosphate | Sodium | Carbonate | Water | Iron* | *Input Quantity lbs* | *Output Balance lbs* |
|---|---|---|---|---|---|---|---|---|---|---|
| Water | | | | | | | 74,308 | | | |
| Zinc Phosphate Coating | 22,638 | | | 48,516 | | | | 4,834 | | |
| Sludge | 1,003 | 133 | 7,689 | 5,413 | 3,037 | 3,963 | 25,599 | 3,183 | | |
| Dragout | 1,513 | 126 | 919 | | | | | | | |
| Initiating and Accelerating | | 1,180 | 22,024 | | | | | | | |
| | 25,154 | 1,439 | 30,632 | 53,929 | 3,037 | 3,963 | 99,907 | 8,017 | | 192,462 |

* Iron is included with Metal Parts

# Input and Output Materials Accounting Balance

| *Chemical* | Sodium | Borate | Nitrite - N | Nitrite - O | Oxygen | *Input Quantity lbs* | *Output Balance lbs* |
|---|---|---|---|---|---|---|---|
| **Input to Neutralizing Process** | | | | | | | |
| *Neutralizer* | | | | | | 3,594 | |
| **Ouputs** | | | | | | | |
| Neutralization | 934 | 1,941 | | | | | |
| Nitrate Formation | | | 74 | 255 | | | |
| Nitrogen Oxide Formation | | | 148 | 170 | | | |
| Oxygen Lost | | | | | 76 | | |
| | 934 | 1,941 | 223 | 424 | 76 | | 3,598 |

| *Chemical* | Sodium Stearate | Oxygen* | Zinc** | *Input Quantity lbs* | *Output Balance lbs* |
|---|---|---|---|---|---|
| **Input to Lubrication** | | | | | |
| *Sodium Stearate* | | | | 76,120 | |
| **Outputs** | | | | | |
| SWLF - Flakes off hollows | 22,836 | | | | |
| Air - Sodium Stearate furnace | 22,836 | 36,191 | | | |
| SWLF - Spent Caustic Solution | 21,694 | | | | |
| POTW - Caustic Tank | 1,142 | | | | |
| SWLF - Sodium Stearate Sludge | 7,612 | | 730 | | |
| | 76,120 | | | | 76,120 |

*Oxygen gained during combustion

** Included in Zinc Phosphate Coating

# Input and Output Materials Accounting Balance

| *Chemical* | *Input Quantity lbs* | *Output Balance lbs* |
|---|---|---|

Raw Materials Input

| | tons | lbs | *Input Quantity lbs* |
|---|---|---|---|
| *Metal Parts and Sheet Metal* | | | 1.35E+08 |
| Metal Parts | 26,000 | 5.20E+07 | |
| Sheet Metal | 41,600 | 8.32E+07 | |

**Output**

| | Metal Parts | Sheet Metal | *Output Balance lbs* |
|---|---|---|---|
| Iron - Pickling | 123,733 | | |
| Iron - Zinc Phosphate Coating | 8,017 | | |
| Product | 44,088,013 | 72,384,000 | |
| Scrap | 7,780,238 | 10,816,000 | |
| | 52,000,000 | 83,200,000 | 1.35E+08 |

**Hydraulic Oil Inputs**

| | | *Input Quantity lbs* |
|---|---|---|
| Hydraulic Oil | 31,808 lbs | 94,308 |
| Kitty Liter | 62,500 lbs | |

**Outputs**

| | Hy. Oil | Kitty Liter | Water | *Output Balance lbs* |
|---|---|---|---|---|
| Energy Recovery | 30,040 | | | |
| NHWIW | 922 | | 91,300 | |
| SWLF - Sorbed Hydraulic Oil | 843 | 62,500 | | |
| | 31,805 | 62,500 | 91,300 | 94,305 |

## Input and Output Materials Accounting Balance

| *Chemical* | | | | | *Input Quantity lbs* | *Output Balance lbs* |
|---|---|---|---|---|---|---|
| **Input** | | | | | | |
| *Coolant* | | | | | 49,273 | |
| **Output** | | | | | | |
| Recycled on Site | 49,273 | | | | | 49,273 |
| **Input** | | | | | | |
| *Cutting Oil* | | | | | 35,839 | |
| **Output** | | | | | | |
| | Cutting Oil | Tramp Oil | Metal Oxides | Oxygen* | | |
| SWLF - In tramp oil | 1,406 | | | | | |
| Energy Reuse | 30,849 | | | | | |
| Solid Waste Landfill (Tramp Oil) | | 11,249 | 6,842 | | | |
| Air - Carry over of CO (furnace) | 3584 | | | 2,973 | | |
| | 35,839 | 11,249 | 6,842 | 2,973 | | 35,839 |

*Oxygen gained in combustion

# Input and Output Materials Accounting Balance

| *Chemical* | | *Input Quantity lbs* | *Output Balance lbs* |
|---|---|---|---|
| **Input to Stencilers** | | | |
| *Stenciling Inks and Cleaners* | | 325 | |
| Methyl Ethyl Ketone - pure (MEK) | 147.85 | | |
| WT0906R White Ink | 40.05 | | |
| 1000Q Wash Solution | 75.66 | | |
| Domino 090C Make-up | 19.05 | | |
| Domino 0906C White Ink | 22.86 | | |
| Domino BK070R Black Ink | 3.81 | | |
| Domino BK0721C Make-up | 15.24 | | |
| | 324.52 | | |
| 1-Methoxy-2-Propanol | 16.05 | | |
| Ethyl Alcohol | 7.32 | | |
| Isopropyl Alcohol | 5.46 | | |
| Methyl Ethyl Ketone | 275.51 | | |
| | 304.34 | | |

**Output**

| | 1-Methoxy 1-Propanol | Ethyl Alcohol | Isopropyl Alcohol | MEK | Other | | *Input Quantity lbs* | *Output Balance lbs* |
|---|---|---|---|---|---|---|---|---|
| Other Ingredients | | | | | 20.18 | | | |
| Air Emissions | 16.00 | 7.00 | 5.00 | 128.00 | | | | |
| Recycled | | | | 148.00 | | | | |
| | 16.00 | 7.00 | 5.00 | 276.00 | 20.18 | 324.18 | | 324 |

# Input and Output Materials Accounting Balance

| *Chemical* | | *Input Quantity lbs* | *Output Balance lbs* |
|---|---|---|---|
| **Input to Rust Prevention** | | | |
| *Preservative* | | 86,578 | |
| **Output** | | | |
| | Preservative | | |
| Air Emissions | 866 | | |
| Product - Carryover | 85,713 | | |
| | 86,578 | | 86,578 |
| **Input to Parts Cleaning** | | | |
| *Mineral Spirits* | | 16,609 | |
| **Output** | | | |
| | Min. Spirits | | |
| Recycled - Parts Cleaning | 13,493 | | |
| Air Emissions | 3,116 | | |
| | 16,609 | | 16,609 |

# Input and Output Materials Accounting Balance

| *Chemical* | Magnesium | Neutralized Hydroxide | Water | *Input Quantity lbs* | *Output Balance lbs* |
|---|---|---|---|---|---|
| **Input** | | | | | |
| *Magnesium Hydroxide (50% Slurry)* | | | | 218,236 | |
| **Output** | | | | | |
| SWLF - IWTF sludge | 62,563 | | | | |
| POTW - IWTF | 6,951 | 48,642 | 100,080 | | |
| | 69,514 | 48,642 | 100,080 | | 218,236 |

*Final Tally:*

| | |
|---|---|
| *136,393,082* | *Inputs* |
| *136,393,107* | *Outputs* |
| *-25* | *Difference* |

# APPENDIX D

# INTEGRATED RISK INDEX SYSTEM (IRIS) WORKSHEETS

| 1 | | WT'd | Notes |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Toxic Via - Ingestion** |
| **Barium Soap of** | | | Fowkes (1967) reports that barium soaps are insoluble in water but very soluble in organic solvents |
| **Oxygenated Hydrocarbons** | | | Adult males are at greatest risk from Barium (constituent of Preservative) |
| N(ap) | 1.00 | | <10,000 lbs used |
| N(pe) | 3.00 | | Occupational, Public and Consumers |
| **P Index** | **4.00** | | |
| | | | |
| N(f) | 1.00 | | Because of the hydrocarbons present it should burn |
| N(x) | 0.00 | | Barium soaps are not explosive |
| **PH Index** | **1.00** | | |
| | | | |
| N(b) | 1.00 | | WHO (1991): no evidence of barium accumulating |
| N(e) | 4.00 | | WHO (1991): LD50 for fresh water fish 46-78 mg/l |
| **EH Index** | **3.50** | | |
| | | | |
| N(a) | 7.00 | 14.00 | WHO (1991): Depends on form, BaCl or CO3 can produce toxic effects in humans; |
| | | | |
| N(s) | 3.00 | 6.00 | IRIS: NOAEL = 10 mg/kg; IRIS lists 7.3 mg/l as not harmful |
| | | | |
| N(c) | 0.00 | 0.00 | WHO (1991): negative in rats and mice |
| | | | |
| N(m) | 1.00 | 1.00 | ESTIMATE; WHO (1991): not adequately studied; no mention in other references |
| | | | |
| N(t) | 3.00 | 9.00 | WHO (1991): Limited data in lab animals, but says there is no evidence this is true for humans |
| | | | |
| N(r) | 3.00 | 9.00 | WHO (1991): inhaled and oral BaCO3 cause reproductive effects in test animals both male and female |
| Total | | 30.00 | |
| **HH Index** | **4.81** | | |
| | | | |
| **Risk Index** | ***60.51*** | | |

| 1207 | | WT'd | **Poison by ingestion and possibly other routes. Moderately toxic by skin and subcutaneous** |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | Lewis (1992): Boron compounds tend to be very toxic; Grosselin: Borate-No major toxicologic |
| **Borate Ion** | | | distinction are made between boric acid and its salts; Borates are mostly insoluble in water |
| | | | but not in weak acid (i.e. stomach acid); humans may be more sensitive than lab animals |
| N(ap) | 1.00 | | 2,018 pounds |
| N(pe) | 2.00 | | Occupational and public (SWLF) |
| **P Index** | **3.00** | | |
| | | | |
| N(f) | 0.00 | | Weiss (1986): Not flammable |
| N(x) | 0.00 | | Weiss (1986): Stable |
| **PH Index** | **1.00** | | |
| | | | |
| N(b) | 3.00 | | Weis (1991) - Can bioaccumulate in fish to lethal levels |
| N(e) | 3.00 | | Thompson (1976) - adverse effect at 113 ug/ml in fresh water salmonids |
| **EH Index** | **6.50** | | |
| | | | Following information from sodium borate (more basic) |
| N(a) | 3.00 | 6.00 | Grosselin - LD50 = .5 - 5 gr/kg |
| | | | |
| N(s) | 3.00 | 6.00 | Grosselin - chronic exposure can cause kidney and liver problems; Larson (1988) - NOAEL 44 mg/kg |
| | | | |
| N(c) | 1.00 | 3.00 | ESTIMATION - not mutagenic and no carcinogenic properties discussed in literature |
| | | | |
| N(m) | 0.00 | 0.00 | Larson (1988) - "Showed no evidence of mutation and no enhancement" |
| | | | |
| N(t) | 1.00 | 3.00 | Larson (1988) - no real data, but boric acid is positive at .2mg for chick embryo test |
| | | | |
| N(r) | 4.00 | 12.00 | Grosselin (and supported by Larson, 1988) - "chronic feeding to rats and dogs lead to accumulation |
| Total | | 18.00 | in testes,germ cell depletion and testicular atrophy". Lewis (1992) Experimental reproductive effects |
| **HH Index** | **3.70** | | |
| | | | |
| **Risk Index** | *47.72* | | |

| 1424 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Carbon Dioxide** | | | **TSCA Inventory; Asphyxiant** |
| | | | |
| N(ap) | 2.00 | | >10,000 lbs but < 100,000 lbs |
| N(pe) | 2.00 | | Occupational and public (air) |
| **P Index** | **4.00** | | |
| | | | |
| N(f) | 0.00 | | Weiss (1986): Not flammable |
| N(x) | 0.00 | | Weiss (1986): Stable |
| **PH Index** | **1.00** | | |
| | | | |
| N(b) | 1.00 | | Weiss (1986): in water no bioaccumulation |
| N(e) | 4.00 | | Weiss (1986): 100-200 mg/l various organisms/LC50/fresh water |
| **EH Index** | **3.50** | | |
| | | | |
| N(a) | 1.00 | 2.00 | OSHA PEL 5,000 ppm asphyxiant |
| | | | |
| N(s) | 0.00 | 0.00 | Weiss (1986): no late symptoms |
| | | | |
| N(c) | 0.00 | 0.00 | Lewis (1991a): No mention |
| | | | |
| N(m) | 0.00 | 0.00 | Lewis (1991a): No mention |
| | | | |
| N(t) | 3.00 | 9.00 | Lewis (1992): Experimental Teratogen |
| | | | |
| N(r) | 3.00 | 9.00 | Lewis (1992): Experimental Reproductive Effects |
| Total | | 11.00 | |
| **HH Index** | **2.47** | | |
| | | | |
| **Risk Index** | ***41.75*** | | |

| 1455 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Carbonic Acid** | | | CRC: exists only in solution |
| | | | |
| N(ap) | 1.00 | | 4,092 lbs |
| N(pe) | 2.00 | | Occupational and public (SWLF) |
| **P Index** | **3.00** | | |
| | | | |
| N(f) | 0.00 | | No mention in literature |
| N(x) | 0.00 | | No mention in literature |
| **PH Index** | **1.00** | | |
| | | | |
| N(b) | 0.00 | | No mention in literature |
| N(e) | 0.00 | | No mention in literature |
| **EH Index** | **1.00** | | |
| | | | |
| N(a) | 0.00 | 0.00 | No mention in literature |
| | | | |
| N(s) | 0.00 | 0.00 | No mention in literature |
| | | | |
| N(c) | 0.00 | 0.00 | No mention in literature |
| | | | |
| N(m) | 0.00 | 0.00 | No mention in literature |
| | | | |
| N(t) | 1.00 | 3.00 | No mention in literature |
| | | | |
| N(r) | 1.00 | 3.00 | No mention in literature |
| Total | | 3.00 | |
| **HH Index** | **0.74** | | |
| | | | |
| **Risk Index** | ***13.44*** | | |

| 494 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Caustic Cleaner** | | | Contains sodium and potassium hydroxide which are corrosive and resin (rosin) acids that sensitize |
| | | | |
| N(ap) | 2.00 | | >10,000 |
| N(pe) | 2.00 | | Occupational and public (ww) |
| **P Index** | **4.00** | | |
| | | | |
| N(f) | 0.00 | | MSDS - none suspected |
| N(x) | 2.00 | | Hydroxide |
| **PH Index** | **6.00** | | |
| | | | |
| N(b) | 1.00 | | No data, none suspected |
| N(e) | 6.00 | | Rosin Acids |
| **EH Index** | **5.50** | | |
| | | | |
| N(a) | 7.00 | 14.00 | MSDS - extremely irritating and can cause burns; Hydroxide present |
| | | | |
| N(s) | 4.00 | 8.00 | MSDS - may cause respiratory and digestive problems; Hydroxide present |
| | | | |
| N(c) | 1.00 | 3.00 | Hydroxide |
| | | | |
| N(m) | 2.00 | 2.00 | Hydroxide |
| | | | |
| N(t) | 1.00 | 3.00 | Hydroxide |
| | | | |
| N(r) | 2.00 | 6.00 | Hydroxide |
| Total | | 30.00 | |
| **HH Index** | **4.44** | | |
| | | | |
| **Risk Index** | ***105.55*** | | |

| 32 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| | | | |
| **Coolant** | | | **Toxic Via: Dermal** |
| N(ap) | 2.00 | | >10,000 lbs used |
| N(pe) | 1.00 | | 1 pop - reused on site |
| **P Index** | **3.00** | | |
| | | | |
| N(f) | 0.00 | | MSDS - Heat stable and non-explosive |
| N(x) | 0.00 | | MSDS - Non-explosive, although incompatible with strong oxidizers |
| **PH Index** | **1.00** | | |
| | | | |
| N(b) | 3.00 | | See diethanolamine |
| N(e) | 3.00 | | See diethanolamine |
| **EH Index** | **6.50** | | |
| | | | |
| N(a) | 0.00 | 0.00 | MSDS - LD50> 5g/kg, non-irritating to skin and eyes unless in concentrated form |
| | | | |
| N(s) | 0.00 | 0.00 | MSDS - no long term effects |
| | | | |
| N(c) | 0.00 | 0.00 | MSDS - not listed here as carcinogen |
| | | | |
| N(m) | 1.00 | 1.00 | See Diethanolamine |
| | | | |
| N(t) | 1.00 | 3.00 | See Diethanolamine |
| | | | |
| N(r) | 3.00 | 9.00 | See Diethanolamine |
| Total | | 4.00 | |
| **HH Index** | **1.60** | | |
| **Risk Index** | ***35.13*** | | |

| 62 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Cutting oil** | | | **Toxic Via: Dermal** |
| | | | Klamann (1990) lists Mineral Oil and an emulsifier as the major ingredients of cutting oil (CO) |
| N(ap) | 2.00 | | >10,000 lbs used |
| N(pe) | 2.00 | | Occupational and Public (Burned or Hazardous Waste Injection Well) |
| **P Index** | **4.00** | | |
| | | | |
| N(f) | 1.00 | | MSDS - BP >300 F, FP - 330 F - Flammable limit 1%-6% |
| N(x) | 3.00 | | MSDS - Material can volatilize and explode if a spark occurs; it will burn; avoid strong oxidizers |
| **PH Index** | **7.25** | | |
| | | | |
| N(b) | 2.00 | | Zahlsen (1992), 1992: naphthenic hydrocarbons can be stored in organs and n-alkanes in fat |
| N(e) | 3.00 | | Due to presence of naphthene |
| **EH Index** | **4.25** | | |
| | | | |
| N(a) | 3.00 | 6.00 | (Tsuji, 1993) and (Niklasson, 1993) - CO can be very sensitizing - Grosselin lists toxicity as |
| | | | 2 w/ an LD 50 of 5-15 gr/kg (oral) |
| N(s) | 2.00 | 4.00 | Tsuji; Niklasson; Goh (1993) - CO can be very sensitizing; Grosselin: inhalation can cause |
| | | | severe pulmonary irritation |
| N(c) | 5.00 | 15.00 | Tsuji; Cruikshank (1993) - Skin Cancer; Lewis(1991a)-Often carcinogenic; see Naphthenic MO |
| | | | |
| N(m) | 3.00 | 3.00 | Apostali (1993) - positive for S.typhimurium with microsomes, negative for e. coli with |
| | | | and w/o activation |
| N(t) | 2.00 | 6.00 | Presence of MO |
| | | | |
| N(r) | 2.00 | 6.00 | Presence of MO |
| Total | | 34.00 | |
| **HH Index** | **4.94** | | |
| **Risk Index** | ***114.50*** | | |

| 92 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Diethanolamine (Coolant)** | | | **Moderately toxic by ingestion, interperitoneal; Mildly toxic to dermal; severe irritant to eyes** |
| | | | Lewis: Reported on TSCA inventory and CRTK list |
| N(ap) | 1.00 | | <10,000 lbs used |
| N(pe) | 1.00 | | See Coolant (Occupational exposure) |
| **P Index** | **2.00** | | |
| | | | |
| N(f) | 1.00 | | Lewis (1991b): FP = 305 F |
| N(x) | 0.00 | | Weiss (1986): Not reactive, stable |
| **PH Index** | **1.00** | | |
| | | | |
| N(b) | 3.00 | | Melnick (1994) - accumulates in tissue of rats |
| N(e) | 3.00 | | Lack of data, may be a problem because there are health problems in humans and it is alkaline |
| **EH Index** | **6.50** | | Weiss (1986) - 2100ppm/24hr/sunfish/bluegill/TLm/fresh water |
| | | | |
| N(a) | 3.00 | 6.00 | Hammer (1987): Oral LD50 rat ingestion = 1.5 gr/kg, although the dermal LD50 and LC50 are higher |
| | | | |
| N(s) | 1.00 | 2.00 | Melnick (1994) - NOAEL for skin lesions is 125 mg/kg for male and 63 for female; |
| | | | Hammer (1987) - Liver and kidney damage at 250 mg/k intraperitoneal and 25 and 6 ppm inhaled |
| N(c) | 2.00 | 6.00 | Melnick (1994) - caused skin lesions and cell proliferation |
| | | | |
| N(m) | 0.00 | 0.00 | Hammer, 1987 - negative ames test |
| | | | |
| N(t) | 1.00 | 3.00 | ESTIMATE - No reference in literature |
| | | | |
| N(r) | 3.00 | 9.00 | Melnick (1994) - testicular degeneration and decreased sperm cell count (oral) |
| Total | | 17.00 | |
| **HH Index** | **3.21** | | |
| | | | |
| **Risk Index** | ***29.84*** | | |

| 123 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Ethyl Alcohol** | | | **Ingestion - cancer; Moderately Toxic by intravenous and interperitoneal;** |
| | | | **Mildly Toxic by inhalation and skin** |
| N(ap) | 1.00 | | <10,000 used |
| N(pe) | 1.00 | | Occupational and public |
| **P Index** | **2.00** | | |
| | | | |
| N(f) | 3.00 | | Kosaric (1987): F.P. < 100 B.P. > 100F |
| N(x) | 4.00 | | Volatile, vapors will detonate under normal conditions if spark is applied |
| **PH Index** | **10.00** | | |
| | | | |
| N(b) | 0.00 | | Weiss (1986): will not concentrate in food chain; is capable of being metabolized |
| N(e) | 2.00 | | CLSES (1984): LC50 = 14.2 g/l and EC50 = 14.2 g/l; adverse effects at high concentrations |
| **EH Index** | **1.00** | | |
| | | | |
| N(a) | 1.00 | 2.00 | Kosaric (1987) - acute oral dose > 5 gr/kg |
| | | | |
| N(s) | 2.00 | 4.00 | MSDS - can cause irritation when mist is inhaled (ESTIMATE) |
| | | | |
| N(c) | 1.00 | 3.00 | Wimer (1983) - possibility exists that it may cause cancer; but Soderman (1982) says no |
| | | | |
| N(m) | 0.00 | 0.00 | Kosaric (1987) - Ames negative; limited data; Soderman (1982) - negative for 4 mutation tests |
| | | | |
| N(t) | 1.00 | 3.00 | High concentration of ingested can cause low birth weight and fetal intoxication syndrome |
| | | | |
| N(r) | 1.00 | 3.00 | Kosaric (1987) - at high doses oral |
| Total | | 12.00 | |
| **HH Index** | **1.85** | | |
| **Risk Index** | ***49.41*** | | |

| 153 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Hydraulic Oil** | | | **Toxic Via: See MO** |
| | | | |
| N(ap) | 2.00 | | >10,000 lbs used |
| N(pe) | 2.00 | | Two populations - occupational and public (Burned, injection well, SWLF) |
| **P Index** | **4.00** | | |
| | | | |
| N(f) | 1.00 | | Moller (1989): F.P. > 140 |
| N(x) | 3.00 | | Mostly mineral oil, which is capable of volatilizing and exploding under the appropriate conditions |
| **PH Index** | **7.25** | | |
| | | | The rest of these numbers are based on mineral oil, unless otherwise stated |
| N(b) | 2.00 | | Zahlsen (1992), various fractions of mineral oil are capable of accumulating in rats through inhalation |
| N(e) | 3.00 | | Based on the potential presence of naphthenes |
| **EH Index** | **4.25** | | |
| | | | |
| N(a) | 1.00 | 2.00 | Mildly irritating to eyes (Moller, 1989) |
| | | | |
| N(s) | 1.00 | 2.00 | Dermal lesions (Moller, 1989) |
| | | | |
| N(c) | 2.00 | 6.00 | Presence of Mineral Oil |
| | | | |
| N(m) | 2.00 | 2.00 | Presence of Mineral Oil |
| | | | |
| N(t) | 2.00 | 6.00 | Presence of Mineral Oil |
| | | | |
| N(r) | 2.00 | 6.00 | Presence of Mineral Oil |
| Total | | 18.00 | |
| **HH Index** | **2.96** | | |
| | | | |
| **Risk Index** | ***98.70*** | | |

| 1393 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Hydrogen Gas** | | | **Lewis (1992): Innocuous** |
| | | | |
| N(ap) | 1.00 | | 252 lbs |
| N(pe) | 2.00 | | Occupational and public (air) |
| **P Index** | **3.00** | | |
| | | | |
| N(f) | 1.00 | | Weiss (1986): Flammable limits 4%-75% |
| N(x) | 1.00 | | Weiss (1986): Explosive air and gas mixtures; explodes in heat and flame |
| **PH Index** | **3.50** | | |
| | | | |
| N(b) | 0.00 | | Weiss (1986): None |
| N(e) | 0.00 | | Weiss (1986): None |
| **EH Index** | **1.00** | | |
| | | | |
| N(a) | 0.00 | 0.00 | Lewis (1991a): Practically no toxicity whatever |
| | | | |
| N(s) | 0.00 | 0.00 | Weiss (1986): None |
| | | | |
| N(c) | 0.00 | 0.00 | No mention in literature |
| | | | |
| N(m) | 0.00 | 0.00 | No mention in literature |
| | | | |
| N(t) | 1.00 | 3.00 | No mention in literature |
| | | | |
| N(r) | 1.00 | 3.00 | No mention in literature |
| Total | | 3.00 | |
| **HH Index** | **0.74** | | |
| | | | |
| **Risk Index** | *28.44* | | |

| 959 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Hydrogen Ion** | | | **Toxic via: (H2SO4) Human poison by unspecified route; experimental by inhalation; moderately toxic by ingestion; irritating to eye; corrosive to tissue** |
| N(ap) | 2.00 | | Potentially > 10,000 |
| N(pe) | 2.00 | | Occupational and public (injection well, wastewater, sw) |
| **P Index** | **4.00** | | |
| | | | |
| N(f) | 0.00 | | |
| N(x) | 2.00 | | Reaction with water |
| **PH Index** | **6.00** | | |
| | | | |
| N(b) | 0.00 | | |
| N(e) | 3.00 | | Localized |
| **EH Index** | **2.50** | | |
| | | | |
| N(a) | 7.00 | 14.00 | Grosselin - ml to ounces can produce death |
| | | | |
| N(s) | 2.00 | 4.00 | ESTIMATION - see sulfuric acid |
| | | | |
| N(c) | 2.00 | 6.00 | ESTIMATION - see sulfuric acid |
| | | | |
| N(m) | 1.00 | 1.00 | ESTIMATION - see sulfuric acid |
| | | | |
| N(t) | 3.00 | 9.00 | ESTIMATION - see sulfuric acid |
| | | | |
| N(r) | 1.00 | 3.00 | ESTIMATION - see sulfuric acid |
| Total | | 34.00 | |
| **HH Index** | **4.57** | | |
| | | | |
| **Risk Index** | ***94.53*** | | |

| 1145 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| Iron | | | **Toxic via: Poison by subcutaneous and oral** |
| | | | |
| N(ap) | 3.00 | | 152,000 released |
| N(pe) | 2.00 | | Occupational and public (injection well, wastewater, swlf) |
| **P Index** | **5.00** | | |
| | | | |
| N(f) | 0.00 | | ESTIMATION |
| N(x) | 0.00 | | ESTIMATION |
| **PH Index** | **1.00** | | |
| | | | |
| N(b) | 2.00 | | ESTIMATION - No data, but possibility exists |
| N(e) | 3.00 | | ESTIMATION - No data, but possibility exists (problem for humans) |
| **EH Index** | **4.25** | | |
| | | | |
| N(a) | 2.00 | 4.00 | Fraizer (1979) - mean lethal dose = .5-5 gr/kg |
| | | | |
| N(s) | 7.00 | 14.00 | Fox and Rader (1988) and Rader (1988) - Maximum tolerable level = .8 mg Fe/kg |
| | | | |
| N(c) | 3.00 | 9.00 | Hsie (1979) - FeSO4 is mutagenic and carcinogenic; Fox and Rader (1988) - Intramuscular injection |
| | | | can cause localized sarcomas; Lewis (1992) - Iron Oxide may be carcinogenic |
| N(m) | 2.00 | 2.00 | Hsie (1979) |
| | | | |
| N(t) | 2.00 | 6.00 | ESTIMATION - Based on Fox and Rader (1988) |
| | | | |
| N(r) | 2.00 | 6.00 | ESTIMATION - Based on Fox and Rader (1988) |
| Total | | 35.00 | |
| **HH Index** | **5.06** | | |
| | | | |
| **Risk Index** | ***81.86*** | | |

| 1486 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Iron II Hydroxide** | | | **Toxic via subcutaneous and oral routes.** |
| | | | Iron II Hydroxide was not listed in any references. Iron data used. |
| N(ap) | 1.00 | | 9,493 lbs |
| N(pe) | 2.00 | | Occupational and public (SWLF) |
| **P Index** | **3.00** | | |
| | | | |
| N(f) | 0.00 | | ESTIMATION (Iron) |
| N(x) | 0.00 | | ESTIMATION (Iron) |
| **PH Index** | **1.00** | | |
| | | | |
| N(b) | 2.00 | | ESTIMATION - No data, but possibility exists (Iron) |
| N(e) | 3.00 | | ESTIMATION - No data, but possibility exists (Iron) |
| **EH Index** | **4.25** | | |
| | | | The following are based on Iron data: |
| N(a) | 2.00 | 4.00 | Fraizer (1979) - mean lethal dose = .5-5 gr/kg |
| | | | |
| N(s) | 7.00 | 14.00 | Fox and Rader (1988) and Rader (1988) - Maximum tolerable level = .8 mg Fe/kg |
| | | | |
| N(c) | 3.00 | 9.00 | Hsie (1979) - FeSO4 is mutagenic and carcinogenic; Fox and Rader (1988) - Intramuscular injection |
| | | | can cause localized sarcomas: Lewis,1992 - Iron Oxide maybe carcinogenic |
| N(m) | 2.00 | 2.00 | Hsie (1979) |
| | | | |
| N(t) | 2.00 | 6.00 | ESTIMATION - Based on Fox and Rader (1988) |
| | | | |
| N(r) | 2.00 | 6.00 | ESTIMATION - Based on Fox and Rader (1988) |
| Total | | 35.00 | |
| **HH Index** | **5.06** | | |
| | | | |
| **Risk Index** | *49.11* | | |

| 1517 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Iron Oxide** | | | **Poison by subcutaneous** |
| | | | Data based on iron unless otherwise stated |
| N(ap) | 1.00 | | 6,842 lbs |
| N(pe) | 2.00 | | Occupational and public (SWLF) |
| **P Index** | 3.00 | | |
| | | | |
| N(f) | 0.00 | | ESTIMATION (Iron) |
| N(x) | 0.00 | | ESTIMATION (Iron) |
| **PH Index** | **1.00** | | |
| | | | |
| N(b) | 2.00 | | ESTIMATION - No data, but possibility exists (Iron) |
| N(e) | 3.00 | | ESTIMATION - No data, but possibility exists (Iron) |
| **EH Index** | **4.25** | | |
| | | | |
| N(a) | 3.00 | 6.00 | Lewis (1991a): LDlo subcutaneous rat for iron oxide - 135 mg/kg |
| | | | |
| N(s) | 7.00 | 14.00 | Fox and Rader (1988) and Rader (1988) - Maximum tolerable level = .8 mg Fe/kg |
| | | | |
| N(c) | 3.00 | 9.00 | Lewis (1991a) - Iron Oxide may be carcinogenic |
| | | | |
| N(m) | 2.00 | 2.00 | Hsie (1979) |
| | | | |
| N(t) | 2.00 | 6.00 | ESTIMATION - Based on Fox and Rader (1988) |
| | | | |
| N(r) | 2.00 | 6.00 | ESTIMATION - Based on Fox and Rader (1988) |
| Total | | 37.00 | |
| **HH Index** | **5.31** | | |
| | | | |
| **Risk Index** | ***50.59*** | | |

| 1548 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Iron III Phosphate** | | | **Ferric Salts - toxic orally in large doses - corrosive irritants and systemic poisons** |
| | | | Iron III Phosphate not mentioned in literature - Data based on iron unless otherwise stated |
| N(ap) | 1.00 | | 8,597 |
| N(pe) | 2.00 | | Occupational and public (SWLF) |
| **P Index** | 3.00 | | |
| | | | |
| N(f) | 0.00 | | ESTIMATION (Iron) |
| N(x) | 0.00 | | ESTIMATION (Iron) |
| **PH Index** | **1.00** | | |
| | | | |
| N(b) | 2.00 | | ESTIMATION - No data, but possibility exists (Iron) |
| N(e) | 3.00 | | ESTIMATION - No data, but possibility exists (Iron) |
| **EH Index** | **4.25** | | |
| | | | The following are based on Iron data: |
| N(a) | 3.00 | 6.00 | Lewis (1991a): LDlo subcutaneous rat for iron oxide - 135 mg/kg |
| | | | |
| N(s) | 7.00 | 14.00 | Fox and Rader (1988) and Rader (1988) - Maximum tolerable level = .8 mg Fe/kg |
| | | | |
| N(c) | 3.00 | 9.00 | Lewis (1992) - Iron Oxide may be carcinogenic |
| | | | |
| N(m) | 2.00 | 2.00 | Hsie (1979) |
| | | | |
| N(t) | 2.00 | 6.00 | ESTIMATION - Based on Fox and Rader (1988) |
| | | | |
| N(r) | 2.00 | 6.00 | ESTIMATION - Based on Fox and Rader (1988) |
| Total | | 37.00 | |
| **HH Index** | **5.31** | | |
| | | | |
| **Risk Index** | ***50.59*** | | |

| 1176 |  | WT'd |  |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Iron (II) Sulfate** |  |  | **Lewis (1991b) - Poison by ingestion; Moderately toxic by unspecified routes** |
|  |  |  |  |
| N(ap) | 3.00 |  | >100,000 |
| N(pe) | 2.00 |  | Occupational and Public |
| **P Index** | **5.00** |  |  |
|  |  |  |  |
| N(f) | 0.00 |  | Not expected - it is dissolved in water |
| N(x) | 0.00 |  | Not expected - it is dissolved in water |
| **PH Index** | 1.00 |  |  |
|  |  |  |  |
| N(b) | 1.00 |  | ESTIMATION - No data, not expected |
| N(e) | 6.00 |  | ESTIMATION - based on Human data; Additionally, Weiss (1986) finds it harmful to aquatic life at low concentrations |
| **EH Index** | **5.50** |  |  |
|  |  |  |  |
| N(a) | 7.00 | 14.00 | Lewis (1991b): LD50 rat oral = 319 mg/kg; LDlo child=390 mg/kg & woman= 1-60 mg/kg GIT and CNS |
|  |  |  |  |
| N(s) | 2.00 | 4.00 | Lewis (1991b) - No data |
|  |  |  |  |
| N(c) | 3.00 | 9.00 | Lewis (1991b) - Questionable carcinogen, experimental tumorogenisis |
|  |  |  |  |
| N(m) | 2.00 | 2.00 | Lewis (1991b) - Experimental mutation information reported |
|  |  |  |  |
| N(t) | 3.00 | 9.00 | Lewis (1991b) - Experimental teratogen |
|  |  |  |  |
| N(r) | 3.00 | 9.00 | Lewis (1991b) - Experimental reproductive effects |
| Total |  | 38.00 |  |
| **HH Index** | **5.80** |  |  |
|  |  |  |  |
| **Risk Index** | ***95.51*** |  |  |

| 184 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Isopropyl Alcohol** | | | **Poison by Ingestion & Subcutaneous; Moderately Toxic by Intravenous & Interperiteanal;** |
| | | | **Mildly Toxic by Dermal** |
| N(ap) | 1.00 | | <10,000 lbs used |
| N(pe) | 2.00 | | 2 pops - public and occupational |
| **P Index** | **3.00** | | |
| | | | |
| N(f) | 3.00 | | WHO, 1990: FP = 62.6 F B.P. = 180 F |
| N(x) | 4.00 | | Volatile, vapors will detonate under normal conditions if spark is applied |
| **PH Index** | **10.00** | | |
| | | | |
| N(b) | 0.00 | | WHO, 1990: Low prOba (1980)bility of bioaccumulation -- BCF = .5; Kow = .14 |
| N(e) | 2.00 | | WHO, 1990: EC50 in fresh water fish = 2285 - 9714 mg/l |
| **EH Index** | **1.00** | | |
| | | | |
| N(a) | 1.00 | 2.00 | Grosselin: LD50 = 8 gr/kg; WHO - 4.5-7.99 gr/kg; Lewis (1991b) poison by ingestion |
| | | | |
| N(s) | 1.00 | 2.00 | ESTIMATE due to ability to irritate when inhaled (MSDS); Lewis (1991b): mildly toxic for dermal |
| | | | |
| N(c) | 2.00 | 6.00 | WHO, 1990: not enough data, but mouse data negative for oral, inhaled and subcutaneous; |
| | | | Lewis (1991a) - carcinogenic questionable |
| N(m) | 3.00 | 3.00 | Soderman (1982) - insufficient, inconclusive; Lewis (1991b)- positive for 2 tests, 1 for inhalation |
| | | | |
| N(t) | 3.00 | 9.00 | WHO, 1990: Can cause teratogenic effects in rats |
| | | | |
| N(r) | 2.00 | 6.00 | WHO, 1990: little test data, but did decrease weight of F generation |
| Total | | 22.00 | |
| **HH Index** | **3.46** | | |
| | | | |
| **Risk Index** | ***83.74*** | | |

| 215 |  | WT'd |  |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
|  |  |  | Lewis (1991a): MgOH listed on TSCA list; (These numbers represent data for Magnesium) |
| **Magnesium Hydroxide** |  |  | **Magnesium Toxic Via: Poison by ingestion; Inhaling powder causes metal fume fever** |
| N(ap) | 2.00 |  | >10,000 lbs of Mg used |
| N(pe) | 2.00 |  | Occupational and public (WWTP) |
| **P Index** | **4.00** |  |  |
|  |  |  |  |
| N(f) | 0.00 |  | Seeger (1993): shouldn't burn and it is in a slurry form; hazardous only in dry form |
| N(x) | 0.00 |  | Seeger (1993): normally stable |
| **PH Index** | **1.00** |  |  |
|  |  |  |  |
| N(b) | 1.00 |  | Lack of information other than most sources say it is not persistent and non-toxic |
| N(e) | 1.00 |  | Lack of information other than most sources say it is not persistent and non-toxic |
| **EH Index** | **2.25** |  |  |
|  |  |  |  |
| N(a) | 2.00 | 4.00 | Seeger (1993): says it is non-toxic, but it can be irritating if inhaled; Frazier (1979) .5-5 g/kg |
|  |  |  | Weiss (1986) and Grosselin - toxicity rating of 3 |
| N(s) | 1.00 | 2.00 | Birch (1988) - minimally toxic to people with kidney problems who can't excrete it |
|  |  |  |  |
| N(c) | 0.00 | 0.00 | Birch (1988) - no danger, non-toxic |
|  |  |  |  |
| N(m) | 1.00 | 1.00 | ESTIMATE based on Birch (1988); also no mention in Lewis (1992,1991a,1991b) or Soderman (1982) |
|  |  |  |  |
| N(t) | 1.00 | 3.00 | ESTIMATE based on Birch (1988); also no mention in Lewis (1992,1991a,1991b) or Soderman (1982) |
|  |  |  |  |
| N(r) | 1.00 | 3.00 | ESTIMATE based on Birch (1988); also no mention in Lewis (1992,1991a,1991b) or Soderman (1982) |
| Total |  | 10.00 |  |
| **HH Index** | **1.60** |  |  |
|  |  |  |  |
| **Risk Index** | ***29.84*** |  |  |

| 1238 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Magnesium Sulfate** | | | |
| | | | |
| N(ap) | 2.00 | | 19,320 pounds |
| N(pe) | 2.00 | | Public (POTW) and occupational |
| **P Index** | **4.00** | | |
| | | | |
| N(f) | 0.00 | | Not applicable |
| N(x) | 0.00 | | Not applicable |
| **PH Index** | **1.00** | | |
| | | | |
| N(b) | 1.00 | | See information on Mg |
| N(e) | 1.00 | | See information on Mg |
| **EH Index** | **2.25** | | |
| | | | |
| N(a) | 1.00 | 2.00 | Lewis (1992): Oral LDlo mouse = 5,000 mg/kg; rabbit 3,000 mg/kg |
| | | | |
| N(s) | 1.00 | 2.00 | Lewis (1992): Systemic heart changes, cyanosis, flaccid paralysis |
| | | | |
| N(c) | 0.00 | 0.00 | Not mentioned in references |
| | | | |
| N(m) | 2.00 | 2.00 | Lewis (1992): Mutation data reported |
| | | | |
| N(t) | 3.00 | 9.00 | Lewis (1992): Experimental |
| | | | |
| N(r) | 1.00 | 3.00 | Not mentioned in references |
| Total | | 15.00 | |
| **HH Index** | **2.22** | | |
| | | | |
| **Risk Index** | *34.77* | | |

| 246 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Methyl Ethyl Ketone** | | | **Moderately Toxic by Ingestion, Dermal & Intraperitoneal; Strong Irritant** |
| | | | CRTK, TSCA Inventory, Genetic toxicology Program |
| N(ap) | 1.00 | | <10,000 lbs used |
| N(pe) | 2.00 | | 2 pops - Public and occupational |
| **P Index** | **3.00** | | |
| | | | |
| N(f) | 3.00 | | WHO (1993): rapidly disperses in air; B.P.> 100F (175) and F.P. < 100F |
| N(x) | 4.00 | | WHO (1993): will volatilize and detonate under normal conditions |
| **PH Index** | **10.00** | | |
| | | | |
| N(b) | 0.00 | | WHO (1993): BCF = .5 |
| N(e) | 2.00 | | WHO (1993): naturally ubiquitous; CLSES (1984) LC50 and EC50 (96hr) = 3220 mg/l |
| **EH Index** | **1.00** | | |
| | | | |
| N(a) | 3.00 | 6.00 | (Neur, 1985): Oral LD50 = 2.5 - 3.4 g/kg; WHO (1993): 2-6g/kg |
| | | | |
| N(s) | 1.00 | 2.00 | Cavender (1984): 5000pmm increased liver weight and decreased brain weight |
| | | | |
| N(c) | 0.00 | 0.00 | WHO (1993) and Strickland |
| | | | |
| N(m) | 0.00 | 0.00 | WHO (1993): does cause mutations in one yeast sp.; Strickland |
| | | | |
| N(t) | 3.00 | 9.00 | WHO (1993): rats at high doses |
| | | | |
| N(r) | 1.00 | 3.00 | WHO (1993) |
| Total | | 17.00 | |
| **HH Index** | **2.47** | | |
| | | | |
| **Risk Index** | ***77.81*** | | |

| 277 |  | WT'd |  |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **1-Methoxy-2-Propanol** |  |  | **Mildly toxic by ingestion and dermal; skin irritant** |
|  |  |  | Lewis (1992): Syn w/ Beta-Propylene glycol monoethylether; Glycerol on CRTK |
| N(ap) | 1.00 |  | <10,000 lbs used |
| N(pe) | 2.00 |  | Occupational and public (air) |
| **P Index** | **3.00** |  |  |
|  |  |  |  |
| N(f) | 3.00 |  | Bosen (1985), 1985: FP = 100.4F BP = 212-217F |
| N(x) | 4.00 |  | ESTIMATE - It is an alcohol and therefore capable of volatilizing |
| **PH Index** | **10.00** |  |  |
|  |  |  |  |
| N(b) | 1.00 |  | Bosen (1985), 1985 (antifreeze) - Biologically degraded |
| N(e) | 1.00 |  | Bosen (1985), 1985: Minor in small concentration to aquatic organisms |
| **EH Index** | **2.25** |  |  |
|  |  |  |  |
| N(a) | 3.00 | 6.00 | Grosselin: 1,2 Propandiol (Propylene glycol); Low toxicity of 2, LD50(rat) - 21 mg/kg |
|  |  |  | Lewis (1992): 3-methoxy-1-propanol LD50 rat oral = 5710mg/kg and rabbit dermal = 5660 mg/kg |
| N(s) | 2.00 | 4.00 | Grosselin: High doses and /or long term exposure can lead to decreased CNS function, depression, |
|  |  |  | hemolysis and kidney problems (1,2 Propandiol, propylene glycol) |
| N(c) | 0.00 | 0.00 | MSDS: Not listed as a carcinogen |
|  |  |  |  |
| N(m) | 0.00 | 0.00 | Not mentioned in sources found |
|  |  |  |  |
| N(t) | 1.00 | 3.00 | Not mentioned in sources found |
|  |  |  |  |
| N(r) | 1.00 | 3.00 | Not mentioned in sources found |
| Total |  | 13.00 |  |
| **HH Index** | **1.97** |  |  |
|  |  |  |  |
| **Risk Index** | *78.60* |  |  |

| 308 | | WT'd | Notes |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Teratogenic and pneumonia by aspiration; Cancer by dermal & maybe by Ingestion; Eye Irritant** |
| **Mineral Oil - Preservative** | | | Lewis (1991a, 1991b, 1992): List Mineral Oil (MO) and individual components separately; |
| | | | Mineral Oil is on the OSHA list and Barium on SARA |
| N(ap) | 2.00 | | >10,000 used |
| N(pe) | 3.00 | | Public (air), consumer, occupational |
| **P Index** | **5.00** | | |
| | | | |
| N(f) | 1.00 | | MSDS - BP >300 F, FP - 330 F - Flammable limit 1%-6% |
| N(x) | 3.00 | | MSDS (cutting oil) - Material can volatilize & explode if a spark occurs; it will burn; |
| **PH Index** | **7.25** | | avoid strong oxidizers |
| | | | |
| N(b) | 2.00 | | Zahlsen (1992), accumulates in rats (inhalation) |
| N(e) | 3.00 | | Based on the potential presence of naphthenic oils |
| **EH Index** | **4.25** | | |
| | | | |
| N(a) | 1.00 | 2.00 | MSDS - mildly irritating to eyes and skin |
| | | | |
| N(s) | 1.00 | 2.00 | MSDS - no long term sub-chronic effects listed, but Cruikshank (1993) found skin lesions in workers |
| | | | |
| N(c) | 5.00 | 15.00 | MSDS - says no, Lewis (1991a, 1991b, 1992): lists components as carcinogens |
| | | | |
| N(m) | 2.00 | 2.00 | Apostali (1993) - cutting oil positive; but no mention in other sources |
| | | | |
| N(t) | 5.00 | 15.00 | Lewis (1992, 1991b): "human teratogen by inhalation which causes testicular tumors in fetus" |
| | | | |
| N(r) | 2.00 | 6.00 | ESTIMATION - based on formation of testicular tumors in fetus |
| Total | | 36.00 | |
| **HH Index** | **5.18** | | |
| | | | |
| **Risk Index** | ***145.59*** | | |

| 339 |  | WT'd |  |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Mineral Spirits** |  |  | **Mildly toxic by inhalation, interperitoneal and ingestion** |
|  |  |  | MSDS lists aliphatic hydrocarbons as a component; sorbed spills can be disposed of in a SWLF. |
| N(ap) | 2.00 |  | >10,000 used |
| N(pe) | 2.00 |  | Pubic (air) and occupational |
| **P Index** | **4.00** |  |  |
|  |  |  |  |
| N(f) | 1.00 |  | MSDS - BP = 217 FP = 150F; but Wiess says that the FP = 105-140F and BP = 210 - 395F |
| N(x) | 4.00 |  | MSDS - "never use welding or cutting torch on or near drum (even empty) because product or even |
| **PH Index** | **10.00** |  | residue can ignite explosively." |
|  |  |  |  |
| N(b) | 1.00 |  | Zahlsen (1992) - accumulates in rats; Weiss (1986) says no food chain accumulation |
| N(e) | 3.00 |  | Potential presence of naphthenes |
| **EH Index** | **3.50** |  |  |
|  |  |  |  |
| N(a) | 3.00 | 6.00 | Grosselin - Lists as 3, severe irritation to eyes, skin gastrointestinal tract (ingested) and respiratory |
|  |  |  | system (inhaled) |
| N(s) | 2.00 | 4.00 | MSDS - no long term health effects listed |
|  |  |  |  |
| N(c) | 0.00 | 0.00 | MSDS - not carcinogenic, but Grosselin says that it may contain up to .1% benzene |
|  |  |  |  |
| N(m) | 0.00 | 0.00 | Conway (1985) - negative for three tests |
|  |  |  |  |
| N(t) | 1.00 | 3.00 | No mention made in Lewis (1991a, 1991b, 1992) |
|  |  |  |  |
| N(r) | 1.00 | 3.00 | No mention made in Lewis (1991a, 1991b, 1992) |
| Total |  | 13.00 |  |
| **HH Index** | **1.97** |  |  |
|  |  |  |  |
| **Risk Index** | ***109.80*** |  |  |

| 370 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Naphthenic Mineral Oil** | | | Cancer Data is from Lewis1991a: MQV810 MO Petroleum distillates, light naphthenic |
| **const of Cutting Oil** | | | **Toxic Action: Dermal** |
| N(ap) | 2.00 | | ESTIMATE >10,000 used |
| N(pe) | 2.00 | | Public (Burned or Hazardous Waste Injection Well), Occupational Exposure |
| **P Index** | **4.00** | | |
| | | | |
| N(f) | 1.00 | | MSDS - FP = 330F, it will burn |
| N(x) | 3.00 | | MSDS - "Do not solder or produce sparks around empty or full drums as explosion can occur" |
| **PH Index** | **7.25** | | |
| | | | |
| N(b) | 3.00 | | Zahlsen (1992) - Can accumulate in rats; inhalation in rats more so |
| N(e) | 3.00 | | Herman - Naphthenic acid acutely toxic |
| **EH Index** | **6.50** | | |
| | | | |
| N(a) | 2.00 | 4.00 | MSDS - mild irritant to eyes; prolonged exposure to skin causes irritation |
| | | | |
| N(s) | 0.00 | 0.00 | Beck (1984) - 5day patch tests on rabbits showed no problems at 5g/kg |
| | | | |
| N(c) | 5.00 | 15.00 | MSDS says not, but other data (Tsjui, 1992) indicate that there may be a risk of skin cancer |
| | | | Lewis (1991a, 1991b, 1992) indicates it is |
| N(m) | 1.00 | 1.00 | Conway (1985) - negative for three tests; but Lewis says that data is insufficient and conflicting |
| | | | |
| N(t) | 1.00 | 3.00 | Not listed in Lewis (1991a, 1991b, 1992); no suspicion |
| | | | |
| N(r) | 1.00 | 3.00 | Not listed in Lewis (1991a, 1991b, 1992); no suspicion |
| Total | | 23.00 | |
| **HH Index** | **3.21** | | |
| | | | |
| **Risk Index** | ***109.67*** | | |

| 463 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Neutralizer** | | | Contains Sodium Nitrite which is toxic and an oxidizer and Sodium Borate an irritant |
| | | | |
| N(ap) | 1.00 | | <10,000 used |
| N(pe) | 2.00 | | Occupational and public (swlf and wastewater) |
| **P Index** | **3.00** | | |
| | | | |
| N(f) | 3.00 | | MSDS - Listed Hazardous Waste for ignitability; CFR 251.21; DOO1 (oxidizer) |
| N(x) | 1.00 | | MSDS - normally stable but acid mixed with the nitrite in this product produces noxious nitrous oxide gas |
| **PH Index** | **4.00** | | |
| | | | |
| N(b) | 3.00 | | Borate |
| N(e) | 6.00 | | Nitrite |
| **EH Index** | **7.00** | | |
| | | | |
| N(a) | 5.00 | 10.00 | MSDS - LD50(rat) = 85 mg/kg NaNO2 |
| | | | |
| N(s) | 4.00 | 8.00 | MSDS - Prolonged exposure can cause corneal burns and permanent damage to eyes (Nitrite) |
| | | | |
| N(c) | 3.00 | 9.00 | Nitrite |
| | | | |
| N(m) | 4.00 | 4.00 | Nitrite |
| | | | |
| N(t) | 3.00 | 9.00 | Nitrite |
| | | | |
| N(r) | 4.00 | 12.00 | Borate |
| Total | | 40.00 | |
| **HH Index** | **6.42** | | |
| | | | |
| **Risk Index** | ***83.51*** | | |

| 990 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Nitrate** | | | **Toxic via: Large amounts taken orally have serious effects** |
| | | | |
| N(ap) | 2.00 | | 27,000 lbs |
| N(pe) | 3.00 | | Consumer, occupational and public (wastewater and sw) |
| **P Index** | **5.00** | | |
| | | | |
| N(f) | 1.00 | | CRC (Weast) - BP > 300C |
| N(x) | 1.00 | | Potential exists for explosion if mixed with organic material and detonated; Lewis (1991b) - can |
| **PH Index** | **3.50** | | explode in dry state if heated |
| | | | |
| N(b) | 0.00 | | ESTIMATION |
| N(e) | 4.00 | | Laue (1991) - (fertilizer) may contribute to eutrophication |
| **EH Index** | **2.50** | | |
| | | | |
| N(a) | 3.00 | 6.00 | Grosselin - Toxicity of 3 |
| | | | |
| N(s) | 3.00 | 6.00 | Thiemann (1991) - daily dose (food additive) of 0-5 mg/kg-d |
| | | | |
| N(c) | 2.00 | 6.00 | National Academy of Sciences (1981) - Lewis (1991b) may increase cancer chances |
| | | | |
| N(m) | 1.00 | 1.00 | National Academy of Sciences (1981) |
| | | | |
| N(t) | 1.00 | 3.00 | National Academy of Sciences (1981) |
| | | | |
| N(r) | 1.00 | 3.00 | National Academy of Sciences (1981) |
| Total | | 22.00 | |
| **HH Index** | **3.09** | | |
| | | | |
| **Risk Index** | ***78.36*** | | |

| 401 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Nitric Acid** | | | **Toxic via: Unspecified route and is an irritant; Poison by Ingestion** |
| From ZnPO4 Tank | | | |
| N(ap) | 2.00 | | >10,000 |
| N(pe) | 2.00 | | Occupational and Public |
| **P Index** | **4.00** | | |
| | | | |
| N(f) | 1.00 | | ESTIMATE - BP = 180.7F, no FP available and will ignite spontaneously with organic substances |
| N(x) | 2.00 | | Laue (1991): will react with water; Mercks - rxn w/alcohol, turpentine, charcoal, organic debris |
| **PH Index** | **3.50** | | |
| | | | |
| N(b) | 0.00 | | Weiss (1986) - doesn't concentrate in food chain |
| N(e) | 6.00 | | Weiss (1986) - harmful at very low concentrations 72ppm/96hr/mosquito fish/TLm/freshwater |
| **EH Index** | **5.25** | | |
| | | | |
| N(a) | 7.00 | 14.00 | Laue (1991): Extremely irritating; Lewis (1992): Oral human LDlo = 430mg/kg; man LD50 - 110mg/kg |
| | | | |
| N(s) | 5.00 | 10.00 | Aerosals of nitrous fumes are strong oxidizers and can cause pulmonary impairment |
| | | | |
| N(c) | 0.00 | 0.00 | No mention in Refences |
| | | | |
| N(m) | 0.00 | 0.00 | No mention in Refences |
| | | | |
| N(t) | 3.00 | 9.00 | Lewis (1992) - Experimental Teratogen |
| | | | |
| N(r) | 3.00 | 9.00 | Lewis (1992) - Experimental Reproductive Effects |
| Total | | 33.00 | |
| **HH Index** | **5.18** | | |
| | | | |
| **Risk Index** | *90.47* | | |

| 1269 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Nitric Oxide (NO)** | | | **Poison gas** |
| | | | Contributes to acid rain; on EPA's Extremely Hazardous Substance List and TSCA Inventory |
| N(ap) | 1.00 | | 310 lbs |
| N(pe) | 2.00 | | Occupational and Public (Air) |
| **P Index** | **3.00** | | |
| | | | |
| N(f) | 0.00 | | Weiss (1986) - not flammable |
| N(x) | 0.00 | | Weiss (1986) - stable, but reacts with water to form nitric acid |
| **PH Index** | **1.00** | | |
| | | | |
| N(b) | 0.00 | | Weiss (1986) - none |
| N(e) | 1.00 | | Weiss (1986) - unknown |
| **EH Index** | **1.00** | | |
| | | | |
| N(a) | 3.00 | 6.00 | Lewis (1992): Inhalation LC50 rat = 1068mg/m3; mouse 320 ppm |
| | | | |
| N(s) | 2.00 | 4.00 | Lewis (1992): Irritation of lungs |
| | | | |
| N(c) | 0.00 | 0.00 | No mention in literature |
| | | | |
| N(m) | 2.00 | 2.00 | Lewis (1992): Mutation data reported |
| | | | |
| N(t) | 1.00 | 3.00 | No mention in literature |
| | | | |
| N(r) | 1.00 | 3.00 | No mention in literature |
| Total | | 15.00 | |
| **HH Index** | **2.22** | | |
| | | | |
| **Risk Index** | ***22.33*** | | |

| 1114 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Nitrosamines** | | | **Toxic via: All routes** |
| | | | |
| N(ap) | 2.00 | | Potentially >10,000 lbs |
| N(pe) | 3.00 | | Occupational, consumer, public |
| **P Index** | **5.00** | | |
| | | | |
| N(f) | 0.00 | | ESTIMATION |
| N(x) | 1.00 | | ESTIMATION |
| **PH Index** | **3.50** | | |
| | | | |
| N(b) | 0.00 | | ESTIMATION |
| N(e) | 4.00 | | NAS (1981) - Ability to cause mutations and teratogenic effects |
| **EH Index** | **2.50** | | |
| | | | |
| N(a) | 3.00 | 6.00 | *NAS (1981)- states that nitros amines have the ability to cause problems in all areas listed below* |
| | | | |
| N(s) | 3.00 | 6.00 | |
| | | | |
| N(c) | 6.00 | 18.00 | Lewis (1991a)- known carcinogen |
| | | | |
| N(m) | 4.00 | 4.00 | |
| | | | |
| N(t) | 3.00 | 9.00 | |
| | | | |
| N(r) | 3.00 | 9.00 | |
| Total | | 43.00 | |
| **HH Index** | **6.42** | | |
| | | | |
| **Risk Index** | *111.68* | | |

| 432 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Paraffinic Petroleum Distillate** | | | **Toxic Via: Dermal** |
| (Cutting Oil Constituent) | | | Lewis (1991a): MQV815 MO petroleum distillates, light paraffinic |
| N(ap) | 2.00 | | ESTIMATION >10,000 |
| N(pe) | 2.00 | | Public and Occupational exposure |
| **P Index** | **4.00** | | |
| | | | |
| N(f) | 1.00 | | MSDS - FP = 330F, will burn |
| N(x) | 3.00 | | MSDS - Do not solder or produce sparks around empty or full drums - explosion can occur |
| **PH Index** | **7.25** | | |
| | | | |
| N(b) | 2.00 | | Zahlsen (1992) - accumulates in rate (inhaled) |
| N(e) | 2.00 | | Less toxic than naphthene |
| **EH Index** | **4.00** | | |
| | | | |
| N(a) | 2.00 | 4.00 | MSDS - Mild irritant to eyes; prolonged exposure to skin caused irritation |
| | | | |
| N(s) | 6.00 | 12.00 | MSDS - no chronic problems listed; Lewis - irritating |
| | | | |
| N(c) | 3.00 | 9.00 | Conway (1985) - cancer in pure concentration; Lewis (1991a) Increases tumorogenicity |
| | | | |
| N(m) | 3.00 | 3.00 | Lewis (1992 and 1991a) - Some mutagenicity data reported |
| | | | |
| N(t) | 1.00 | 3.00 | Not mentioned in references, not suspected |
| | | | |
| N(r) | 1.00 | 3.00 | Not mentioned in references, not suspected |
| Total | | 31.00 | |
| **HH Index** | **4.20** | | |
| | | | |
| **Risk Index** | ***107.57*** | | |

| 1021 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Phosphate** | | | |
| | | | |
| N(ap) | 2.00 | | 43,000 lbs |
| N(pe) | 3.00 | | Consumer, occupational and public (wastewater and sw) |
| **P Index** | **5.00** | | |
| | | | |
| N(f) | 0.00 | | ESTIMATION |
| N(x) | 1.00 | | ESTIMATION |
| **PH Index** | **3.50** | | |
| | | | |
| N(b) | 0.00 | | ESTIMATION |
| N(e) | 4.00 | | Potential for contribution to eutrophication |
| **EH Index** | **2.50** | | |
| | | | |
| N(a) | 3.00 | 6.00 | Grosselin - Intramuscular injection into rats - 250mg/kg; oral mice 250mg/kg caused diarrhea only |
| | | | |
| N(s) | 3.00 | 6.00 | Grosselin - Diarrhea at 250 mg/kg in mice; Schrodtler (1991): 0-70 mg/kg-d acceptable for humans |
| | | | |
| N(c) | 0.00 | 0.00 | Not mentioned as a problem in literature found |
| | | | |
| N(m) | 0.00 | 0.00 | Not mentioned as a problem in literature found |
| | | | |
| N(t) | 1.00 | 3.00 | Not mentioned as a problem in literature found |
| | | | |
| N(r) | 1.00 | 3.00 | |
| Total | | 15.00 | |
| **HH Index** | **2.22** | | |
| | | | |
| **Risk Index** | ***69.72*** | | |

| 525 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Potassium Hydroxide** | | | **Toxic Via: Ingestion and is an irritant and corrosive to skin, eyes and mucous membranes** |
| (Caustic Cleaner Constituent) | | | |
| N(ap) | 1.00 | | <10,000 |
| N(pe) | 2.00 | | Occupational and public (ww) |
| **P Index** | **3.00** | | |
| | | | |
| N(f) | 0.00 | | Schultz (1993) |
| N(x) | 2.00 | | Release of heat when mixed with water |
| **PH Index** | **6.00** | | |
| | | | |
| N(b) | 0.00 | | Weiss (1986) - no food chain accumulation expected |
| N(e) | 6.00 | | Local problems from hydroxide; Weiss (1986) - Harmful in low concentrations |
| **EH Index** | **5.25** | | |
| | | | |
| N(a) | 5.00 | 10.00 | Martin (1988) - LD50 = 40 mg/kg for NaOH; Weiss (1986) - LD50 KOH = 364 mg/kg oral rat |
| | | | |
| N(s) | 4.00 | 8.00 | Martin (1988) - 20% solution for 20 minutes for 2 1/2 days caused respiratory damage from NaOH |
| | | | |
| N(c) | 1.00 | 3.00 | Martin (1988) - Cancer potential may come from repeated damage and scar tissue (NaOH) |
| | | | |
| N(m) | 2.00 | 2.00 | Lewis (1991b) - Mutagenicity data reported |
| | | | |
| N(t) | 1.00 | 3.00 | Martin (1988) - may cause embryo mortality but no teratogenic effects noted |
| | | | |
| N(r) | 2.00 | 6.00 | Martin (1988) - positive for male grasshoppers (1966 study - limited data) and see above |
| Total | | 26.00 | |
| **HH Index** | **3.95** | | |
| | | | |
| **Risk Index** | *75.45* | | |

| 1300 |  | WT'd |  |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Potassium Ion** |  |  | **Toxicity usually comes from anion** |
|  |  |  |  |
| N(ap) | 1.00 |  | <10,000 lbs |
| N(pe) | 2.00 |  | Public and workers |
| **P Index** | **3.00** |  |  |
|  |  |  |  |
| N(f) | 0.00 |  | Not applicable (in solution) |
| N(x) | 0.00 |  | Not applicable (in solution) |
| **PH Index** | **1.00** |  |  |
|  |  |  |  |
| N(b) | 0.00 |  | Weiss (1986): None |
| N(e) | 4.00 |  | Weiss (1986): 80 ppm/24hr/mosquito fish/ TLm/fresh water |
| **EH Index** | **2.50** |  |  |
|  |  |  |  |
| N(a) | 3.00 | 6.00 | Grosselin: Toxicity =3; but rarely happens as most people vomit or excrete it before toxic levels build up |
|  |  |  | unless exposed person has kidney disease. |
| N(s) | 0.00 | 0.00 | No mention in literature |
|  |  |  |  |
| N(c) | 0.00 | 0.00 | No mention in literature |
|  |  |  |  |
| N(m) | 0.00 | 0.00 | No mention in literature |
|  |  |  |  |
| N(t) | 1.00 | 3.00 | No mention in literature |
|  |  |  |  |
| N(r) | 1.00 | 3.00 | No mention in literature |
| Total |  | 9.00 |  |
| **HH Index** | **1.48** |  |  |
|  |  |  |  |
| **Risk Index** | ***22.39*** |  |  |

| 556 |  | WT'd |  |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Preservative** |  |  | **MO Toxic via: Teratogenic and pneumonia by aspiration; Cancer by dermal & questionable by** |
|  |  |  | **ingestion; Eye irritant** |
| N(ap) | 2.00 |  | >10,000 |
| N(pe) | 3.00 |  | Occupational, public and consumer |
| **P Index** | 5.00 |  |  |
|  |  |  |  |
| N(f) | 1.00 |  |  |
| N(x) | 3.00 |  | See Mineral Oil |
| **PH Index** | 7.25 |  |  |
|  |  |  |  |
| N(b) | 2.00 |  | See Mineral Oil |
| N(e) | 4.00 |  | See Barium |
| **EH Index** | 4.25 |  |  |
|  |  |  |  |
| N(a) | 7.00 | 14.00 | MSDS - Acute Hazard (SARA); Barium may also be acutely hazardous - see Barium |
|  |  |  |  |
| N(s) | 3.00 | 6.00 | Barium |
|  |  |  |  |
| N(c) | 1.00 | 3.00 | MSDS - states no component is considered carcinogenic, however Lewis (1991a) says the possibility |
|  |  |  | exists for the mineral oil or one of its components to cause cancer |
| N(m) | 2.00 | 2.00 | There is reason to suspect because MO can be mutagenic (see mineral oil). |
|  |  |  |  |
| N(t) | 2.00 | 6.00 | There is reason to suspect because MO can be teratogenic (see mineral oil). |
|  |  |  |  |
| N(r) | 3.00 | 9.00 | There is reason to suspect because both MO and barium can cause reproductive effects. (See Mineral |
| Total |  | 31.00 | oil and Barium). |
| **HH Index** | **4.94** |  |  |
|  |  |  |  |
| **Risk Index** | *143.12* |  |  |

| 587 |  | **WT'd** |  |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Resin (Rosin) Acids** |  |  | **Toxic Via: Irritant** |
| (Caustic Cleaner Constituent) |  |  |  |
| N(ap) | 1.00 |  | <10,000 |
| N(pe) | 2.00 |  | Occupational and public (ww) |
| **P Index** | **3.00** |  |  |
|  |  |  |  |
| N(f) | 1.00 |  | Organic, should burn |
| N(x) | 0.00 |  | MSDS - no mention of explosive characteristics |
| **PH Index** | **1.00** |  |  |
|  |  |  |  |
| N(b) | 1.00 |  | No data; not expected to bioaccumulate |
| N(e) | 6.00 |  | Grosselin - Reports rosin acid in pulp mill waste is toxic to fish in 1-2 ppm; 4 rating due to low data |
| **EH Index** | **5.50** |  | Abietic Acid a component of rosins can cause CNS paralysis in frogs (Shao ,1993) |
|  |  |  |  |
| N(a) | 5.00 | 10.00 | Grosselin - PrOba (1980)bility of low toxicity LD50 = 5-15 gr/kg, but Shao (1993) says it is very sensitizing |
|  |  |  |  |
| N(s) | 2.00 | 4.00 | ESTIMATION - prolonged exposure could cause irritation or lesions Shao (1993) |
|  |  |  |  |
| N(c) | 0.00 | 0.00 | ESTIMATION - no data, no suspicion |
|  |  |  |  |
| N(m) | 0.00 | 0.00 | ESTIMATION - no data, no suspicion |
|  |  |  |  |
| N(t) | 1.00 | 3.00 | ESTIMATION - no data, no suspicion |
|  |  |  |  |
| N(r) | 1.00 | 3.00 | ESTIMATION - no data, no suspicion |
| Total |  | 17.00 |  |
| **HH Index** | **2.47** |  |  |
|  |  |  |  |
| **Risk Index** | *37.31* |  |  |

| 1331 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Sodium Ion** | | | **Grosselin: Toxicity comes from anion salts** |
| | | | |
| N(ap) | 1.00 | | <10,000 lbs |
| N(pe) | 2.00 | | Public and occupational |
| **P Index** | **3.00** | | |
| | | | |
| N(f) | 0.00 | | Not applicable |
| N(x) | 0.00 | | Not applicable |
| **PH Index** | **1.00** | | |
| | | | |
| N(b) | 0.00 | | Weiss (1986): None |
| N(e) | 2.00 | | Weiss (1986): Dangerous at high concentrations |
| **EH Index** | **1.00** | | |
| | | | |
| N(a) | 0.00 | 0.00 | Weiss (1986): Not pertinent |
| | | | |
| N(s) | 0.00 | 0.00 | Weiss (1986): Not pertinent |
| | | | |
| N(c) | 0.00 | 0.00 | No mention in literature |
| | | | |
| N(m) | 0.00 | 0.00 | No mention in literature |
| | | | |
| N(t) | 1.00 | 3.00 | No mention in literature |
| | | | |
| N(r) | 1.00 | 3.00 | No mention in literature |
| Total | | 3.00 | |
| **HH Index** | **0.74** | | |
| | | | |
| **Risk Index** | *13.44* | | |

| 618 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Sodium Borate** | | | **Toxic Via: Lewis no mention of routes; guess ingestion** |
| Neutralizer Constituent | | | Lewis (1991b): sodium borate is less hazardous than borax. When heated it decomposes to toxic Na2O gas. |
| N(ap) | 1.00 | | < 10,000 lbs used |
| N(pe) | 2.00 | | Occupational and public (wastewater) |
| **P Index** | **3.00** | | |
| | | | |
| N(f) | 0.00 | | ESTIMATE - CRC (Weast) BP 320C; Wiess - not flammable |
| N(x) | 0.00 | | ESTIMATE - no mention of explosive properties |
| **PH Index** | **1.00** | | |
| | | | |
| N(b) | 3.00 | | Weis (1991) - Can bioaccumulate in fish to lethal levels |
| N(e) | 3.00 | | Thompson (1976) - adverse effect at 113 ug/ml in fresh water salmonids |
| **EH Index** | **6.50** | | |
| | | | |
| N(a) | 3.00 | 6.00 | Grosselin - LD50 = .5 - 5 gr/kg |
| | | | |
| N(s) | 3.00 | 6.00 | Grosselin - chronic exposure can cause kidney and liver problems; Larson (1988) - NOAEL 44 mg/kg |
| | | | |
| N(c) | 1.00 | 3.00 | ESTIMATION - not mutagenic and no carcinogenic properties discussed in literature |
| | | | |
| N(m) | 0.00 | 0.00 | Larson (1988) - "Showed no evidence of mutation and no enhancement" |
| | | | |
| N(t) | 1.00 | 3.00 | Larson (1988) - no real data, but boric acid is positive at .2mg for chick embryo test |
| | | | |
| N(r) | 4.00 | 12.00 | Grosselin (and supported by Larson, 1988) - "chronic feeding to rats and dogs lead to accumulation |
| Total | | 18.00 | in testes; germ cell depletion and testicular atrophy". Lewis(1991b) Experimental reproductive effects |
| **HH Index** | **3.70** | | |
| | | | |
| **Risk Index** | *47.72* | | |

| 649 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Sodium Carbonate** | | | **Poison by interperitoneal; Moderately Toxic by inhalation and subcutaneous; Mildly toxic** |
| (Anhydrous) | | | **ingestion; Irritant to eyes** |
| N(ap) | 2.00 | | >7,000 used |
| N(pe) | 2.00 | | Occupational and public (SWLF) |
| **P Index** | **4.00** | | |
| | | | |
| N(f) | 0.00 | | Thieme (1993) - no indication that it is flammable |
| N(x) | 2.00 | | Thieme (1993) - release of heat when mixed with water |
| **PH Index** | **6.00** | | |
| | | | |
| N(b) | 1.00 | | No data; none expected |
| N(e) | 3.00 | | Due to alkalinity |
| **EH Index** | **3.50** | | |
| | | | |
| N(a) | 5.00 | 10.00 | Grosselin - LD50(oral) - 4gr/kg; Mercks - LD50 (mice-30 days) = 116 mg/kg and can cause |
| | | | methemoglOba (1980)nemia |
| N(s) | 2.00 | 4.00 | Grosselin - Repeated exposure from inhaling can cause necrosis of the nasal membranes |
| | | | |
| N(c) | 0.00 | 0.00 | ESTIMATE - no data to consider otherwise |
| | | | |
| N(m) | 0.00 | 0.00 | ESTIMATE - no data to consider otherwise |
| | | | |
| N(t) | 1.00 | 3.00 | ESTIMATE - no data to consider otherwise |
| | | | |
| N(r) | 3.00 | 9.00 | Lewis (1991b) - Experimental reproductive effects |
| Total | | 17.00 | |
| **HH Index** | **3.21** | | |
| | | | |
| **Risk Index** | *87.67* | | |

| 680 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Sodium Hydroxide** | | | **Liquid poison via interperitoneal; Moderately toxic by ingestion** |
| (Caustic Cleaner Constituent) | | | |
| N(ap) | 2.00 | | >10,000 used |
| N(pe) | 2.00 | | Occupational and public (wastewater) |
| **P Index** | **4.00** | | |
| | | | |
| N(f) | 0.00 | | Minz (1993) - Not flammable |
| N(x) | 2.00 | | Minz (1993) - Produces heat when mixed with water |
| **PH Index** | **6.00** | | |
| | | | |
| N(b) | 1.00 | | No data; no bioaccumulation expected |
| N(e) | 3.00 | | Local problem from alkalinity |
| **EH Index** | **3.50** | | |
| | | | |
| N(a) | 7.00 | 14.00 | Martin (1988) - LD50 = 40 mg/kg |
| | | | |
| N(s) | 4.00 | 8.00 | Martin (1988) - 20% solution for 20 minutes for 2 1/2 caused respiratory damage |
| | | | |
| N(c) | 1.00 | 3.00 | Martin (1988) - Cancer potential may come from repeated damage and scar tissue |
| | | | |
| N(m) | 2.00 | 2.00 | Martin (1988) - well tested; Lewis (1991b) says there is some positive mutagenicity data |
| | | | |
| N(t) | 1.00 | 3.00 | Martin (1988) - may cause embryo mortality but no teratogenic effects noted |
| | | | |
| N(r) | 2.00 | 6.00 | Martin (1988) - positive for male grasshoppers (1966 study - limited data) |
| Total | | **30.00** | |
| **HH Index** | **4.44** | | |
| | | | |
| **Risk Index** | ***97.55*** | | |

| 711 |  | WT'd |  |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Sodium Metaborate** |  |  | **Experimental poison subcutaneously; moderately toxic by ingestion; moderately toxic** |
| (Borax) |  |  | **experimentally via intravenous and interperitoneal** |
| N(ap) | 1.00 |  | < 10,000 lbs used |
| N(pe) | 2.00 |  | Occupational and public (ww) |
| **P Index** | **3.00** |  |  |
|  |  |  |  |
| N(f) | 0.00 |  | ESTIMATE - CRC (Weast) BP 320C; Weiss (1986) - not flammable |
| N(x) | 0.00 |  | ESTIMATE - no mention of explosive properties; Weiss (1986) - stable |
| **PH Index** | **1.00** |  |  |
|  |  |  |  |
| N(b) | 3.00 |  | Weis (1991) - Can bioaccumulate in fish to lethal levels |
| N(e) | 3.00 |  | Thompson (1976) - adverse effect at 113 ug/ml in fresh water salmonids |
| **EH Index** | **6.50** |  |  |
|  |  |  | Moderately toxic by ingestion |
| N(a) | 3.00 | 6.00 | Grosselin - LD50 = .5 - 5 gr/kg; Lewis 1 - oral man LD50 = 709 mg/kg |
|  |  |  |  |
| N(s) | 3.00 | 6.00 | Grosselin - chronic exposure can cause kidney and liver problems; Larson (1988) - NOAEL 44 mg/kg |
|  |  |  |  |
| N(c) | 1.00 | 3.00 | ESTIMATION - not mutagenic and no carcinogenic properties discussed in literature |
|  |  |  |  |
| N(m) | 2.00 | 2.00 | Larson (1988) - "Showed no evidence of mutation and no enhancement"; Lewis 1 - some positive |
|  |  |  | data reported |
| N(t) | 1.00 | 3.00 | Larson (1988) - no real data, but boric acid is positive at .2mg for chick embryo test |
|  |  |  |  |
| N(r) | 4.00 | 12.00 | Grosselin (and supported by Larson (1988)) - "chronic feeding to rats and dogs lead to accumulation |
| Total |  | 20.00 | in testes, germ cell depletion and testicular atrophy".; Weiss (1986) - positive reproduction effects |
| **HH Index** | **3.95** |  |  |
|  |  |  |  |
| **Risk Index** | ***49.20*** |  |  |

| 742 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Sodium Nitrite** | | | **Poison by ingestion; experimental poison by subcutaneous, intravenous, interperitoneal** |
| (Neutralizer Constituent) | | | |
| N(ap) | 1.00 | | <1,000 used |
| N(pe) | 2.00 | | Occupational and public (ww and sw) |
| **P Index** | **3.00** | | |
| | | | |
| N(f) | 1.00 | | CRC (Weast) - BP = 262 (saturated) |
| N(x) | 2.00 | | MSDS - Hazardous waste due to oxidizing nature of compound |
| **PH Index** | **6.00** | | |
| | | | |
| N(b) | 0.00 | | Weiss (1986) - not expected to accumulate in food chain |
| N(e) | 6.00 | | Weiss (1986) - harmful in low concentrations |
| **EH Index** | **5.25** | | |
| | | | |
| N(a) | 5.00 | 10.00 | Grosselin - LD median = 5-50 mg/kg; Lewis (1992) - oral rat = 4090 mg/kg |
| | | | |
| N(s) | 4.00 | 8.00 | Hawkes (1992) - Test data limited but infants can be affected at low doses |
| | | | |
| N(c) | 3.00 | 9.00 | NAS (1981) - potential exists if it combines with amines to form nitrosamines: Yoshida (1994) |
| | | | - promotes forestomach cancer and causes mutations |
| N(m) | 4.00 | 4.00 | Balimandawa (1994) - positive for 3 strains |
| | | | |
| N(t) | 3.00 | 9.00 | Hawkes (1992) - notes study where high doses in drinking water may have caused nerve problems |
| | | | in children whose mothers drank the water; Lewis (1992) - experimental data that it is a teratogen |
| N(r) | 3.00 | 9.00 | Lewis (1992) - experimental data that it causes reproductive effects |
| Total | | 40.00 | |
| **HH Index** | **6.05** | | |
| | | | |
| **Risk Index** | ***88.04*** | | |

| 1579 | | **WT'd** | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| Na/K/Rosin Acid Soaps | | | *See Sodium Stearate* |
| | | | |
| N(ap) | | | |
| N(pe) | | | |
| **P Index** | 0.00 | | |
| | | | |
| N(f) | | | |
| N(x) | | | |
| **PH Index** | | | |
| | | | |
| N(b) | | | |
| N(e) | | | |
| **EH Index** | | | |
| | | | |
| N(a) | | 0.00 | |
| | | | |
| N(s) | | 0.00 | |
| | | | |
| N(c) | | 0.00 | |
| | | | |
| N(m) | | 0.00 | |
| | | | |
| N(t) | | 0.00 | |
| | | | |
| N(r) | | 0.00 | |
| Total | | 0.00 | |
| **HH Index** | **0.00** | | |
| | | | |
| **Risk Index** | ***0.00*** | | |

| 773 | | WT'd | Notes |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | |
| **Sodium Stearate Soap** | | | **Toxic via: Intravenous routes and possibly others** |
| | | | |
| N(ap) | 2.00 | | >10,000 used |
| N(pe) | 2.00 | | 2 pops - occupational and public (swlf and air) |
| **P Index** | **4.00** | | |
| | | | |
| N(f) | 1.00 | | Organic, will prOba (1980)bly burn |
| N(x) | 0.00 | | MSDS - stable (pH = 1.00) |
| **PH Index** | **1.00** | | |
| | | | |
| N(b) | 1.00 | | Estimation: Mostly organic, should be broken down readily |
| N(e) | 4.00 | | Guthrie (1980) - 100 ppm is a LC to fathead minnows; ability to solubilize contaminants |
| **EH Index** | **3.50** | | |
| | | | |
| N(a) | 1.00 | 2.00 | MSDS - slightly irritating to eyes and respiratory tract; Grosselin - 5 to 15 g/kg is LD50; Mercks - syn |
| | | | is Stearic Acid Sodium Salt, LD50 for Stearic acid is 19.7-23.7mg/kg, w/Na is basic not acid |
| N(s) | 1.00 | 2.00 | MSDS - repeated exposure to skin can cause irritation |
| | | | |
| N(c) | 0.00 | 0.00 | MSDS - no component is listed as a carcinogen |
| | | | |
| N(m) | 1.00 | 1.00 | Oba (1980) - other anionic surfactants considered more toxic than sodium stearate were tested for |
| | | | mutagenicity, teratogenicity and reproductive effects and were either equivocal or negative |
| N(t) | 1.00 | 3.00 | No data, no suspicion |
| | | | |
| N(r) | 1.00 | 3.00 | No data, no suspicion |
| Total | | 8.00 | |
| **HH Index** | **1.36** | | |
| | | | |
| **Risk Index** | ***32.86*** | | |

| 1362 |  | WT'd |  |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Sulfate Ion** |  |  | **Lewis (1992) & Grosselin: Toxicity is from the cation although it reacts violently with Al and Mg** |
|  |  |  |  |
| N(ap) | 1.00 |  | <10,000 lbs |
| N(pe) | 2.00 |  | Occupational and public (SWLF) |
| **P Index** | **3.00** |  |  |
|  |  |  |  |
| N(f) | 0.00 |  | In solution |
| N(x) | 0.00 |  | In solution |
| **PH Index** | 1.00 |  |  |
|  |  |  |  |
| N(b) | 0.00 |  |  |
| N(e) | 1.00 |  |  |
| **EH Index** | 1.00 |  |  |
|  |  |  |  |
| N(a) | 3.00 | 6.00 | Grosselin |
|  |  |  |  |
| N(s) | 0.00 | 0.00 | No mention in references |
|  |  |  |  |
| N(c) | 0.00 | 0.00 | No mention in references |
|  |  |  |  |
| N(m) | 0.00 | 0.00 | No mention in references |
|  |  |  |  |
| N(t) | 1.00 | 3.00 | No mention in references |
|  |  |  |  |
| N(r) | 1.00 | 3.00 | No mention in references |
| Total |  | 9.00 |  |
| **HH Index** | **1.48** |  |  |
|  |  |  |  |
| **Risk Index** | *17.89* |  |  |

| 835 | | WT'd | Notes |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | |
| **Sulfuric Acid (93%)** | | | **Poison via unspecified route; experimental poison by inhalation; moderately toxic by ingestion;** |
| | | | **irritating to eyes and corrosive to all tissue** |
| N(ap) | 3.00 | | >100,000 |
| N(pe) | 2.00 | | Occupational and public (inj well, swlf, wastewater) |
| **P Index** | **5.00** | | |
| | | | |
| N(f) | 0.00 | | CRC (Weast) |
| N(x) | 2.00 | | Reacts with water |
| **PH Index** | **6.00** | | |
| | | | |
| N(b) | 0.00 | | Weiss (1986) - No food chain accumulation expected |
| N(e) | 6.00 | | Weiss (1986) - Harmful effects at low concentrations |
| **EH Index** | **5.25** | | |
| | | | |
| N(a) | 7.00 | 14.00 | Extremely irritating |
| | | | |
| N(s) | 2.00 | 4.00 | Lewis (1992, 1991a) - Repeated exposure at low doses can cause chronic bronchitis |
| | | | |
| N(c) | 2.00 | 6.00 | Zelikoff (1992) - 50ug can cause depression of immune system and may contribute to cancer |
| | | | at acute exposure |
| N(m) | 0.00 | 0.00 | ESTIMATION; no data, no suspicion |
| | | | |
| N(t) | 3.00 | 9.00 | Lewis (1992) - Experimental teratogen |
| | | | |
| N(r) | 1.00 | 3.00 | ESTIMATION; no data, no suspicion |
| Total | | 33.00 | |
| **HH Index** | **4.44** | | |
| | | | |
| **Risk Index** | ***130.68*** | | |

| 1610 | | **WT'd** | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Tramp Oil** | | | |
| | | | |
| N(ap) | 2.00 | | 11,000 lbs produced |
| N(pe) | 2.00 | | Public and occupational |
| **P Index** | 4.00 | | |
| | | | |
| N(f) | 1.00 | | See Mineral Oil |
| N(x) | 3.00 | | See Mineral Oil |
| **PH Index** | 7.25 | | |
| | | | |
| N(b) | 2.00 | | See Iron Oxide and Mineral Oil |
| N(e) | 3.00 | | See Iron Oxide and Mineral Oil |
| **EH Index** | 4.25 | | |
| | | | |
| N(a) | 2.00 | 4.00 | No data, expected to be mildly irritating (presence of cutting oil) |
| | | | |
| N(s) | 2.00 | 4.00 | No data, expected to be mildly irritating (presence of cutting oil) |
| | | | |
| N(c) | 2.00 | 6.00 | Insufficient data, suspected based on presence of Cutting Oil |
| | | | |
| N(m) | 2.00 | 2.00 | Insufficient data, suspected based on presence of mineral oil |
| | | | |
| N(t) | 2.00 | 6.00 | Insufficient data, suspected based on presence of mineral oil |
| | | | |
| N(r) | 2.00 | 6.00 | Insufficient data, suspected based on presence of mineral oil |
| Total | | 22.00 | |
| **HH Index** | **3.46** | | |
| | | | |
| **Risk Index** | *102.65* | | |

| 866 |  | WT'd | Notes |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **$H_3PO_4$ - Poison by unspecified route; moderately toxic by ingestion and dermal; corrosive and** |
| **Zinc Dihydrogen Phosphate** |  |  | **reacts violently with Borax** |
|  |  |  | Information is available through IRIS for Zinc and Zinc Compounds; CAS NO# 7440-66-6 |
| N(ap) | 2.00 |  | 73,000 lbs used |
| N(pe) | 3.00 |  | Product, public, occupational |
| **P Index** | **5.00** |  |  |
|  |  |  |  |
| N(f) | 0.00 |  | CRC (Weast) - no bp listed |
| N(x) | 1.00 |  | Presence of acid may release heat if mixed with water and also see nitrate |
| **PH Index** | **3.50** |  |  |
|  |  |  |  |
| N(b) | 3.00 |  | (Zn) Heath (1987) - Bioconc. in fish highest in skin and bone, although it accumulates in other areas |
| N(e) | 6.00 |  | (Zn) Sorenson (1991) - (p165) .87-40.90 ppm zn is LC50; can also cause growth retardation |
| **EH Index** | **7.00** |  |  |
|  |  |  |  |
| N(a) | 5.00 | 10.00 | (Zn) Frazier (1979) - Rates a 4 on Sax scale or 50-500 mg/kg |
|  |  |  |  |
| N(s) | 7.00 | 14.00 | (Zn) IRIS - LOAEL = 59.72 mg/day or 1.0 mg/kg/day; no NOAEL; Zn alters copper balance and can |
|  |  |  | result in anemia |
| N(c) | 1.00 | 3.00 | (Zn) IRIS - "D" not classifiable as a human carcinogen |
|  |  |  |  |
| N(m) | 2.00 | 2.00 | (Zn) IRIS - equivocal; those that dissociate may bind to media and not be taken into the cell |
|  |  |  |  |
| N(t) | 1.00 | 3.00 | (Zn) ESTIMATE - no mention in references |
|  |  |  |  |
| N(r) | 2.00 | 6.00 | (Zn) IRIS - direct injection may cause testicular tumors in test animals |
| Total |  | 32.00 |  |
| **HH Index** | **4.69** |  |  |
|  |  |  |  |
| **Risk Index** | ***116.90*** |  |  |

| 928 | | WT'd | Notes |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Toxic via: Inhalation and ingestion** |
| **Zinc** | | | Zn when heated forms ZnO, which when fresh causes flu symptoms. ZnO is innocuous after a time. Build up an |
| | | | immunity but immunity ceases after exposure cessation. On CRTK List |
| N(ap) | 2.00 | | > 10,000 lbs used |
| N(pe) | 3.00 | | Product, public, occupational |
| **P Index** | **5.00** | | |
| | | | |
| N(f) | 0.00 | | No mention of instability or flammability in literature found |
| N(x) | 0.00 | | Lewis (1992) - Hazardous as a powder |
| **PH Index** | **1.00** | | |
| | | | |
| N(b) | 3.00 | | Heath (1987) - (p71) Bioconc. in fish is highest in skin and bone, although it accumulates in other areas |
| N(e) | 6.00 | | Sorenson (1991) - (p165) .87-40.90 ppm zn is LC50; can also cause growth retardation |
| **EH Index** | **7.00** | | |
| | | | |
| N(a) | 5.00 | 10.00 | Frazier (1979) - Rates a 4 on Sax scale or 50-500 mg/kg |
| | | | |
| N(s) | 7.00 | 14.00 | IRIS - LOAEL = 59.72 mg/day or 1.0 mg/kg/day; no NOAEL; Zn alters cu balance and can result |
| | | | in anemia |
| N(c) | 1.00 | 3.00 | IRIS - "D" not classifiable as a human carcinogen |
| | | | |
| N(m) | 2.00 | 2.00 | IRIS - equivocal; those that dissociate may bind to media and not be taken into the cell |
| | | | |
| N(t) | 1.00 | 3.00 | ESTIMATE |
| | | | |
| N(r) | 2.00 | 6.00 | IRIS - direct injection may cause testicular tumors in test animals |
| Total | | 32.00 | |
| **HH Index** | **4.69** | | |
| | | | |
| **Risk Index** | ***91.90*** | | |

| 897 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Zinc Nitrate** | | | **Toxic Via: No route specified - See Zinc** |
| | | | |
| N(ap) | 2.00 | | 18,000 lbs used |
| N(pe) | 3.00 | | Product, public, occupational |
| **P Index** | **5.00** | | |
| | | | |
| N(f) | 0.00 | | CRC (Weast) - no bp listed |
| N(x) | 1.00 | | See nitrate; Lewis (1992) - strong oxidizer |
| **PH Index** | **3.50** | | |
| | | | |
| N(b) | 3.00 | | (Zn) Heath (1987) - Bioconc. in fish is highest in skin and bone, although it accumulates in other areas |
| N(e) | 6.00 | | (Zn) Sorenson (1991) - (p165) .87-40.90 ppm zn is LC50; can also cause growth retardation |
| **EH Index** | **7.00** | | Weiss (1986) (Zinc Nitrate) - Harmful at low concentrations |
| | | | |
| N(a) | 5.00 | 10.00 | (Zn) Frazier (1979) - Rates a 4 on Sax scale or 50-500 mg/kg |
| | | | |
| N(s) | 7.00 | 14.00 | (Zn) IRIS - LOAEL = 59.72 mg/day or 1.0 mg/kg/day; no NOAEL; Zn alters cu balance and can result |
| | | | in anemia; Weiss (1986) (Zinc Nitrate) can cause enlarged liver and spleen in rabbits |
| N(c) | 1.00 | 3.00 | (Zn) IRIS - "D" not classifiable as a human carcinogen |
| | | | |
| N(m) | 2.00 | 2.00 | (Zn) IRIS - equivocal; those that dissociate may bind to media and not be taken into the cell |
| | | | |
| N(t) | 1.00 | 3.00 | (Zn) ESTIMATE |
| | | | |
| N(r) | 2.00 | 6.00 | (Zn) IRIS - direct injection may cause testicular tumors in test animals |
| Total | | 32.00 | |
| **HH Index** | **4.69** | | |
| | | | |
| **Risk Index** | ***116.90*** | | |

| 1083 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Zinc Phosphate Coating Makeup** | | | |
| | | | |
| N(ap) | 3.00 | | >100,000 used (180,000 lbs) |
| N(pe) | 3.00 | | Consumer, occupational and public (wastewater and swlf) |
| **P Index** | **6.00** | | |
| | | | |
| N(f) | 0.00 | | |
| N(x) | 1.00 | | Nitric Acid and Nitrate |
| **PH Index** | **3.50** | | |
| | | | |
| N(b) | 3.00 | | Zinc |
| N(e) | 6.00 | | Zinc |
| **EH Index** | **7.00** | | |
| | | | |
| N(a) | 7.00 | 14.00 | Nitric Acid |
| | | | |
| N(s) | 7.00 | 14.00 | Zinc |
| | | | |
| N(c) | 1.00 | 3.00 | ESTIMATION based on Zinc |
| | | | |
| N(m) | 2.00 | 2.00 | Zinc |
| | | | |
| N(t) | 3.00 | 9.00 | Nitric Acid |
| | | | |
| N(r) | 3.00 | 9.00 | Nitric Acid |
| Total | | 42.00 | |
| **HH Index** | **6.29** | | |
| | | | |
| **Risk Index** | ***159.54*** | | |

| 1052 | | WT'd | |
|---|---|---|---|
| **Chemical** | **Score** | **Ave** | **Notes** |
| **Zinc Phosphate Coating Soln** | | | |
| | | | |
| N(ap) | 1.00 | | 1,900 lbs |
| N(pe) | 3.00 | | Consumer, occupational and public (wastewater and sw) |
| **P Index** | **4.00** | | |
| | | | |
| N(f) | 0.00 | | |
| N(x) | 1.00 | | Nitric Acid and Nitrate |
| **PH Index** | **3.50** | | |
| | | | |
| N(b) | 3.00 | | Zinc |
| N(e) | 6.00 | | Zinc |
| **EH Index** | **7.00** | | |
| | | | |
| N(a) | 7.00 | 14.00 | Nitric Acid |
| | | | |
| N(s) | 7.00 | 14.00 | Zinc |
| | | | |
| N(c) | 1.00 | 3.00 | (See zinc) |
| | | | |
| N(m) | 2.00 | 2.00 | Zinc |
| | | | |
| N(t) | 3.00 | 9.00 | Nitric Acid |
| | | | |
| N(r) | 3.00 | 9.00 | Nitric Acid |
| Total | | 42.00 | |
| **HH Index** | **6.29** | | |
| | | | |
| **Risk Index** | ***106.36*** | | |

# APPENDIX E

# INDUSTRIAL SOURCE COMPLEX SHORT TERM MODEL INPUT/OUTPUT FILES AND EMISSIONS FACTOR CALCULATIONS

# Calculating Emission Factors

**Mineral Spirits:**

| | | | | |
|---|---|---|---|---|
| Quantity Release: | 3,116 lbs | or | 1,413,394 | gr |
| Time: | 1 year | or | 3.16E+07 | seconds |
| Area: | 3,003 square inches | or | 1.937415 | square meters |

| | | | |
|---|---|---|---|
| Length | 42 | 21 | |
| Width | 22 | 11 | |
| No of Cleaners | 3 | 1 | |
| | 2,772 | 231 | square inches |

| | gr | | m3 | | sec | | gr/m3/sec |
|---|---|---|---|---|---|---|---|
| Emission Rate = | 1,413,394 | / | 1.937415 | / | 3.16E+07 | = | 0.02307 |

Release Height = 0.6604 meters

Length = 3.7338 meters

**Methyl Ethyl Ketone:**

| | | | | |
|---|---|---|---|---|
| Quantity Release: | 128 lbs | or | 58,060 | gr |
| Time: | 1 year | or | 3.16E+07 | seconds |
| Area: | 1 square meter (assumed) | | | |

| | gr | | m3 | | sec | | gr/m3/sec |
|---|---|---|---|---|---|---|---|
| Emission Rate = | 58,060 | / | 1 | / | 3.16E+07 | = | 0.001836 |

Release Height = 1 meters

Length = 1 meters

# Calculating Emission Factors

**Rust Preventative:**

| | | | | | | |
|---|---|---|---|---|---|---|
| Quantity Release: | 866 lbs/year | or | 392,811 gr/year | or | 1076 | gr/day |
| Time: | 1 year | or | 3.16E+07 seconds | | | |
| Area: | 1409.35 square meters | | | | | |

It is assumed that the rust preventative will evaporate off the surface of the bundles and that:

| | |
|---|---|
| Number of Bundles = | 26 per day |
| Diameter of Bundles = | 0.9144 meters |
| Length of Bundles = | 9.14 meters |
| Circumference = | 5.9280 meters |

| No# of Bundles | x | Circumference | x | Length | | Area |
|---|---|---|---|---|---|---|
| 26 | | 5.9280 | | 9.14 | = | 1409.35 |

| | gr | | m3 | | sec | | gr/m3/sec |
|---|---|---|---|---|---|---|---|
| Emission Rate = | 1,076 | / | 1409.35 | / | 1.44E+03 | = | 0.00053 |

Release Height = 0.9144 meters

Length = 9.144 meters

```
CO STARTING
CO TITLEONE Industial Source Complex: Short Term 2,  (1991)
CO TITLETWO Methyl Ethyl Ketone 128 lbs
CO MODELOPT DFAULT CONC URBAN
CO AVERTIME 24 PERIOD
CO POLLUTID OTHER
**CO dcaycoef or halflife
**CO TERRHTS (FLAT OR ELEV)
**CO ELEVUNIT (METERS OR FEET)
CO RUNORNOT RUN
CO FINISHED

SO STARTING
SO LOCATION  MEK AREA 0.0 0.0
SO SRCPARAM MEK  .00184  1  2
SO SRCGROUP All
SO FINISHED

RE STARTING
**RE GRIDCART CG1 STA
**RE GRIDCART CG1 XYINC -500. 21 50. -500 21 50
**RE GRIDCART CG1 END
RE GRIDCART CG2 STA
RE GRIDCART CG2 XYINC -1000. 21 100. -1000 21 100
RE GRIDCART CG2 END
RE FINISHED

ME STARTING
ME INPUTFIL S1396891.ASC
ME ANEMHGHT 10
ME SURFDATA 13968 1991 TULSA
ME UAIRDATA 03948 1991  NORMAN
ME FINISHED

OU STARTING
OU RECTABLE ALLAVE FIRST
OU MAXTABLE ALLAVE 50
OU PLOTFILE 24 ALL FIRST MEK100MX.PLT
OU PLOTFILE PERIOD ALL MEK100AN.PLT
OU FINISHED
```

```
CO STARTING
CO TITLEONE Industial Source Complex: Short Term 2,  (1991)
CO TITLETWO Mineral Sprits, 3116 lbs
CO MODELOPT DFAULT CONC URBAN
CO AVERTIME 24 PERIOD
CO POLLUTID OTHER
**CO dcaycoef or halflife
**CO TERRHTS (FLAT OR ELEV)
**CO ELEVUNIT (METERS OR FEET)
CO RUNORNOT RUN
CO FINISHED

SO STARTING
SO LOCATION  MSPIRITS AREA 0.0 0.0
SO SRCPARAM MSPIRITS  .02307  .6604  3.7338
SO SRCGROUP All
SO FINISHED

RE STARTING
**RE GRIDCART CG1 STA
**RE GRIDCART CG1 XYINC -500. 21 50. -500 21 50
**RE GRIDCART CG1 END
RE GRIDCART CG2 STA
RE GRIDCART CG2 XYINC -1000. 21 100. -1000 21 100
RE GRIDCART CG2 END
RE FINISHED

ME STARTING
ME INPUTFIL S1396891.ASC
ME ANEMHGHT 10
ME SURFDATA 13968 1991 TULSA
ME UAIRDATA 03948 1991  NORMAN
ME FINISHED

OU STARTING
OU RECTABLE ALLAVE FIRST
OU MAXTABLE ALLAVE 50
OU PLOTFILE 24 ALL FIRST MSP100MX.PLT
OU PLOTFILE PERIOD ALL MSP100AN.PLT
OU FINISHED
```

```
CO STARTING
CO TITLEONE Industial Source Complex: Short Term 2,  (1991)
CO TITLETWO Rust Preventative, 866lbs
CO MODELOPT DFAULT CONC URBAN
CO AVERTIME 24 PERIOD
CO POLLUTID OTHER
**CO dcaycoef or halflife
**CO TERRHTS (FLAT OR ELEV)
**CO ELEVUNIT (METERS OR FEET)
CO RUNORNOT RUN
CO FINISHED

SO STARTING
SO LOCATION  RUST AREA 0.0 0.0
SO SRCPARAM RUST .0005302  1  9.144
SO SRCGROUP All
SO FINISHED

RE STARTING
**RE GRIDCART CG1 STA
**RE GRIDCART CG1 XYINC -500. 21 50. -500 21 50
**RE GRIDCART CG1 END
RE GRIDCART CG2 STA
RE GRIDCART CG2 XYINC -1000. 21 100. -1000 21 100
RE GRIDCART CG2 END
RE FINISHED

ME STARTING
ME INPUTFIL S1396891.ASC
ME ANEMHGHT 10
ME SURFDATA 13968 1991 TULSA
ME UAIRDATA 03948 1991  NORMAN
ME FINISHED

OU STARTING
OU RECTABLE ALLAVE FIRST
OU MAXTABLE ALLAVE 50
OU PLOTFILE 24 ALL FIRST RST100MX.PLT
OU PLOTFILE PERIOD ALL RST100AN.PLT
OU FINISHED
```

| **Methyl Ethyl Ketone**<br>21 x 21 grid<br>every 100 meters<br>Yearly Average | **Methyl Ethyl Ketone**<br>21 x 21 grid<br>every 100 meters<br>Yearly Maximum | **Mineral Spirits**<br>21 x 21 grid<br>every 100 meters<br>Yearly Averages | **Mineral Spirits**<br>21 x 21 grid<br>every 100 meters<br>Yearly Maximum | **Rust Preventative**<br>21 x 21 grid<br>every 100 meters<br>Yearly Average | **Rust Preventative**<br>21 x 21 grid<br>every 100 meters<br>Yearly Maximum |
|---|---|---|---|---|---|
| north: 4003761 | north: 4003761 | north: 4003761 | north: 4003761 | north: 4003761 | north: 4003761 |
| south: 4001661 | south: 4001661 | south: 4001661 | south: 4001661 | south: 4001661 | south: 4001661 |
| east: 762770 | east: 762770 | east: 762770 | east: 762770 | east: 762770 | east: 762770 |
| west: 760670 | west: 760670 | west: 760670 | west: 760670 | west: 760670 | west: 760670 |
| cols: 21 | cols: 21 | cols: 21 | cols: 21 | cols: 21 | cols: 21 |
| rows: 21 | rows: 21 | rows: 21 | rows: 21 | rows: 21 | rows: 21 |
| 1.79 | 2 | 7.8 | 9.09 | 10.7 | 10.7 |
| 2.13 | 2.4 | 9.28 | 10.78 | 12.72 | 12.72 |
| 2.55 | 2.6 | 11.14 | 11.6 | 15.27 | 15.27 |
| 3.09 | 3.2 | 13.46 | 14.26 | 18.45 | 18.45 |
| 3.72 | 3.5 | 16.23 | 15.38 | 22.27 | 22.27 |
| 4.5 | 3 | 19.64 | 13.51 | 26.93 | 26.93 |
| 5.65 | 3.4 | 24.64 | 14.97 | 33.72 | 33.72 |
| 7.86 | 4.4 | 34.25 | 19.22 | 46.73 | 46.73 |
| 10.92 | 6.2 | 47.66 | 27.41 | 65.34 | 65.34 |
| 12.79 | 6.5 | 55.92 | 28.46 | 77.19 | 77.19 |
| 12.2 | 5.7 | 53.46 | 25.27 | 74.26 | 74.26 |
| 9.13 | 4.5 | 40.04 | 19.83 | 55.91 | 55.91 |
| 5.82 | 3.5 | 25.55 | 15.36 | 35.65 | 35.65 |
| 3.91 | 3.2 | 17.13 | 14.2 | 23.83 | 23.83 |
| 2.83 | 2.7 | 12.37 | 11.9 | 17.19 | 17.19 |
| 2.17 | 1.9 | 9.48 | 8.45 | 13.16 | 13.16 |
| 1.75 | 1.8 | 7.66 | 7.89 | 10.62 | 10.62 |
| 1.46 | 1.9 | 6.37 | 8.43 | 8.83 | 8.83 |
| 1.21 | 1.8 | 5.28 | 8.16 | 7.32 | 7.32 |
| 0.97 | 1.5 | 4.25 | 6.81 | 5.89 | 5.89 |
| 0.77 | 1 | 3.38 | 4.7 | 4.68 | 4.68 |
| 1.78 | 2.2 | 7.74 | 9.62 | 10.6 | 10.6 |
| 2.14 | 2.4 | 9.35 | 10.73 | 12.81 | 12.81 |
| 2.6 | 2.9 | 11.35 | 12.9 | 15.54 | 15.54 |
| 3.2 | 3.3 | 13.93 | 14.61 | 19.08 | 19.08 |
| 3.94 | 4 | 17.2 | 17.76 | 23.57 | 23.57 |
| 4.86 | 4 | 21.21 | 17.87 | 29.08 | 29.08 |
| 6.1 | 3.9 | 26.61 | 17.08 | 36.43 | 36.43 |

| | | | | | |
|---|---|---|---|---|---|
| 8.41 | 4.8 | 36.63 | 21.15 | 49.93 | 49.93 |
| 12.34 | 6.9 | 53.8 | 30.08 | 73.6 | 73.6 |
| 15.24 | 7.7 | 66.6 | 33.74 | 91.87 | 91.87 |
| 14.65 | 6.8 | 64.22 | 30.18 | 89.27 | 89.27 |
| 10.51 | 5.3 | 46.16 | 23.25 | 64.54 | 64.54 |
| 6.41 | 4.1 | 28.12 | 18.19 | 39.27 | 39.27 |
| 4.23 | 3.6 | 18.53 | 16.02 | 25.79 | 25.79 |
| 3.02 | 2.6 | 13.23 | 11.82 | 18.38 | 18.38 |
| 2.32 | 2.2 | 10.15 | 9.67 | 14.08 | 14.08 |
| 1.87 | 2.2 | 8.18 | 9.88 | 11.34 | 11.34 |
| 1.52 | 2.2 | 6.65 | 9.9 | 9.22 | 9.22 |
| 1.2 | 1.9 | 5.25 | 8.32 | 7.28 | 7.28 |
| 0.93 | 1.2 | 4.08 | 5.59 | 5.65 | 5.65 |
| 0.75 | 1.4 | 3.27 | 6.4 | 4.52 | 4.52 |
| 1.71 | 2.2 | 7.46 | 9.92 | 10.2 | 10.2 |
| 2.12 | 2.5 | 9.26 | 11.32 | 12.66 | 12.66 |
| 2.63 | 2.9 | 11.46 | 13.01 | 15.68 | 15.68 |
| 3.28 | 3.6 | 14.27 | 15.8 | 19.54 | 19.54 |
| 4.14 | 4.3 | 18.03 | 18.94 | 24.68 | 24.68 |
| 5.25 | 5.1 | 22.87 | 22.32 | 31.32 | 31.32 |
| 6.68 | 4.5 | 29.12 | 19.83 | 39.87 | 39.87 |
| 9.07 | 5.3 | 39.48 | 23.12 | 53.84 | 53.84 |
| 13.92 | 7.3 | 60.63 | 31.94 | 82.7 | 82.7 |
| 18.48 | 9.4 | 80.74 | 41.67 | 111.26 | 111.26 |
| 18.02 | 8.3 | 78.98 | 36.88 | 109.89 | 109.89 |
| 12.25 | 6.3 | 53.83 | 27.69 | 75.41 | 75.41 |
| 7.1 | 5 | 31.18 | 21.98 | 43.55 | 43.55 |
| 4.59 | 4.2 | 20.12 | 18.6 | 28.02 | 28.02 |
| 3.26 | 2.8 | 14.27 | 12.54 | 19.82 | 19.82 |
| 2.5 | 2.6 | 10.95 | 11.52 | 15.19 | 15.19 |
| 1.98 | 2.7 | 8.67 | 12.25 | 12.02 | 12.02 |
| 1.53 | 2.3 | 6.69 | 10.43 | 9.27 | 9.27 |
| 1.15 | 1.5 | 5.04 | 6.8 | 6.98 | 6.98 |
| 0.9 | 1.8 | 3.95 | 8.11 | 5.47 | 5.47 |
| 0.76 | 2.2 | 3.31 | 9.89 | 4.59 | 4.59 |
| 1.61 | 2.3 | 7 | 10.42 | 9.57 | 9.57 |
| 2.03 | 2.7 | 8.86 | 12.05 | 12.09 | 12.09 |
| 2.6 | 3.1 | 11.32 | 13.58 | 15.47 | 15.47 |
| 3.32 | 3.7 | 14.47 | 16.23 | 19.78 | 19.78 |
| 4.28 | 4.5 | 18.64 | 19.87 | 25.48 | 25.48 |
| 5.6 | 5.8 | 24.41 | 25.43 | 33.38 | 33.38 |
| 7.36 | 6.3 | 32.09 | 27.85 | 43.92 | 43.92 |
| 9.96 | 6.1 | 43.37 | 26.86 | 59.2 | 59.2 |
| 15.63 | 8.2 | 68.02 | 36.17 | 92.49 | 92.49 |

| | | | | | |
|---|---|---|---|---|---|
| 22.87 | 12.1 | 99.89 | 53.25 | 137.41 | 137.41 |
| 22.82 | 10.5 | 100 | 46.41 | 139.45 | 139.45 |
| 14.46 | 7.6 | 63.59 | 33.54 | 89.28 | 89.28 |
| 7.94 | 5.9 | 34.87 | 26.03 | 48.73 | 48.73 |
| 5.02 | 4.4 | 22 | 19.72 | 30.64 | 30.64 |
| 3.56 | 3.4 | 15.57 | 14.93 | 21.64 | 21.64 |
| 2.7 | 3.5 | 11.81 | 15.47 | 16.4 | 16.4 |
| 2.02 | 3 | 8.85 | 13.53 | 12.27 | 12.27 |
| 1.47 | 1.9 | 6.42 | 8.51 | 8.9 | 8.9 |
| 1.12 | 2.4 | 4.89 | 10.58 | 6.78 | 6.78 |
| 0.92 | 2.7 | 4.04 | 12.24 | 5.6 | 5.6 |
| 0.8 | 2.4 | 3.49 | 10.66 | 4.84 | 4.84 |
| 1.55 | 2.3 | 6.76 | 10.38 | 9.26 | 9.26 |
| 1.9 | 2.8 | 8.29 | 12.52 | 11.31 | 11.31 |
| 2.46 | 3.4 | 10.72 | 14.96 | 14.61 | 14.61 |
| 3.27 | 3.8 | 14.25 | 16.67 | 19.43 | 19.43 |
| 4.36 | 4.8 | 18.98 | 21.03 | 25.91 | 25.91 |
| 5.88 | 5.9 | 25.6 | 25.86 | 34.93 | 34.93 |
| 8.08 | 8.1 | 35.2 | 35.44 | 48.07 | 48.07 |
| 11.2 | 7.4 | 48.8 | 32.84 | 66.65 | 66.65 |
| 17.51 | 9.8 | 76.13 | 42.77 | 103.26 | 103.26 |
| 28.94 | 15.7 | 126.2 | 68.92 | 173.2 | 173.2 |
| 30.08 | 13.7 | 131.9 | 60.76 | 184.19 | 184.19 |
| 17.32 | 9.3 | 76.2 | 41.22 | 107.27 | 107.27 |
| 8.97 | 7.3 | 39.38 | 32.17 | 55.08 | 55.08 |
| 5.55 | 4.7 | 24.35 | 21 | 33.92 | 33.92 |
| 3.92 | 4.5 | 17.16 | 19.84 | 23.84 | 23.84 |
| 2.81 | 4.1 | 12.33 | 18.34 | 17.12 | 17.12 |
| 1.95 | 2.5 | 8.52 | 11.07 | 11.81 | 11.81 |
| 1.43 | 3.2 | 6.25 | 14.31 | 8.66 | 8.66 |
| 1.16 | 3.4 | 5.07 | 15.3 | 7.02 | 7.02 |
| 0.98 | 2.9 | 4.28 | 12.76 | 5.92 | 5.92 |
| 0.82 | 2.8 | 3.6 | 12.36 | 4.98 | 4.98 |
| 1.65 | 2.7 | 7.21 | 12.23 | 9.92 | 9.92 |
| 1.9 | 2.9 | 8.29 | 12.82 | 11.38 | 11.38 |
| 2.32 | 3.4 | 10.11 | 15.25 | 13.81 | 13.81 |
| 3.06 | 4.3 | 13.32 | 19.09 | 18.13 | 18.13 |
| 4.27 | 5 | 18.59 | 22.28 | 25.29 | 25.29 |
| 6.04 | 6.5 | 26.28 | 28.68 | 35.79 | 35.79 |
| 8.68 | 8.6 | 37.79 | 37.72 | 51.47 | 51.47 |
| 12.78 | 11.5 | 55.65 | 50.61 | 75.89 | 75.89 |
| 19.88 | 11.3 | 86.45 | 49.69 | 117.29 | 117.29 |
| 37.39 | 20.3 | 162.9 | 88.65 | 222.21 | 222.21 |
| 41.86 | 19 | 183.8 | 83.96 | 257.14 | 257.14 |

| | | | | | |
|---|---|---|---|---|---|
| 21.07 | 11.5 | 92.8 | 50.71 | 131.01 | 131.01 |
| 10.24 | 9 | 44.98 | 39.73 | 62.96 | 62.96 |
| 6.27 | 6 | 27.48 | 26.63 | 38.28 | 38.28 |
| 4.22 | 6 | 18.49 | 26.37 | 25.72 | 25.72 |
| 2.72 | 3.4 | 11.93 | 15.18 | 16.56 | 16.56 |
| 1.91 | 4.6 | 8.34 | 20.28 | 11.56 | 11.56 |
| 1.5 | 4.3 | 6.57 | 19.17 | 9.11 | 9.11 |
| 1.22 | 3.9 | 5.33 | 17.15 | 7.39 | 7.39 |
| 0.98 | 3.2 | 4.29 | 14.36 | 5.94 | 5.94 |
| 0.79 | 2.3 | 3.46 | 10.28 | 4.78 | 4.78 |
| 1.88 | 2.6 | 8.21 | 11.58 | 11.31 | 11.31 |
| 2.14 | 3.4 | 9.32 | 14.99 | 12.83 | 12.83 |
| 2.46 | 4 | 10.75 | 17.66 | 14.78 | 14.78 |
| 2.98 | 4.3 | 12.97 | 18.87 | 17.75 | 17.75 |
| 3.96 | 5.7 | 17.22 | 25.16 | 23.41 | 23.41 |
| 5.87 | 7.3 | 25.49 | 32.06 | 34.55 | 34.55 |
| 9.04 | 9.7 | 39.31 | 42.21 | 53.37 | 53.37 |
| 14.35 | 14.4 | 62.4 | 62.98 | 84.74 | 84.74 |
| 23.57 | 15.4 | 102.5 | 68.2 | 139.33 | 139.33 |
| 48.85 | 24.7 | 212.2 | 106.98 | 286.74 | 286.74 |
| 63.08 | 28.4 | 277.4 | 125.64 | 389.29 | 389.29 |
| 26.18 | 16.8 | 115.4 | 74 | 163.38 | 163.38 |
| 11.93 | 10 | 52.42 | 44.02 | 73.39 | 73.39 |
| 7.08 | 9.3 | 31.04 | 40.87 | 43.29 | 43.29 |
| 4.13 | 5.1 | 18.09 | 22.48 | 25.15 | 25.15 |
| 2.69 | 6.9 | 11.8 | 30.45 | 16.37 | 16.37 |
| 2.03 | 5.6 | 8.88 | 24.87 | 12.32 | 12.32 |
| 1.55 | 5 | 6.77 | 21.97 | 9.37 | 9.37 |
| 1.18 | 3.3 | 5.16 | 14.84 | 7.14 | 7.14 |
| 0.93 | 1.9 | 4.06 | 8.63 | 5.62 | 5.62 |
| 0.76 | 1.5 | 3.33 | 6.65 | 4.61 | 4.61 |
| 2.08 | 2.9 | 9.09 | 12.82 | 12.49 | 12.49 |
| 2.44 | 3 | 10.65 | 13.48 | 14.63 | 14.63 |
| 2.88 | 3.5 | 12.56 | 15.56 | 17.27 | 17.27 |
| 3.42 | 5 | 14.93 | 22.15 | 20.53 | 20.53 |
| 4.16 | 6.5 | 18.14 | 28.66 | 24.89 | 24.89 |
| 5.49 | 7.7 | 23.89 | 33.88 | 32.51 | 32.51 |
| 8.64 | 11.4 | 37.51 | 49.93 | 50.57 | 50.57 |
| 15.33 | 16.1 | 66.59 | 70.14 | 89.9 | 89.9 |
| 28.76 | 27.8 | 124.9 | 121.58 | 168.91 | 168.91 |
| 63.4 | 34.1 | 274.4 | 148.61 | 366.7 | 366.7 |
| 107.92 | 48.1 | 475.6 | 213.65 | 670.99 | 670.99 |
| 33.59 | 25.5 | 148.2 | 112.42 | 210.38 | 210.38 |
| 14.4 | 15.6 | 63.26 | 68.79 | 88.65 | 88.65 |

| | | | | | |
|---|---|---|---|---|---|
| 7.1 | 8.5 | 31.15 | 37.68 | 43.43 | 43.43 |
| 4.16 | 11 | 18.24 | 48.71 | 25.36 | 25.36 |
| 2.87 | 8.8 | 12.56 | 38.59 | 17.43 | 17.43 |
| 2 | 5.5 | 8.73 | 24.07 | 12.09 | 12.09 |
| 1.46 | 2.6 | 6.4 | 11.68 | 8.85 | 8.85 |
| 1.15 | 2.3 | 5.01 | 10.25 | 6.95 | 6.95 |
| 0.95 | 2.2 | 4.13 | 9.68 | 5.73 | 5.73 |
| 0.8 | 1.9 | 3.51 | 8.72 | 4.86 | 4.86 |
| 2.19 | 3.4 | 9.56 | 14.86 | 13.11 | 13.11 |
| 2.62 | 4 | 11.41 | 17.66 | 15.63 | 15.63 |
| 3.18 | 4.8 | 13.88 | 21 | 19.02 | 19.02 |
| 3.96 | 5.6 | 17.27 | 24.6 | 23.65 | 23.65 |
| 5.04 | 6.2 | 21.97 | 27.31 | 30.11 | 30.11 |
| 6.54 | 8.3 | 28.53 | 36.31 | 39.14 | 39.14 |
| 8.81 | 13.2 | 38.41 | 57.9 | 52.53 | 52.53 |
| 14.34 | 19.8 | 62.12 | 86.39 | 83.34 | 83.34 |
| 32.71 | 33.7 | 141.5 | 145.72 | 189.05 | 189.05 |
| 86.92 | 56.2 | 376.4 | 250.47 | 503.55 | 503.55 |
| 233.31 | 103 | 1032 | 460.67 | 1470.4 | 1470.4 |
| 45.41 | 36.7 | 200.5 | 162.13 | 285.41 | 285.41 |
| 15.42 | 18 | 67.78 | 79.53 | 95.02 | 95.02 |
| 7.38 | 18.8 | 32.39 | 83.2 | 45.16 | 45.16 |
| 4.24 | 11.1 | 18.58 | 48.65 | 25.77 | 25.77 |
| 2.72 | 4.9 | 11.92 | 21.83 | 16.53 | 16.53 |
| 1.98 | 4.3 | 8.68 | 19.23 | 12.05 | 12.05 |
| 1.55 | 3.6 | 6.77 | 16.06 | 9.4 | 9.4 |
| 1.25 | 3.1 | 5.49 | 13.92 | 7.62 | 7.62 |
| 1.04 | 2.8 | 4.57 | 12.4 | 6.34 | 6.34 |
| 0.89 | 2.5 | 3.89 | 11.01 | 5.39 | 5.39 |
| 2.22 | 3 | 9.66 | 13.42 | 13.22 | 13.22 |
| 2.67 | 3.5 | 11.65 | 15.55 | 15.93 | 15.93 |
| 3.3 | 4.5 | 14.36 | 19.66 | 19.64 | 19.64 |
| 4.18 | 5.9 | 18.23 | 25.8 | 24.89 | 24.89 |
| 5.51 | 8 | 23.99 | 35.02 | 32.73 | 32.73 |
| 7.61 | 11.3 | 33.14 | 49.33 | 45.14 | 45.14 |
| 11.24 | 16.3 | 48.93 | 71.27 | 66.54 | 66.54 |
| 18.13 | 21.8 | 78.94 | 96.52 | 107.34 | 107.34 |
| 32.75 | 46.4 | 142.4 | 202.43 | 193.02 | 193.02 |
| 122.22 | 122 | 524.3 | 530.42 | 676.11 | 676.11 |
| 897.44 | 394 | 4023 | 1797.55 | 5835.9 | 5835.9 |
| 59.4 | 67.1 | 262.9 | 297.97 | 375.3 | 375.3 |
| 15.9 | 39 | 69.83 | 170.71 | 97.41 | 97.41 |
| 7.31 | 15 | 32.07 | 66.25 | 44.76 | 44.76 |
| 4.52 | 10.9 | 19.85 | 48.25 | 27.69 | 27.69 |

| | | | | | |
|---|---|---|---|---|---|
| 3.16 | 8.1 | 13.86 | 35.98 | 19.33 | 19.33 |
| 2.37 | 6 | 10.41 | 26.67 | 14.51 | 14.51 |
| 1.87 | 4.5 | 8.2 | 19.92 | 11.43 | 11.43 |
| 1.52 | 3.9 | 6.68 | 17.43 | 9.31 | 9.31 |
| 1.27 | 3.5 | 5.58 | 15.65 | 7.77 | 7.77 |
| 1.09 | 3.1 | 4.75 | 14.01 | 6.61 | 6.61 |
| 2.07 | 3.5 | 9 | 15.67 | 12.29 | 12.29 |
| 2.49 | 4.2 | 10.83 | 18.75 | 14.77 | 14.77 |
| 3.06 | 5.2 | 13.34 | 22.95 | 18.17 | 18.17 |
| 3.89 | 6.6 | 16.93 | 28.93 | 23.02 | 23.02 |
| 5.14 | 8.6 | 22.35 | 37.9 | 30.31 | 30.31 |
| 7.17 | 12 | 31.14 | 52.36 | 42.09 | 42.09 |
| 10.82 | 17.9 | 46.93 | 78.2 | 63.1 | 63.1 |
| 18.51 | 30.4 | 80.06 | 132.19 | 106.73 | 106.73 |
| 39.8 | 64.6 | 171.3 | 280.38 | 224.55 | 224.55 |
| 149.3 | 240 | 634 | 1033.1 | 789.98 | 789.98 |
| 0 | 0 | 0 | 0 | 65396 | 65396 |
| 100.02 | 233 | 447.5 | 1016.51 | 647.35 | 647.35 |
| 26 | 63 | 114.9 | 275.66 | 163.13 | 163.13 |
| 12.01 | 29.9 | 52.89 | 130.87 | 74.45 | 74.45 |
| 7.01 | 17.8 | 30.83 | 78.1 | 43.19 | 43.19 |
| 4.65 | 12 | 20.42 | 52.76 | 28.53 | 28.53 |
| 3.34 | 8.8 | 14.66 | 38.52 | 20.44 | 20.44 |
| 2.54 | 6.7 | 11.12 | 29.64 | 15.48 | 15.48 |
| 2 | 5.4 | 8.77 | 23.7 | 12.2 | 12.2 |
| 1.63 | 4.4 | 7.13 | 19.5 | 9.91 | 9.91 |
| 1.36 | 3.7 | 5.94 | 16.41 | 8.25 | 8.25 |
| 1.82 | 3.4 | 7.93 | 14.86 | 10.84 | 10.84 |
| 2.17 | 4 | 9.45 | 17.56 | 12.9 | 12.9 |
| 2.64 | 4.8 | 11.51 | 21.09 | 15.69 | 15.69 |
| 3.31 | 5.9 | 14.41 | 25.74 | 19.62 | 19.62 |
| 4.3 | 7.3 | 18.7 | 31.84 | 25.41 | 25.41 |
| 5.85 | 9.1 | 25.43 | 39.47 | 34.45 | 34.45 |
| 8.46 | 15.2 | 36.7 | 66.5 | 49.47 | 49.47 |
| 13.07 | 25.3 | 56.55 | 109.85 | 75.46 | 75.46 |
| 20.39 | 46.8 | 87.72 | 201.5 | 114.89 | 114.89 |
| 57.3 | 85.4 | 245.5 | 367.7 | 316.77 | 316.77 |
| 290.51 | 283 | 1235 | 1254.22 | 1545 | 1545 |
| 103.88 | 116 | 457.7 | 508.4 | 642.39 | 642.39 |
| 30.86 | 53.8 | 135.3 | 232.17 | 188.01 | 188.01 |
| 13.63 | 47.6 | 59.99 | 208.45 | 84.5 | 84.5 |
| 7.3 | 24.5 | 32.02 | 109.14 | 44.72 | 44.72 |
| 4.73 | 11.9 | 20.68 | 53.13 | 28.67 | 28.67 |
| 3.41 | 7.9 | 14.89 | 34.76 | 20.58 | 20.58 |

| | | | | | |
|---|---|---|---|---|---|
| 2.61 | 6 | 11.4 | 26.46 | 15.74 | 15.74 |
| 2.08 | 4.8 | 9.07 | 21.09 | 12.53 | 12.53 |
| 1.7 | 4 | 7.43 | 17.89 | 10.26 | 10.26 |
| 1.42 | 3.5 | 6.21 | 15.34 | 8.58 | 8.58 |
| 1.68 | 2.7 | 7.32 | 11.92 | 10.02 | 10.02 |
| 1.99 | 3.4 | 8.67 | 15.19 | 11.84 | 11.84 |
| 2.39 | 4.5 | 10.42 | 19.81 | 14.22 | 14.22 |
| 2.93 | 5.8 | 12.73 | 25.6 | 17.33 | 17.33 |
| 3.63 | 7.3 | 15.79 | 32.03 | 21.43 | 21.43 |
| 4.52 | 10.3 | 19.62 | 44.94 | 26.52 | 26.52 |
| 5.5 | 13.2 | 23.84 | 57.28 | 32.03 | 32.03 |
| 7.63 | 12.7 | 33.07 | 55.34 | 44.45 | 44.45 |
| 15.5 | 23.8 | 67.09 | 103.55 | 89.57 | 89.57 |
| 31.38 | 35.7 | 134.9 | 154.56 | 176.84 | 176.84 |
| 77.14 | 75 | 332.3 | 330.49 | 436.81 | 436.81 |
| 61.7 | 65.7 | 269.5 | 293.24 | 370.07 | 370.07 |
| 27.39 | 31.8 | 120.1 | 138.6 | 167.32 | 167.32 |
| 13.56 | 18.4 | 59.44 | 81.55 | 82.65 | 82.65 |
| 8.37 | 15.1 | 36.64 | 65.68 | 50.69 | 50.69 |
| 5.57 | 16.1 | 24.44 | 70.21 | 34.02 | 34.02 |
| 3.77 | 14.1 | 16.55 | 61.88 | 23.1 | 23.1 |
| 2.69 | 10.5 | 11.78 | 46.22 | 16.41 | 16.41 |
| 2.04 | 7.3 | 8.91 | 32.4 | 12.37 | 12.37 |
| 1.62 | 5 | 7.1 | 22.3 | 9.83 | 9.83 |
| 1.34 | 3.4 | 5.87 | 15.38 | 8.12 | 8.12 |
| 1.53 | 3.2 | 6.65 | 14 | 9.1 | 9.1 |
| 1.76 | 3.6 | 7.65 | 16.02 | 10.44 | 10.44 |
| 2.02 | 4.3 | 8.81 | 19.19 | 12 | 12 |
| 2.31 | 5.7 | 10.05 | 25.13 | 13.66 | 13.66 |
| 2.59 | 6.4 | 11.27 | 28.17 | 15.28 | 15.28 |
| 3.04 | 5 | 13.21 | 22.01 | 17.9 | 17.9 |
| 4.52 | 7.4 | 19.67 | 32.27 | 26.68 | 26.68 |
| 7.35 | 11.6 | 31.91 | 50.46 | 43.09 | 43.09 |
| 10.6 | 11.5 | 45.93 | 50.28 | 61.56 | 61.56 |
| 21.56 | 22.7 | 93.12 | 98.64 | 123.65 | 123.65 |
| 35.8 | 35 | 154.9 | 154.15 | 207.03 | 207.03 |
| 36.44 | 44.1 | 158.7 | 190.86 | 216.23 | 216.23 |
| 22.11 | 23.6 | 96.66 | 103.98 | 133.18 | 133.18 |
| 12.77 | 15.1 | 55.95 | 66.03 | 77.68 | 77.68 |
| 7.86 | 10.9 | 34.43 | 47.98 | 47.8 | 47.8 |
| 5.32 | 7.4 | 23.29 | 32.39 | 32.22 | 32.22 |
| 4 | 7.3 | 17.48 | 32.05 | 24.15 | 24.15 |
| 3.08 | 7.8 | 13.48 | 33.92 | 18.68 | 18.68 |
| 2.36 | 8 | 10.35 | 35.03 | 14.39 | 14.39 |

| | | | | | |
|---|---|---|---|---|---|
| 1.83 | 7.2 | 8.01 | 31.61 | 11.14 | 11.14 |
| 1.45 | 6 | 6.34 | 26.41 | 8.81 | 8.81 |
| 1.3 | 3.1 | 5.68 | 13.65 | 7.76 | 7.76 |
| 1.42 | 3.7 | 6.2 | 16.32 | 8.46 | 8.46 |
| 1.54 | 3.9 | 6.69 | 17.28 | 9.1 | 9.1 |
| 1.69 | 3.3 | 7.36 | 14.72 | 10.01 | 10.01 |
| 2.1 | 3.6 | 9.13 | 15.98 | 12.44 | 12.44 |
| 3.09 | 5.9 | 13.43 | 26.1 | 18.29 | 18.29 |
| 4.38 | 7.7 | 19.05 | 33.76 | 25.87 | 25.87 |
| 5.54 | 6.8 | 24.06 | 29.68 | 32.55 | 32.55 |
| 8.53 | 10.3 | 36.99 | 44.88 | 49.74 | 49.74 |
| 14.98 | 14 | 64.89 | 60.97 | 87.09 | 87.09 |
| 20.92 | 20.6 | 90.76 | 90.68 | 122.26 | 122.26 |
| 22.62 | 20.7 | 98.43 | 89.99 | 133.7 | 133.7 |
| 16.78 | 18.1 | 73.3 | 80.27 | 100.93 | 100.93 |
| 11.39 | 11.4 | 49.81 | 49.83 | 68.81 | 68.81 |
| 7.5 | 9 | 32.86 | 39.41 | 45.55 | 45.55 |
| 5.2 | 6.8 | 22.74 | 30.14 | 31.52 | 31.52 |
| 3.77 | 5.5 | 16.5 | 24.23 | 22.85 | 22.85 |
| 2.93 | 4.4 | 12.79 | 19.42 | 17.66 | 17.66 |
| 2.4 | 4.4 | 10.48 | 19.48 | 14.47 | 14.47 |
| 1.99 | 4.6 | 8.69 | 19.96 | 12.02 | 12.02 |
| 1.64 | 5 | 7.15 | 21.91 | 9.92 | 9.92 |
| 1.03 | 2.7 | 4.49 | 11.95 | 6.13 | 6.13 |
| 1.1 | 2.4 | 4.78 | 10.57 | 6.53 | 6.53 |
| 1.25 | 2.1 | 5.44 | 9.42 | 7.44 | 7.44 |
| 1.61 | 3.5 | 7.03 | 15.6 | 9.61 | 9.61 |
| 2.26 | 5.2 | 9.86 | 22.94 | 13.47 | 13.47 |
| 2.96 | 6.2 | 12.87 | 27.35 | 17.54 | 17.54 |
| 3.5 | 5.7 | 15.24 | 25.18 | 20.72 | 20.72 |
| 4.65 | 6.7 | 20.2 | 29.51 | 27.37 | 27.37 |
| 7.15 | 8.4 | 31.01 | 36.56 | 41.83 | 41.83 |
| 10.81 | 12 | 46.95 | 52.05 | 63.39 | 63.39 |
| 13.87 | 14 | 60.26 | 61.07 | 81.57 | 81.57 |
| 15.15 | 12.8 | 65.91 | 55.68 | 89.59 | 89.59 |
| 13.07 | 17.3 | 57.08 | 75.71 | 78.48 | 78.48 |
| 9.53 | 10.8 | 41.65 | 47.4 | 57.37 | 57.37 |
| 6.99 | 7.3 | 30.57 | 32.29 | 42.27 | 42.27 |
| 5 | 6 | 21.88 | 26.57 | 30.31 | 30.31 |
| 3.72 | 5.1 | 16.29 | 22.68 | 22.55 | 22.55 |
| 2.85 | 4.3 | 12.49 | 19.25 | 17.29 | 17.29 |
| 2.26 | 3.1 | 9.9 | 13.67 | 13.68 | 13.68 |
| 1.89 | 3 | 8.25 | 13.12 | 11.39 | 11.39 |
| 1.63 | 3 | 7.1 | 13.31 | 9.8 | 9.8 |

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|---|---|---|---|---|---|
| 0.85 | 1.4 | 3.7 | 6.27 | 5.07 | 5.07 |
| 1.01 | 2.3 | 4.38 | 10.12 | 6 | 6 |
| 1.31 | 3.4 | 5.71 | 15.21 | 7.81 | 7.81 |
| 1.75 | 4.6 | 7.61 | 20.32 | 10.41 | 10.41 |
| 2.16 | 5.2 | 9.4 | 23.06 | 12.84 | 12.84 |
| 2.46 | 4.9 | 10.71 | 21.72 | 14.61 | 14.61 |
| 3 | 4.9 | 13.03 | 21.73 | 17.73 | 17.73 |
| 4.07 | 6.3 | 17.7 | 27.7 | 24.01 | 24.01 |
| 6.02 | 6.7 | 26.17 | 29.5 | 35.43 | 35.43 |
| 8.17 | 10.1 | 35.5 | 44.14 | 48.12 | 48.12 |
| 9.95 | 11.3 | 43.29 | 49.53 | 58.79 | 58.79 |
| 10.84 | 10 | 47.17 | 43.91 | 64.21 | 64.21 |
| 10.24 | 12.9 | 44.67 | 56.54 | 61.27 | 61.27 |
| 8 | 8.8 | 34.98 | 38.79 | 48.2 | 48.2 |
| 6.21 | 6.9 | 27.15 | 30.39 | 37.44 | 37.44 |
| 4.76 | 5.1 | 20.83 | 22.51 | 28.82 | 28.82 |
| 3.6 | 4.4 | 15.77 | 19.32 | 21.83 | 21.83 |
| 2.82 | 4 | 12.32 | 17.57 | 17.05 | 17.05 |
| 2.25 | 3.4 | 9.85 | 15.11 | 13.64 | 13.64 |
| 1.83 | 2.8 | 8 | 12.37 | 11.07 | 11.07 |
| 1.54 | 2.2 | 6.72 | 9.97 | 9.28 | 9.28 |
| 0.85 | 2.3 | 3.71 | 10.48 | 5.09 | 5.09 |
| 1.09 | 3.3 | 4.77 | 14.53 | 6.54 | 6.54 |
| 1.4 | 4.1 | 6.09 | 18.19 | 8.35 | 8.35 |
| 1.66 | 4.5 | 7.24 | 19.99 | 9.9 | 9.9 |
| 1.85 | 4.3 | 8.05 | 19.05 | 11 | 11 |
| 2.13 | 3.8 | 9.27 | 16.86 | 12.65 | 12.65 |
| 2.69 | 4.9 | 11.68 | 21.79 | 15.91 | 15.91 |
| 3.64 | 5.6 | 15.81 | 24.86 | 21.47 | 21.47 |
| 5.07 | 5.4 | 22.05 | 23.63 | 29.95 | 29.95 |
| 6.41 | 8.5 | 27.87 | 36.93 | 37.88 | 37.88 |
| 7.54 | 9.6 | 32.84 | 41.94 | 44.7 | 44.7 |
| 8.16 | 8.7 | 35.53 | 38.29 | 48.44 | 48.44 |
| 8.09 | 8.9 | 35.27 | 38.87 | 48.31 | 48.31 |
| 6.83 | 9 | 29.86 | 39.63 | 41.13 | 41.13 |
| 5.43 | 6.3 | 23.72 | 27.63 | 32.69 | 32.69 |
| 4.4 | 4.7 | 19.21 | 20.8 | 26.51 | 26.51 |
| 3.48 | 3.8 | 15.22 | 16.66 | 21.05 | 21.05 |
| 2.74 | 3.3 | 11.99 | 14.79 | 16.59 | 16.59 |
| 2.22 | 3.2 | 9.71 | 14 | 13.42 | 13.42 |
| 1.83 | 2.7 | 8.01 | 11.97 | 11.09 | 11.09 |
| 1.52 | 2.4 | 6.67 | 10.79 | 9.23 | 9.23 |
| 0.93 | 3.1 | 4.07 | 13.76 | 5.59 | 5.59 |
| 1.15 | 3.7 | 5.02 | 16.45 | 6.88 | 6.88 |

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|---|---|---|---|---|---|
| 1.33 | 4 | 5.79 | 17.67 | 7.94 | 7.94 |
| 1.45 | 3.8 | 6.33 | 16.96 | 8.66 | 8.66 |
| 1.62 | 3.3 | 7.04 | 14.83 | 9.62 | 9.62 |
| 1.93 | 4 | 8.42 | 17.7 | 11.5 | 11.5 |
| 2.44 | 4.7 | 10.63 | 20.6 | 14.49 | 14.49 |
| 3.27 | 5 | 14.24 | 21.95 | 19.37 | 19.37 |
| 4.29 | 4.7 | 18.65 | 20.8 | 25.4 | 25.4 |
| 5.18 | 7.3 | 22.55 | 31.98 | 30.71 | 30.71 |
| 5.95 | 8.3 | 25.91 | 36.55 | 35.34 | 35.34 |
| 6.39 | 7.7 | 27.84 | 33.93 | 38.01 | 38.01 |
| 6.49 | 6.3 | 28.31 | 27.73 | 38.76 | 38.76 |
| 5.85 | 8 | 25.56 | 35 | 35.17 | 35.17 |
| 4.79 | 5.3 | 20.94 | 23.49 | 28.87 | 28.87 |
| 3.96 | 4.6 | 17.32 | 20.19 | 23.88 | 23.88 |
| 3.29 | 3.4 | 14.37 | 15.29 | 19.84 | 19.84 |
| 2.67 | 2.9 | 11.68 | 12.88 | 16.15 | 16.15 |
| 2.17 | 2.6 | 9.48 | 11.76 | 13.12 | 13.12 |
| 1.8 | 2.6 | 7.88 | 11.44 | 10.9 | 10.9 |
| 1.53 | 2.2 | 6.67 | 9.68 | 9.23 | 9.23 |
| 0.97 | 3.4 | 4.23 | 15.01 | 5.8 | 5.8 |
| 1.1 | 3.6 | 4.77 | 15.86 | 6.55 | 6.55 |
| 1.18 | 3.5 | 5.14 | 15.29 | 7.05 | 7.05 |
| 1.28 | 3.1 | 5.59 | 13.66 | 7.65 | 7.65 |
| 1.48 | 3.3 | 6.44 | 14.7 | 8.8 | 8.8 |
| 1.78 | 3.9 | 7.77 | 17.33 | 10.62 | 10.62 |
| 2.25 | 4.3 | 9.79 | 19.08 | 13.36 | 13.36 |
| 2.95 | 4.4 | 12.82 | 19.22 | 17.48 | 17.48 |
| 3.66 | 4.7 | 15.92 | 20.81 | 21.71 | 21.71 |
| 4.29 | 6.7 | 18.69 | 29.36 | 25.49 | 25.49 |
| 4.84 | 7.4 | 21.07 | 32.49 | 28.78 | 28.78 |
| 5.16 | 6.9 | 22.49 | 30.49 | 30.74 | 30.74 |
| 5.31 | 5.9 | 23.15 | 26.11 | 31.7 | 31.7 |
| 5.01 | 6.5 | 21.87 | 28.66 | 30.07 | 30.07 |
| 4.28 | 5.6 | 18.69 | 24.61 | 25.77 | 25.77 |
| 3.57 | 4.2 | 15.59 | 18.45 | 21.5 | 21.5 |
| 3.04 | 3.4 | 13.28 | 15.24 | 18.32 | 18.32 |
| 2.56 | 2.7 | 11.2 | 12.23 | 15.47 | 15.47 |
| 2.12 | 2.3 | 9.29 | 10.31 | 12.85 | 12.85 |
| 1.77 | 2.2 | 7.73 | 9.61 | 10.69 | 10.69 |
| 1.5 | 2.1 | 6.56 | 9.53 | 9.06 | 9.06 |
| 0.92 | 3.3 | 4.03 | 14.41 | 5.53 | 5.53 |
| 0.98 | 3.1 | 4.29 | 13.92 | 5.88 | 5.88 |
| 1.05 | 2.8 | 4.58 | 12.63 | 6.28 | 6.28 |
| 1.18 | 2.8 | 5.13 | 12.42 | 7.02 | 7.02 |

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|---|---|---|---|---|---|
| 1.38 | 3.3 | 6 | 14.81 | 8.21 | 8.21 |
| 1.66 | 3.7 | 7.23 | 16.49 | 9.88 | 9.88 |
| 2.09 | 4 | 9.09 | 17.52 | 12.41 | 12.41 |
| 2.65 | 3.8 | 11.53 | 16.75 | 15.73 | 15.73 |
| 3.15 | 4.7 | 13.74 | 20.49 | 18.76 | 18.76 |
| 3.63 | 6.2 | 15.8 | 27.1 | 21.57 | 21.57 |
| 4.03 | 6.7 | 17.55 | 29.29 | 23.99 | 23.99 |
| 4.27 | 6.3 | 18.62 | 27.7 | 25.47 | 25.47 |
| 4.42 | 5.5 | 19.28 | 24.47 | 26.4 | 26.4 |
| 4.3 | 5.1 | 18.77 | 22.54 | 25.78 | 25.78 |
| 3.83 | 5.3 | 16.73 | 23.36 | 23.06 | 23.06 |
| 3.24 | 3.7 | 14.17 | 16.17 | 19.54 | 19.54 |
| 2.79 | 3.3 | 12.17 | 14.49 | 16.78 | 16.78 |
| 2.41 | 2.7 | 10.54 | 11.88 | 14.55 | 14.55 |
| 2.06 | 2.2 | 9 | 9.94 | 12.44 | 12.44 |
| 1.74 | 1.9 | 7.6 | 8.46 | 10.51 | 10.51 |
| 1.47 | 1.8 | 6.44 | 8.03 | 8.91 | 8.91 |

# APPENDIX F

# CENSUS TRACT POPULATION FILES

## Number of People Exposed at Different Concentration Levels to Various Chemicals

| Chemical | Annual or Maximum Value | Conc. ug/l | Type of Population | Area Number | People per 25 M2 | Number of 25 M2 Units In Area | People In Area | Total People |
|---|---|---|---|---|---|---|---|---|
| MEK | Maximum | 3 | Total | 23 | 0.209 | 4873 | 1,018 | |
| MEK | Maximum | 3 | Total | 24 | 0.063 | 127 | 8 | |
| MEK | Maximum | 3 | Total | 26 | 0.470 | 355 | 167 | |
| MEK | Maximum | 3 | Total | 30 | 0.072 | 421 | 30 | 1,224 |
| Mineral Spirits | Maximum | 10 | Total | 23 | 0.209 | 5321 | 1,112 | |
| Mineral Spirits | Maximum | 10 | Total | 24 | 0.063 | 143 | 9 | |
| Mineral Spirits | Maximum | 10 | Total | 26 | 0.470 | 499 | 235 | |
| Mineral Spirits | Maximum | 10 | Total | 30 | 0.072 | 565 | 41 | 1,396 |
| Rust Preventative | Maximum | 25 | Total | 23 | 0.209 | 3,905 | 816 | |
| Rust Preventative | Maximum | 25 | Total | 24 | 0.063 | 82 | 5 | |
| Rust Preventative | Maximum | 25 | Total | 26 | 0.470 | 155 | 73 | |
| Rust Preventative | Maximum | 25 | Total | 30 | 0.072 | 242 | 17 | 912 |

# Number of People Exposed at Various Concentration Levels

| Chemical | Annual or Maximum Value | Conc. ug/l | Type of Population | Area Number | People per 25 M2 | Number of 25 M2 Units In Area | People In Area | Total People |
|---|---|---|---|---|---|---|---|---|
| MEK | Annual | 6 | Total | 23 | 0.209 | 2,186 | 457 | |
| MEK | Annual | 6 | Total | 30 | 0.072 | 22 | 2 | 458 |
| MEK | Maximum | 6 | Total | 23 | 0.209 | 2,716 | 568 | |
| MEK | Maximum | 6 | Total | 24 | 0.063 | 68 | 4 | |
| MEK | Maximum | 6 | Total | 26 | 0.470 | 56 | 26 | |
| MEK | Maximum | 6 | Total | 30 | 0.072 | 88 | 6 | 605 |
| Mineral Spirits | Annual | 35 | Total | 23 | 0.209 | 1,696 | 354 | 354 |
| Mineral Spirits | Maximum | 35 | Total | 23 | 0.209 | 1,998 | 418 | |
| Mineral Spirits | Maximum | 35 | Total | 24 | 0.063 | 2 | 0 | |
| Mineral Spirits | Maximum | 35 | Total | 26 | 0.470 | 12 | 6 | |
| Mineral Spirits | Maximum | 35 | Total | 30 | 0.072 | 4 | 0 | 424 |
| Rust Preventative | Annual | 25 | Total | 23 | 0.209 | 2,902 | 607 | |
| Rust Preventative | Annual | 25 | Total | 24 | 0.063 | 36 | 2 | |
| Rust Preventative | Annual | 25 | Total | 30 | 0.072 | 182 | 13 | 622 |
| Rust Preventative | Maximum | 25 | Total | 23 | 0.209 | 3,905 | 816 | |
| Rust Preventative | Maximum | 25 | Total | 24 | 0.063 | 82 | 5 | |
| Rust Preventative | Maximum | 25 | Total | 26 | 0.470 | 155 | 73 | |
| Rust Preventative | Maximum | 25 | Total | 30 | 0.072 | 242 | 17 | 912 |

## Number of People Exposed at Various Concentration Levels

| Chemical | Annual or Maximum Value | Conc. ug/l | Type of Population | Area Number | People per 25 M2 | Number of 25 M2 Units In Area | People In Area | Total People |
|---|---|---|---|---|---|---|---|---|
| MEK | Annual | 6 | Total | 23 | 0.209 | 2,186 | 457 | |
| MEK | Annual | 6 | Total | 30 | 0.072 | 22 | 2 | 458 |
| MEK | Maximum | 6 | Total | 23 | 0.209 | 2,716 | 568 | |
| MEK | Maximum | 6 | Total | 24 | 0.063 | 68 | 4 | |
| MEK | Maximum | 6 | Total | 26 | 0.470 | 56 | 26 | |
| MEK | Maximum | 6 | Total | 30 | 0.072 | 88 | 6 | 605 |
| Mineral Spirits | Annual | 35 | Total | 23 | 0.209 | 1,696 | 354 | 354 |
| Mineral Spirits | Maximum | 35 | Total | 23 | 0.209 | 1,998 | 418 | |
| Mineral Spirits | Maximum | 35 | Total | 24 | 0.063 | 2 | 0 | |
| Mineral Spirits | Maximum | 35 | Total | 26 | 0.470 | 12 | 6 | |
| Mineral Spirits | Maximum | 35 | Total | 30 | 0.072 | 4 | 0 | 424 |
| Rust Preventative | Annual | 25 | Total | 23 | 0.209 | 2,902 | 607 | |
| Rust Preventative | Annual | 25 | Total | 24 | 0.063 | 36 | 2 | |
| Rust Preventative | Annual | 25 | Total | 30 | 0.072 | 182 | 13 | 622 |
| Rust Preventative | Maximum | 25 | Total | 23 | 0.209 | 3,905 | 816 | |
| Rust Preventative | Maximum | 25 | Total | 24 | 0.063 | 82 | 5 | |
| Rust Preventative | Maximum | 25 | Total | 26 | 0.470 | 155 | 73 | |
| Rust Preventative | Maximum | 25 | Total | 30 | 0.072 | 242 | 17 | 912 |

## Number of People Exposed to Various Concentrations of Rust Preventative

| Chemical | Conc. ug/l | Yearly Average or Maximum Value | Type of Population | Total Exposed This Level |
|---|---|---|---|---|
| Rust Preventative | 250 | Annual | Total | 0 |
| | 100 | Annual | Total | 0 |
| | 10 | Annual | Total | 3 |
| | 1 | Annual | Total | 10 |
| | 0.1 | Annual | Total | 161 |
| | 0.01 | Annual | Total | 37 |
| | 0.001 | Annual | Total | 9,548 |
| Rust Preventative | 250 | Maximum | Total | 3 |
| | 100 | Maximum | Total | 0 |
| | 10 | Maximum | Total | 14 |
| | 1 | Maximum | Total | 160 |
| | 0.1 | Maximum | Total | 2,730 |
| | 0.01 | Maximum | Total | 24,180 |
| | 0.001 | Maximum | Total | 55,026 |
| Rust Preventative | 250 | Maximum | Adult | 1 |
| | 100 | Maximum | Adult | 0 |
| | 10 | Maximum | Adult | 6 |
| | 1 | Maximum | Adult | 63 |
| | 0.1 | Maximum | Adult | 1,095 |
| | 0.01 | Maximum | Adult | 10,560 |
| | 0.001 | Maximum | Adult | 25,111 |

## Numpber of People Exposed to Various Concentrations of Rust Preventative

| Chemical | Conc. ug/l | Yearly Average or Maximum Value | Type of Population | Area | People per 25 M2 | Number of 25 M2 Units In Area | People In Area | Total Exposed at this Level or Above |
|---|---|---|---|---|---|---|---|---|
| Rust Preventative | 250 | Annual | Total | None | | | | 0 |
| | 100 | Annual | Total | None | | | | 0 |
| | 10 | Annual | Total | 23 | 0.209 | 16 | 3 | 3 |
| | 1 | Annual | Total | 23 | 0.209 | 64 | 13 | 13 |
| | 0.1 | Annual | Total | 23 | 0.209 | 816 | 171 | 171 |
| | 0.01 | Annual | Total | 25 | 0.271 | 728 | 197 | |
| | 0.01 | Annual | Total | 26 | 0.470 | 1 | 0 | 198 |
| | 0.001 | Annual | Total | 1 | 0.002 | 2,752 | 6 | |
| | 0.001 | Annual | Total | 2 | 0.012 | 46,435 | 557 | |
| | 0.001 | Annual | Total | 22 | 0.320 | 3,453 | 1,105 | |
| | 0.001 | Annual | Total | 23 | 0.209 | 6,384 | 1,334 | |
| | 0.001 | Annual | Total | 24 | 0.063 | 9,968 | 628 | |
| | 0.001 | Annual | Total | 25 | 0.271 | 6,487 | 1,758 | |
| | 0.001 | Annual | Total | 26 | 0.470 | 6,746 | 3,171 | |
| | 0.001 | Annual | Total | 30 | 0.072 | 16,676 | 1,201 | 9,759 |
| Rust Preventative | 250 | Maximum | Total | 23 | 0.209 | 16 | 3 | |
| | 100 | Maximum | Total | 23 | 0.209 | 16 | 3 | |

## Numpber of People Exposed to Various Concentrations of Rust Preventative

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 10 | Maximum | Total | 23 | 0.209 | 80 | 17 | |
| 1 | Maximum | Total | 23 | 0.209 | 848 | 177 | |
| 0.1 | Maximum | Total | 2 | 0.012 | 486 | 6 | |
| 0.1 | Maximum | Total | 22 | 0.320 | 205 | 66 | |
| 0.1 | Maximum | Total | 23 | 0.209 | 1,069 | 223 | |
| 0.1 | Maximum | Total | 24 | 0.063 | 265 | 17 | |
| 0.1 | Maximum | Total | 25 | 0.271 | 3,979 | 1,078 | |
| 0.1 | Maximum | Total | 26 | 0.470 | 3,052 | 1,434 | |
| 0.1 | Maximum | Total | 30 | 0.072 | 1,150 | 83 | 2,907 |
| 0.01 | Maximum | Total | 1 | 0.002 | 30,979 | 62 | |
| 0.01 | Maximum | Total | 2 | 0.012 | 45,563 | 547 | |
| 0.01 | Maximum | Total | 9 | 0.429 | 610 | 262 | |
| 0.01 | Maximum | Total | 20 | 0.181 | 10,713 | 1,939 | |
| 0.01 | Maximum | Total | 21 | 0.154 | 17,929 | 2,761 | |
| 0.01 | Maximum | Total | 22 | 0.320 | 3,628 | 1,161 | |
| 0.01 | Maximum | Total | 23 | 0.209 | 10,337 | 2,160 | |
| 0.01 | Maximum | Total | 24 | 0.063 | 32,590 | 2,053 | |
| 0.01 | Maximum | Total | 25 | 0.271 | 8,477 | 2,297 | |
| 0.01 | Maximum | Total | 26 | 0.470 | 6,805 | 3,198 | |
| 0.01 | Maximum | Total | 27 | 0.605 | 3,953 | 2,392 | |
| 0.01 | Maximum | Total | 28 | 0.456 | 2,317 | 1,057 | |
| 0.01 | Maximum | Total | 30 | 0.072 | 33,986 | 2,447 | |
| 0.01 | Maximum | Total | 31 | 0.393 | 3,363 | 1,322 | |
| 0.01 | Maximum | Total | 32 | 0.849 | 1,142 | 970 | |
| 0.01 | Maximum | Total | 33 | 1.234 | 1,204 | 1,486 | |
| 0.01 | Maximum | Total | 34 | 0.137 | 836 | 115 | |
| 0.01 | Maximum | Total | 35 | 0.231 | 946 | 219 | |
| 0.01 | Maximum | Total | 40 | 0.815 | 787 | 641 | 27,087 |

## Numpber of People Exposed to Various Concentrations of Rust Preventative

| | | | | | | |
|---|---|---|---|---|---|---|
| 0.001 | Maximum | Total | 1 | 0.002 | 50,731 | 101 |
| 0.001 | Maximum | Total | 2 | 0.012 | 101,544 | 1,219 |
| 0.001 | Maximum | Total | 3 | 0.948 | 3,001 | 2,845 |
| 0.001 | Maximum | Total | 4 | 0.386 | 433 | 167 |
| 0.001 | Maximum | Total | 5 | 0.550 | 5,847 | 3,216 |
| 0.001 | Maximum | Total | 6 | 0.276 | 860 | 237 |
| 0.001 | Maximum | Total | 7 | 0.369 | 6,514 | 2,404 |
| 0.001 | Maximum | Total | 8 | 0.134 | 323 | 43 |
| 0.001 | Maximum | Total | 9 | 0.429 | 12,558 | 5,387 |
| 0.001 | Maximum | Total | 10 | 0.937 | 1,870 | 1,752 |
| 0.001 | Maximum | Total | 11 | 0.915 | 2,038 | 1,865 |
| 0.001 | Maximum | Total | 12 | 0.553 | 2,166 | 1,198 |
| 0.001 | Maximum | Total | 13 | 0.872 | 438 | 382 |
| 0.001 | Maximum | Total | 14 | 0.967 | 1,987 | 1,921 |
| 0.001 | Maximum | Total | 15 | 0.576 | 2,237 | 1,289 |
| 0.001 | Maximum | Total | 16 | 0.332 | 2,830 | 940 |
| 0.001 | Maximum | Total | 20 | 0.181 | 20,743 | 3,754 |
| 0.001 | Maximum | Total | 21 | 0.154 | 25,778 | 3,970 |
| 0.001 | Maximum | Total | 22 | 0.320 | 3,628 | 1,161 |
| 0.001 | Maximum | Total | 23 | 0.209 | 11,087 | 2,317 |
| 0.001 | Maximum | Total | 24 | 0.063 | 32,590 | 2,053 |
| 0.001 | Maximum | Total | 25 | 0.271 | 8,967 | 2,430 |
| 0.001 | Maximum | Total | 26 | 0.470 | 6,805 | 3,198 |
| 0.001 | Maximum | Total | 27 | 0.605 | 3,953 | 2,392 |
| 0.001 | Maximum | Total | 28 | 0.456 | 5,885 | 2,684 |
| 0.001 | Maximum | Total | 29 | 0.858 | 1,018 | 873 |
| 0.001 | Maximum | Total | 30 | 0.072 | 41,326 | 2,975 |
| 0.001 | Maximum | Total | 31 | 0.393 | 5,214 | 2,049 |
| 0.001 | Maximum | Total | 32 | 0.849 | 5,412 | 4,595 |
| 0.001 | Maximum | Total | 33 | 1.234 | 2,778 | 3,428 |

## Numpber of People Exposed to Various Concentrations of Rust Preventative

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0.001 | Maximum | Total | 34 | 0.137 | 14,563 | 1,995 | |
| | 0.001 | Maximum | Total | 35 | 0.231 | 4,197 | 970 | |
| | 0.001 | Maximum | Total | 36 | 1.182 | 2,287 | 2,703 | |
| | 0.001 | Maximum | Total | 37 | 0.697 | 2,317 | 1,615 | |
| | 0.001 | Maximum | Total | 38 | 1.163 | 35 | 41 | |
| | 0.001 | Maximum | Total | 39 | 1.252 | 27 | 34 | |
| | 0.001 | Maximum | Total | 40 | 0.815 | 3,123 | 2,545 | |
| | 0.001 | Maximum | Total | 42 | 1.204 | 2,349 | 2,828 | |
| | 0.001 | Maximum | Total | 44 | 0.855 | 2,398 | 2,050 | |
| | 0.001 | Maximum | Total | 46 | 1.199 | 1,097 | 1,315 | |
| | 0.001 | Maximum | Total | 62 | 0.467 | 5,600 | 2,615 | |
| | 0.001 | Maximum | Total | 63 | 0.509 | 990 | 504 | |
| | 0.001 | Maximum | Total | 64 | 0.929 | 56 | 52 | 82,113 |
| Rust Preventative | 250 | Maximum | Adult | 23 | 0.082 | 16 | 1 | 1 |
| | 100 | Maximum | Adult | 23 | 0.082 | 16 | 1 | 1 |
| | 10 | Maximum | Adult | 23 | 0.082 | 80 | 7 | 7 |
| | 1 | Maximum | Adult | 23 | 0.082 | 848 | 70 | 70 |
| Rust Preventative | 0.1 | Maximum | Adult | 2 | 0.006 | 486 | 3 | |
| | 0.1 | Maximum | Adult | 22 | 0.126 | 205 | 26 | |
| | 0.1 | Maximum | Adult | 23 | 0.082 | 1,069 | 88 | |
| | 0.1 | Maximum | Adult | 24 | 0.029 | 265 | 8 | |
| | 0.1 | Maximum | Adult | 25 | 0.109 | 3,979 | 434 | |
| | 0.1 | Maximum | Adult | 26 | 0.188 | 3,052 | 574 | |
| | 0.1 | Maximum | Adult | 30 | 0.029 | 1,150 | 33 | 1,165 |

# Numpber of People Exposed to Various Concentrations of Rust Preventative

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Rust Preventative | 0.01 | Maximum | Adult | 1 | 0.001 | 30,979 | 31 | |
| | 0.01 | Maximum | Adult | 2 | 0.006 | 45,563 | 273 | |
| | 0.01 | Maximum | Adult | 9 | 0.189 | 610 | 115 | |
| | 0.01 | Maximum | Adult | 20 | 0.079 | 10,713 | 846 | |
| | 0.01 | Maximum | Adult | 21 | 0.078 | 17,929 | 1,398 | |
| | 0.01 | Maximum | Adult | 22 | 0.126 | 3,628 | 457 | |
| | 0.01 | Maximum | Adult | 23 | 0.082 | 10,337 | 848 | |
| | 0.01 | Maximum | Adult | 24 | 0.029 | 32,590 | 945 | |
| | 0.01 | Maximum | Adult | 25 | 0.109 | 8,477 | 924 | |
| | 0.01 | Maximum | Adult | 26 | 0.188 | 6,805 | 1,279 | |
| | 0.01 | Maximum | Adult | 27 | 0.242 | 3,953 | 957 | |
| | 0.01 | Maximum | Adult | 28 | 0.219 | 2,317 | 507 | |
| | 0.01 | Maximum | Adult | 30 | 0.029 | 33,986 | 986 | |
| | 0.01 | Maximum | Adult | 31 | 0.163 | 3,363 | 548 | |
| | 0.01 | Maximum | Adult | 32 | 0.351 | 1,142 | 401 | |
| | 0.01 | Maximum | Adult | 33 | 0.645 | 1,204 | 777 | |
| | 0.01 | Maximum | Adult | 34 | 0.061 | 836 | 51 | |
| | 0.01 | Maximum | Adult | 35 | 0.097 | 946 | 92 | |
| | 0.01 | Maximum | Adult | 40 | 0.367 | 787 | 289 | 11,724 |
| | | | | | | | | |
| Rust Preventative | 0.001 | Maximum | Adult | 1 | 0.001 | 50,731 | 51 | |
| | 0.001 | Maximum | Adult | 2 | 0.006 | 101,544 | 609 | |
| | 0.001 | Maximum | Adult | 3 | 0.430 | 3,001 | 1,290 | |
| | 0.001 | Maximum | Adult | 4 | 0.169 | 433 | 73 | |
| | 0.001 | Maximum | Adult | 5 | 0.236 | 5,847 | 1,380 | |
| | 0.001 | Maximum | Adult | 6 | 0.118 | 860 | 101 | |
| | 0.001 | Maximum | Adult | 7 | 0.143 | 6,514 | 932 | |
| | 0.001 | Maximum | Adult | 8 | 0.044 | 323 | 14 | |
| | 0.001 | Maximum | Adult | 9 | 0.189 | 12,558 | 2,373 | |
| | 0.001 | Maximum | Adult | 10 | 0.349 | 1,870 | 653 | |
| | 0.001 | Maximum | Adult | 11 | 0.309 | 2,038 | 630 | |

## Numpber of People Exposed to Various Concentrations of Rust Preventative

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 0.001 | Maximum | Adult | 12 | 0.187 | 2,166 | 405 | |
| 0.001 | Maximum | Adult | 13 | 0.334 | 438 | 146 | |
| 0.001 | Maximum | Adult | 14 | 0.413 | 1,987 | 821 | |
| 0.001 | Maximum | Adult | 15 | 0.208 | 2,237 | 465 | |
| 0.001 | Maximum | Adult | 16 | 0.142 | 2,830 | 402 | |
| 0.001 | Maximum | Adult | 20 | 0.079 | 20,743 | 1,639 | |
| 0.001 | Maximum | Adult | 21 | 0.078 | 25,778 | 2,011 | |
| 0.001 | Maximum | Adult | 22 | 0.126 | 3,628 | 457 | |
| 0.001 | Maximum | Adult | 23 | 0.082 | 11,087 | 909 | |
| 0.001 | Maximum | Adult | 24 | 0.029 | 32,590 | 945 | |
| 0.001 | Maximum | Adult | 25 | 0.109 | 8,967 | 977 | |
| 0.001 | Maximum | Adult | 26 | 0.188 | 6,805 | 1,279 | |
| 0.001 | Maximum | Adult | 27 | 0.242 | 3,953 | 957 | |
| 0.001 | Maximum | Adult | 28 | 0.219 | 5,885 | 1,289 | |
| 0.001 | Maximum | Adult | 29 | 0.358 | 1,018 | 364 | |
| 0.001 | Maximum | Adult | 30 | 0.029 | 41,326 | 1,198 | |
| 0.001 | Maximum | Adult | 31 | 0.163 | 5,214 | 850 | |
| 0.001 | Maximum | Adult | 32 | 0.351 | 5,412 | 1,900 | |
| 0.001 | Maximum | Adult | 33 | 0.645 | 2,778 | 1,792 | |
| 0.001 | Maximum | Adult | 34 | 0.061 | 14,563 | 888 | |
| 0.001 | Maximum | Adult | 35 | 0.097 | 4,197 | 407 | |
| 0.001 | Maximum | Adult | 36 | 0.590 | 2,287 | 1,349 | |
| 0.001 | Maximum | Adult | 37 | 0.357 | 2,317 | 827 | |
| 0.001 | Maximum | Adult | 38 | 0.641 | 35 | 22 | |
| 0.001 | Maximum | Adult | 39 | 0.650 | 27 | 18 | |
| 0.001 | Maximum | Adult | 40 | 0.367 | 3,123 | 1,146 | |
| 0.001 | Maximum | Adult | 42 | 0.730 | 2,349 | 1,715 | |
| 0.001 | Maximum | Adult | 44 | 0.403 | 2,398 | 966 | |
| 0.001 | Maximum | Adult | 46 | 0.609 | 1,097 | 668 | |
| 0.001 | Maximum | Adult | 62 | 0.296 | 5,600 | 1,658 | |
| 0.001 | Maximum | Adult | 63 | 0.260 | 990 | 257 | 36,835 |

# APPENDIX G

# RISK CHARACTERIZATION CALCULATIONS

# Estimating Reference Concentrations (RfC)

## Mineral Spirits

Formula for Estimating the Reference Concentration:

$$\text{RfC (mg/kg/day)} = \frac{\text{AAL (mg/m3) x ABR (m3/day)}}{\text{ABW (kg)}}$$

| | | | | |
|---|---|---|---|---|
| Where: | AAL = | 350 | ug/m3 | Natich Database, ambient air level for Mineral Spirits in Texas, annual average time |
| | AAL = | 3,500 | ug/m3 | Natich Database, ambient air level for Mineral Spirits in Texas, 30 min average time |
| | ABR = | 20 | (m3/day) | Average breathing rate for a human adult |
| | ABW = | 70 | (kg) | Average weight of an human adult |
| | *RfC =* | 0.10 | (mg/kg/day) | *Annual Average Exposure* |
| | *RfC =* | 1.00 | (mg/kg/day) | *Short Term Exposure* |

# Estimating Reference Concentrations (RfC)

## Rust Preventative

Formula for Estimating the Reference Concentration:

$$\text{RfC (mg/kg/day)} = \frac{\text{AAL (mg/m3) x ABR (m3/day)}}{\text{ABW (kg)}}$$

Where: AAL = 25 ug/m3 Natich Database, ambient air level for mineral oil in South Carolina over a 24 hour averaging time. It is based on the Occupational Exposure Level of 5 mg/m3.

ABR = 20 (m3/day)

ABW = 70 (kg)

*RfC* = **0.007** (mg/kg/day)

# Estimating Reference Concentrations (RfC)

**Methyl Ethyl Ketone**

| **Endpoint** | **AALG**<br>**mg/m3*** | **RfC**<br>**mg/kg/day** |
|---|---|---|
| Developmental Toxicity | 0.130 | 0.037 |
| Systemic Toxicity | | |
| Neuromotor Problems | 0.330 | 0.094 |
| Decreased Weight | 1.500 | 0.429 |
| Irritation | 12.000 | 3.429 |

*As listed in Calabrese and Kenyon, 1991

Formula for Estimating the Reference Concentration:

$$\text{RfC (mg/kg/day)} = \frac{\text{AALG (mg/m3)* x ABR (m3/day)}}{\text{ABW (kg)}}$$

Where: ABR = 20 (m3/day)

ABW = 70 (kg)

# Reasonably Exposed Individual (REI) Calculations

**Chemical Concentration (ug/M3) at Nearest Residential Neighbor to the North, South, East and West**

| | *North* | *N-Date* | *South* | *S-Date* | *East* | *E-Date* | *West* | *W-Date* |
|---|---|---|---|---|---|---|---|---|
| **Mineral Spirits** | | | | | | | | |
| Maximum - 24 hour | 2.83343 | 9-Nov | 0.45924 | 35054.00 | 0.83002 | 6-Jun | 0.57822 | 25-Aug |
| Average | 0.55648 | | 0.0096 | | 0.04869 | | 0.04493 | |
| **Rust Preventative** | | | | | | | | |
| Maximum - 24 | 0.3095 | 5-Apr | 0.06318 | 35054.00 | 0.11323 | 6-Jun | 0.07943 | 25-Aug |
| Average | 0.0768 | | 0.00132 | | 0.00667 | | 0.00619 | |
| **Methyl Ethyl Ketone** | | | | | | | | |
| Maximum - 24 | 0.06484 | 9-Nov | 0.01052 | 35054.00 | 0.01905 | 6-Jun | 0.01324 | 25-Aug |
| Average | 0.01273 | | 0.00022 | | 0.00112 | | 0.00103 | |

| **Chemical** | **Reference Conc.** | | |
|---|---|---|---|
| Mineral Spirits | 0.1 | *Annual* | 1.0 *Short Term* |
| Rust Preventative | 0.007 | | |
| Methyl Ethyl Ketone | 0.037 | | |

# Reasonably Exposed Individual (REI) Calculations

**Calculations to Determine REI**

| *Chemical* | *Location* | *Average or Maximum* | CA *Concent. in Air mg/m3* | IR *Inhalation Rate m3/day* | ET *Exposure Time hours/day* | EF *Exposure Frequency days/year* | ED *Exposure Duration years* | BW *Body Weight kg* | AT *Averaging Time Days* | *Intake mg/kg-d* | *Hazard Index* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mineral Spirits** | North | Maximum | 2.83E-03 | 0.83 | 4 | 365 | 30 | 70 | 25550 | 5.78E-05 | 5.78E-05 |
| | South | Maximum | 4.59E-04 | 0.83 | 4 | 365 | 30 | 70 | 25550 | 9.37E-06 | 9.37E-06 |
| | East | Maximum | 8.30E-04 | 0.83 | 4 | 365 | 30 | 70 | 25550 | 1.69E-05 | 1.69E-05 |
| | West | Maximum | 5.78E-04 | 0.83 | 4 | 365 | 30 | 70 | 25550 | 1.18E-05 | 1.18E-05 |
| | North | Average | 5.56E-04 | 0.83 | 4 | 365 | 30 | 70 | 25550 | 1.14E-05 | 1.14E-04 |
| | South | Average | 9.60E-06 | 0.83 | 4 | 365 | 30 | 70 | 25550 | 1.96E-07 | 1.96E-06 |
| | East | Average | 4.87E-05 | 0.83 | 4 | 365 | 30 | 70 | 25550 | 9.94E-07 | 9.94E-06 |
| | West | Average | 4.49E-05 | 0.83 | 4 | 365 | 30 | 70 | 25550 | 9.17E-07 | 9.17E-06 |
| **Rust Preventative** | North | Maximum | 3.10E-04 | 0.83 | 4 | 365 | 30 | 70 | 25550 | 6.32E-06 | 9.02E-04 |
| | South | Maximum | 6.32E-05 | 0.83 | 4 | 365 | 30 | 70 | 25550 | 1.29E-06 | 1.84E-04 |
| | East | Maximum | 1.13E-04 | 0.83 | 4 | 365 | 30 | 70 | 25550 | 2.31E-06 | 3.30E-04 |
| | West | Maximum | 7.94E-05 | 0.83 | 4 | 365 | 30 | 70 | 25550 | 1.62E-06 | 2.32E-04 |
| | North | Average | 7.68E-05 | 0.83 | 4 | 365 | 30 | 70 | 25550 | 1.57E-06 | 2.24E-04 |
| | South | Average | 1.32E-06 | 0.83 | 4 | 365 | 30 | 70 | 25550 | 2.69E-08 | 3.85E-06 |
| | East | Average | 6.67E-06 | 0.83 | 4 | 365 | 30 | 70 | 25550 | 1.36E-07 | 1.94E-05 |
| | West | Average | 6.19E-06 | 0.83 | 4 | 365 | 30 | 70 | 25550 | 1.26E-07 | 1.80E-05 |
| **Methyl Ethyl Ketone** | North | Maximum | 6.48E-05 | 0.83 | 4 | 365 | 30 | 70 | 25550 | 1.32E-06 | 3.58E-05 |
| | South | Maximum | 1.05E-05 | 0.83 | 4 | 365 | 30 | 70 | 25550 | 2.15E-07 | 5.80E-06 |
| | East | Maximum | 1.91E-05 | 0.83 | 4 | 365 | 30 | 70 | 25550 | 3.89E-07 | 1.05E-05 |
| | West | Maximum | 1.32E-05 | 0.83 | 4 | 365 | 30 | 70 | 25550 | 2.70E-07 | 7.30E-06 |
| | North | Average | 1.27E-05 | 0.83 | 4 | 365 | 30 | 70 | 25550 | 2.60E-07 | 7.02E-06 |
| | South | Average | 2.20E-07 | 0.83 | 4 | 365 | 30 | 70 | 25550 | 4.49E-09 | 1.21E-07 |
| | East | Average | 1.12E-06 | 0.83 | 4 | 365 | 30 | 70 | 25550 | 2.29E-08 | 6.18E-07 |
| | West | Average | 1.03E-06 | 0.83 | 4 | 365 | 30 | 70 | 25550 | 2.10E-08 | 5.68E-07 |

# Maximum Exposed Individual (MEI) Calculations

## Highest Concentration (ug/M3) of Chemicals at Fenceline

| | *ug/l* | *Date* | *Location* |
|---|---|---|---|
| **Mineral Spirits** | | | |
| Maximum - 24 hour | 46.067 | 9-Nov | |
| Average | 10.327 | | 0x, 200y |
| **Rust Preventative** | | | |
| Maximum - 24 | 6.718 | 9-Nov | |
| Average | 1.470 | | 0x, 200y |
| **Methyl Ethyl Ketone** | | | |
| Maximum - 24 | 1.031 | 9-Nov | |
| Average | 0.233 | | 0x, 200y |

| **Chemical** | **Reference Conc.** | | |
|---|---|---|---|
| Mineral Spirits | 0.1 | *Annual* | 1.0 *Short Term* |
| Rust Preventative | 0.007 | | |
| Methyl Ethyl Ketone | 0.13 | | |

## Maximum Exposed Individual (MEI) Calculations

**Calculations to Determine MEI**

| *Chemical* | *Location* | *Average or Maximum* | **CA** *Concent. in Air ug/m3* | **IR** *Inhalation Rate m3/hour* | **ET** *Exposure Time hours/day* | **EF** *Exposure Frequency days/year* | **ED** *Exposure Duration years* | **BW** *Body Weight kg* | **AT** *Averaging Time Days* | *Intake mg/kg-d* | *Hazard Index* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mineral Spirits** | Fenceline | Maximum | 46.067 | 0.83 | 24 | 365 | 70 | 70 | 25550 | 1.31E-02 | 1.31E-02 |
| | Fenceline | Average | 10.327 | 0.83 | 24 | 365 | 70 | 70 | 25550 | 2.94E-03 | 2.94E-02 |
| **Rust Preventative** | Fenceline | Maximum | 6.718 | 0.83 | 24 | 365 | 70 | 70 | 25550 | 1.91E-03 | 2.73E-01 |
| | Fenceline | Average | 1.470 | 0.83 | 24 | 365 | 70 | 70 | 25550 | 4.18E-04 | 5.98E-02 |
| **Methyl Ethyl Ketone** | Fenceline | Maximum | 1.031 | 0.83 | 24 | 365 | 70 | 70 | 25550 | 2.93E-04 | 2.26E-03 |
| | Fenceline | Average | 0.233 | 0.83 | 24 | 365 | 70 | 70 | 25550 | 6.64E-05 | 5.11E-04 |

# Cancer Calculations

## Calculations to Determine Cancer Incidence for Rust Preventative

| *Type of Population* | *Conc. in Air ug/m3* | *Inhalation Rate m3/day* | *Exposure Frequency days/year* | *Exposure Duration years* | *Body Weight kg* | *Averaging Time Days* | *Intake mg/kg-d* | *Cancer Slope Factor** | *Cancer Incidence* | *Average Number of Exposed People* | *Maximum Number of Exposed People* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Total | 250 | 20 | 365 | 70 | 70 | 25550 | 7.14E-05 | 0.51 | 3.64E-05 | 0 | 3 |
| Total | 100 | 20 | 365 | 70 | 70 | 25550 | 2.86E-05 | 0.51 | 1.46E-05 | 0 | 3 |
| Total | 10 | 20 | 365 | 70 | 70 | 25550 | 2.86E-06 | 0.51 | 1.46E-06 | 3 | 17 |
| Total | 1 | 20 | 365 | 70 | 70 | 25550 | 2.86E-07 | 0.51 | 1.46E-07 | 13 | 177 |
| Total | 0.1 | 20 | 365 | 70 | 70 | 25550 | 2.86E-08 | 0.51 | 1.46E-08 | 171 | 2,907 |
| Total | 0.01 | 20 | 365 | 70 | 70 | 25550 | 2.86E-09 | 0.51 | 1.46E-09 | 198 | 27,087 |
| Total | 0.001 | 20 | 365 | 70 | 70 | 25550 | 2.86E-10 | 0.51 | 1.46E-10 | 9,759 | 82,113 |

** Note: This is a hypothetical value.*

# Reproductive Effects Calculations

## Calculations to Determine Cancer Incidence for Rust Preventative

| *Type of Population* | *Conc. in Air ug/m3* | *Inhalation Rate m3/day* | *Exposure Frequency days/year* | *Exposure Duration years* | *Body Weight kg* | *Averaging Time Days* | *Intake mg/kg-d* | *Reference Conc.* | *Hazard Index* | *Maximum Number of Exposed People* |
|---|---|---|---|---|---|---|---|---|---|---|
| Adult | 250 | 20 | 365 | 70 | 70 | 25550 | 7.14E-05 | 0.007 | 1.02E-02 | 1 |
| Adult | 100 | 20 | 365 | 70 | 70 | 25550 | 2.86E-05 | 0.007 | 4.08E-03 | 1 |
| Adult | 10 | 20 | 365 | 70 | 70 | 25550 | 2.86E-06 | 0.007 | 4.08E-04 | 7 |
| Adult | 1 | 20 | 365 | 70 | 70 | 25550 | 2.86E-07 | 0.007 | 4.08E-05 | 70 |
| Adult | 0.1 | 20 | 365 | 70 | 70 | 25550 | 2.86E-08 | 0.007 | 4.08E-06 | 1,165 |
| Adult | 0.01 | 20 | 365 | 70 | 70 | 25550 | 2.86E-09 | 0.007 | 4.08E-07 | 11,724 |
| Adult | 0.001 | 20 | 365 | 70 | 70 | 25550 | 2.86E-10 | 0.007 | 4.08E-08 | 36,835 |

## Comparison of Hazard Indexes and Number of Exposed People

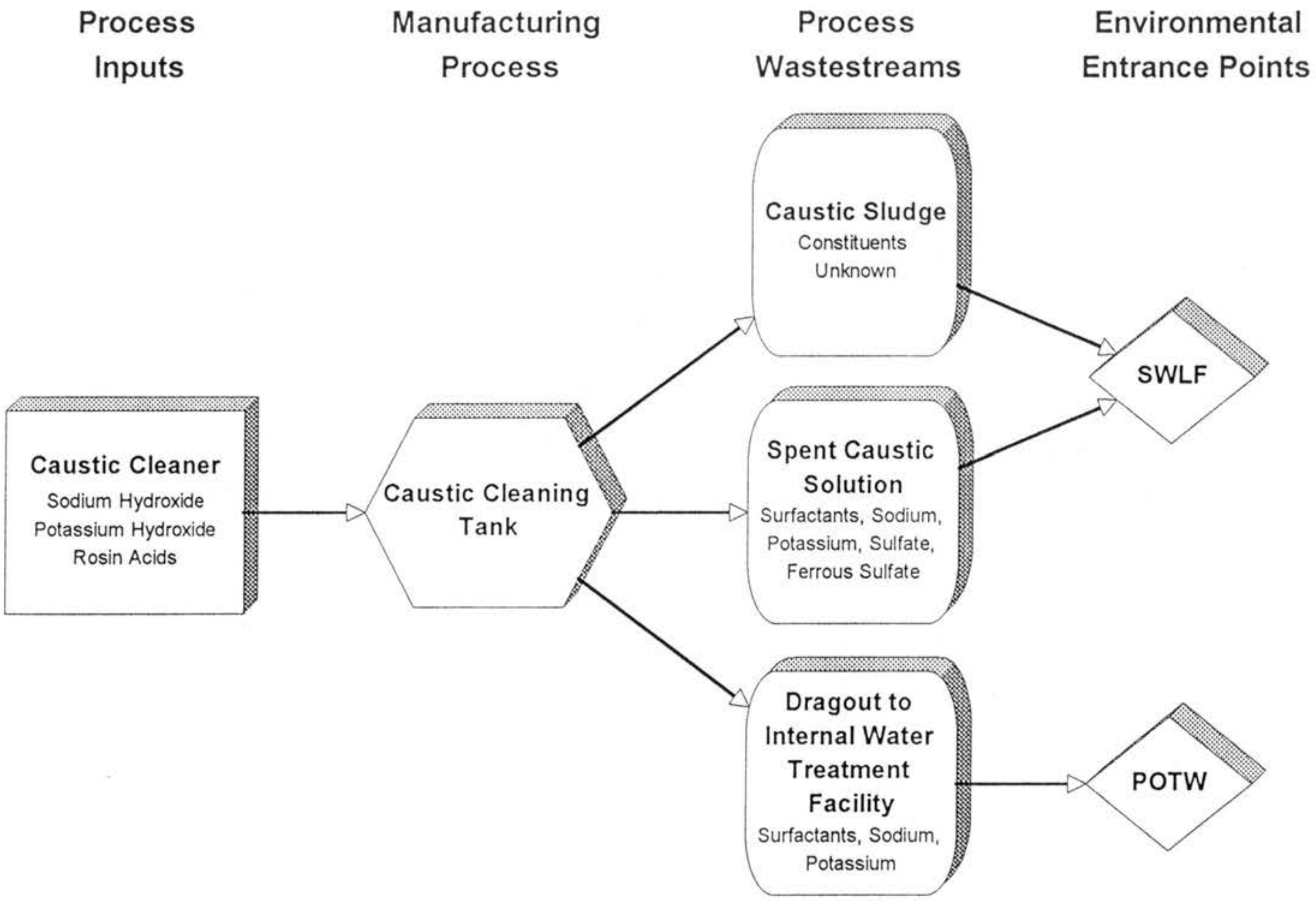
**Calculations of Hazard Indexes**

| *Chemical* | *Average or Maximum* | CA *Concent. in Air mg/m3* | IR *Inhalation Rate m3/day* | ET *Exposure Time hours/day* | EF *Exposure Frequency days/year* | ED *Exposure Duration years* | BW *Body Weight kg* | AT *Averaging Time Days* | *Intake mg/kg-d* | *Hazard Index* | *Total People* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mineral Spirits | Maximum | 35 | 0.83 | 4 | 365 | 30 | 70 | 25550 | 7.14E-01 | 7.14E-01 | 424 |
| Mineral Spirits | Annual | 35 | 0.83 | 4 | 365 | 30 | 70 | 25550 | 7.14E-01 | 7.14E+00 | 354 |
| Rust Preventative | Maximum | 25 | 0.83 | 4 | 365 | 30 | 70 | 25550 | 5.10E-01 | 7.29E+01 | 912 |
| Rust Preventative | Annual | 25 | 0.83 | 4 | 365 | 30 | 70 | 25550 | 5.10E-01 | 7.29E+01 | 622 |
| MEK | Maximum | 6 | 0.83 | 4 | 365 | 30 | 70 | 25550 | 1.22E-01 | 3.31E+00 | 605 |
| MEK | Annual | 6 | 0.83 | 4 | 365 | 30 | 70 | 25550 | 1.22E-01 | 3.31E+00 | 458 |

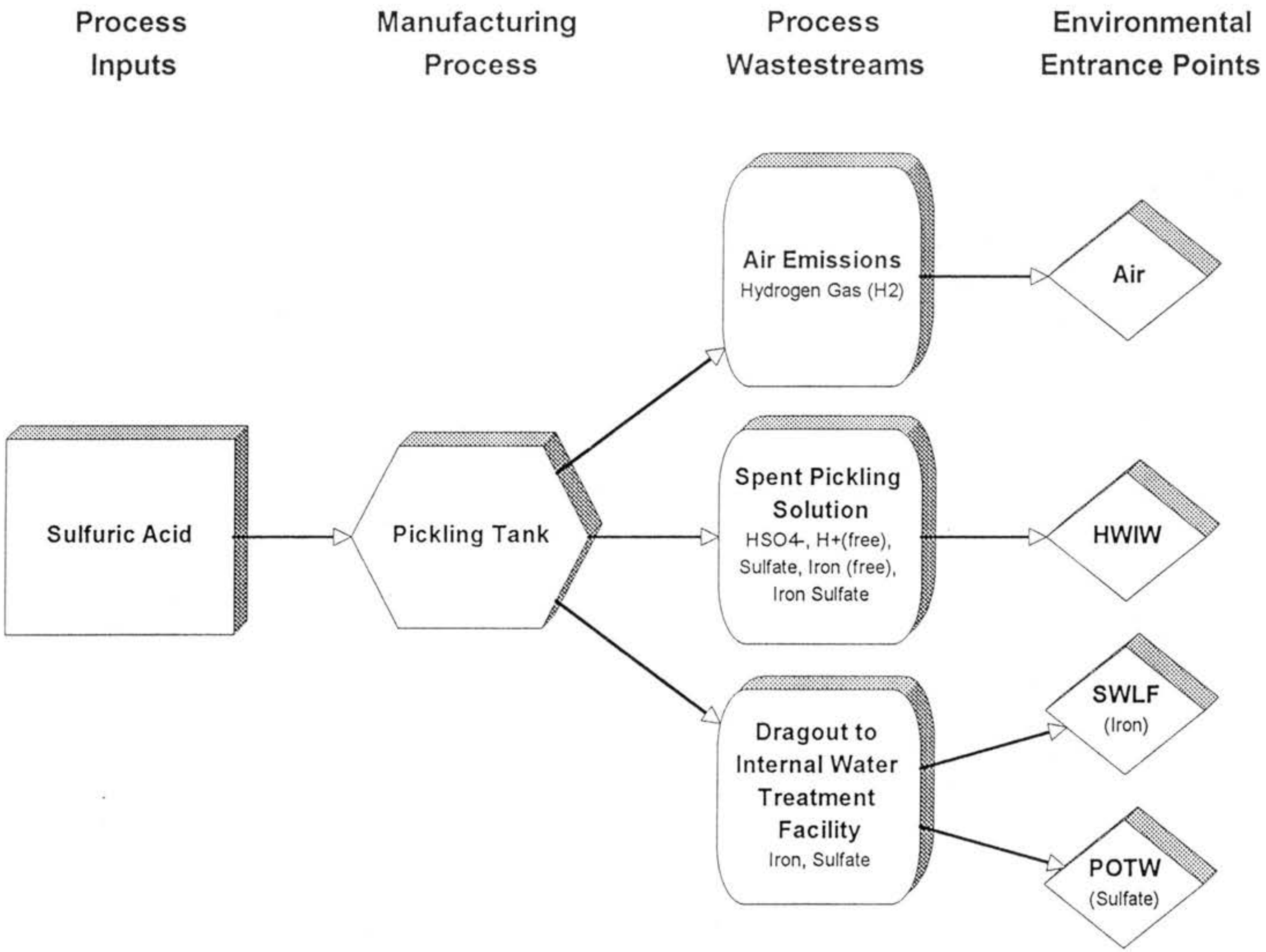
| **Chemical** | **Reference Conc.** | |
|---|---|---|
| Mineral Spirits | 0.1 *Annual* | 1.0 *Short Term* |
| Rust Preventative | 0.007 | |
| Methyl Ethyl Ketone | 0.037 | |

# APPENDIX H

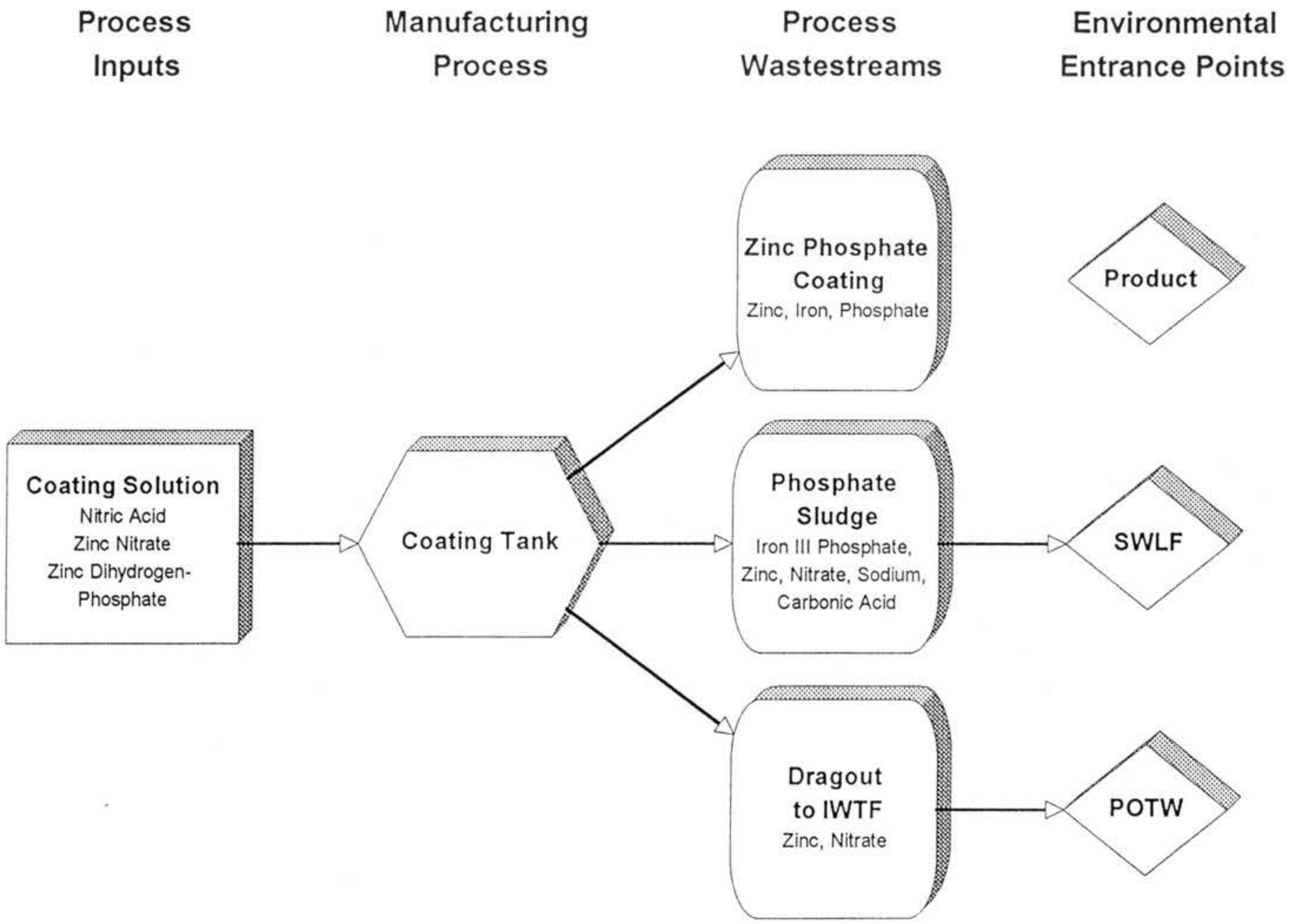
# PROCESS WASTESTREAM SCHEMATICS



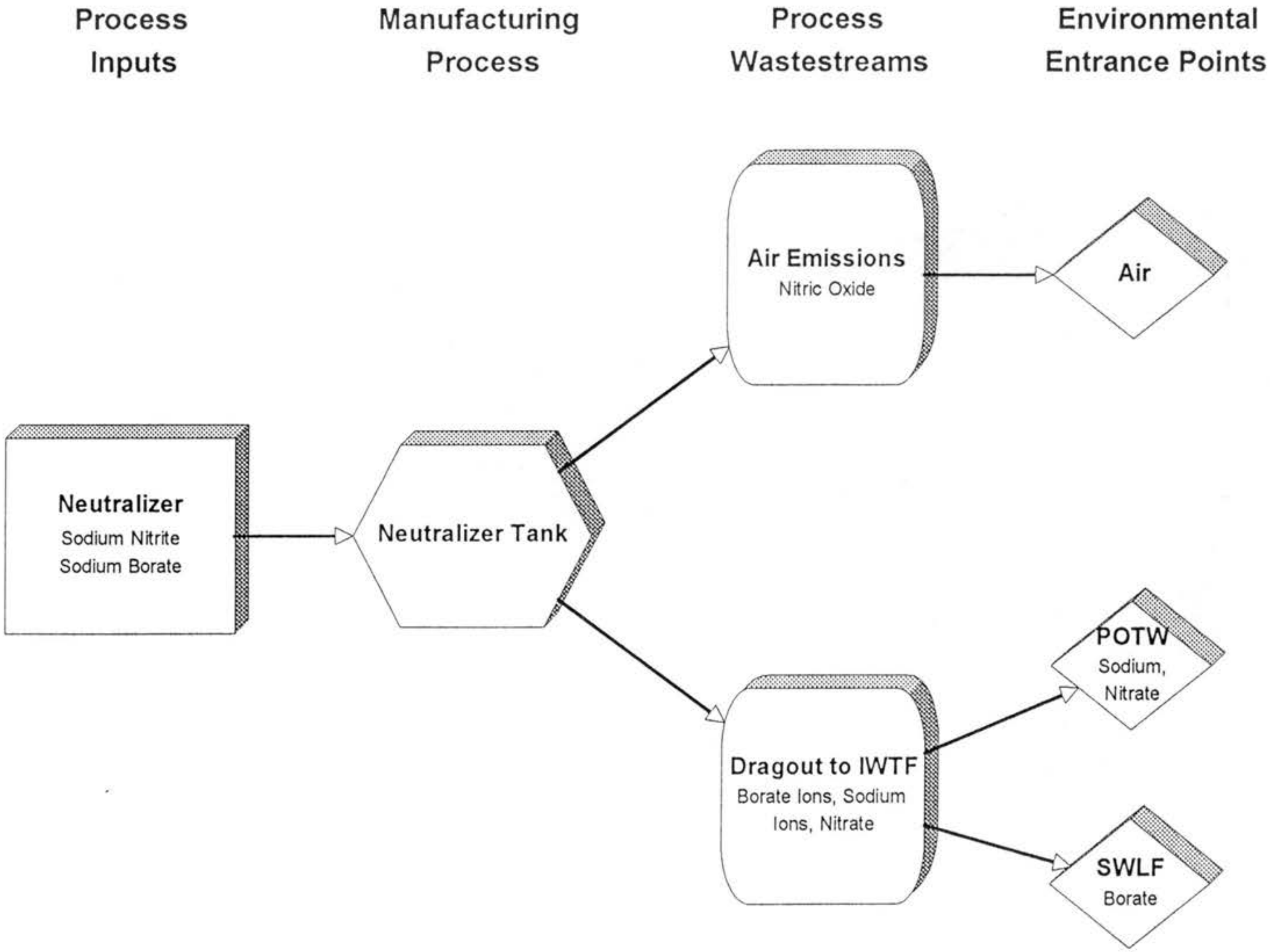
Process Wastestreams - Caustic Cleaner



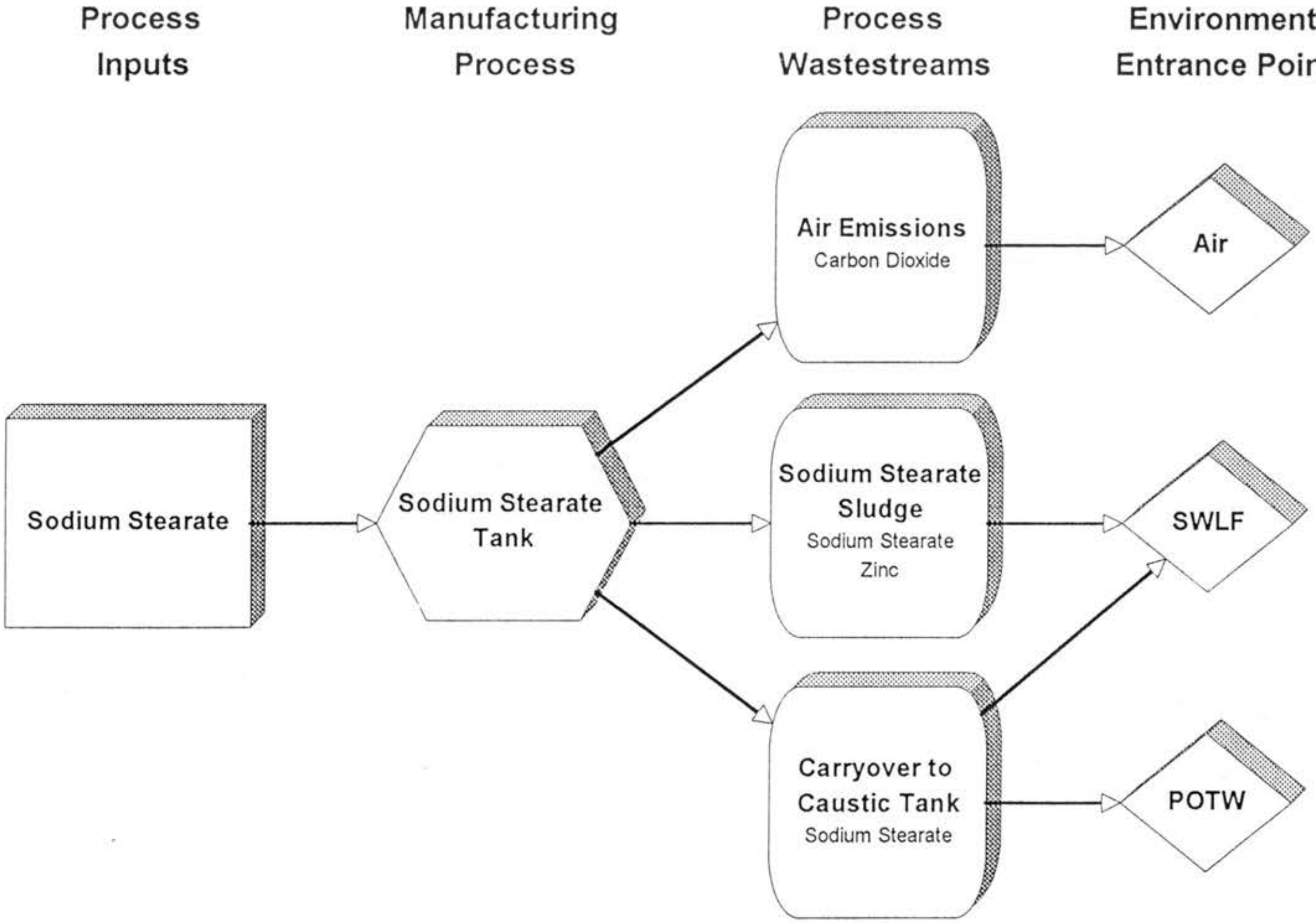
Process Wastestreams - Sulfuric Acid



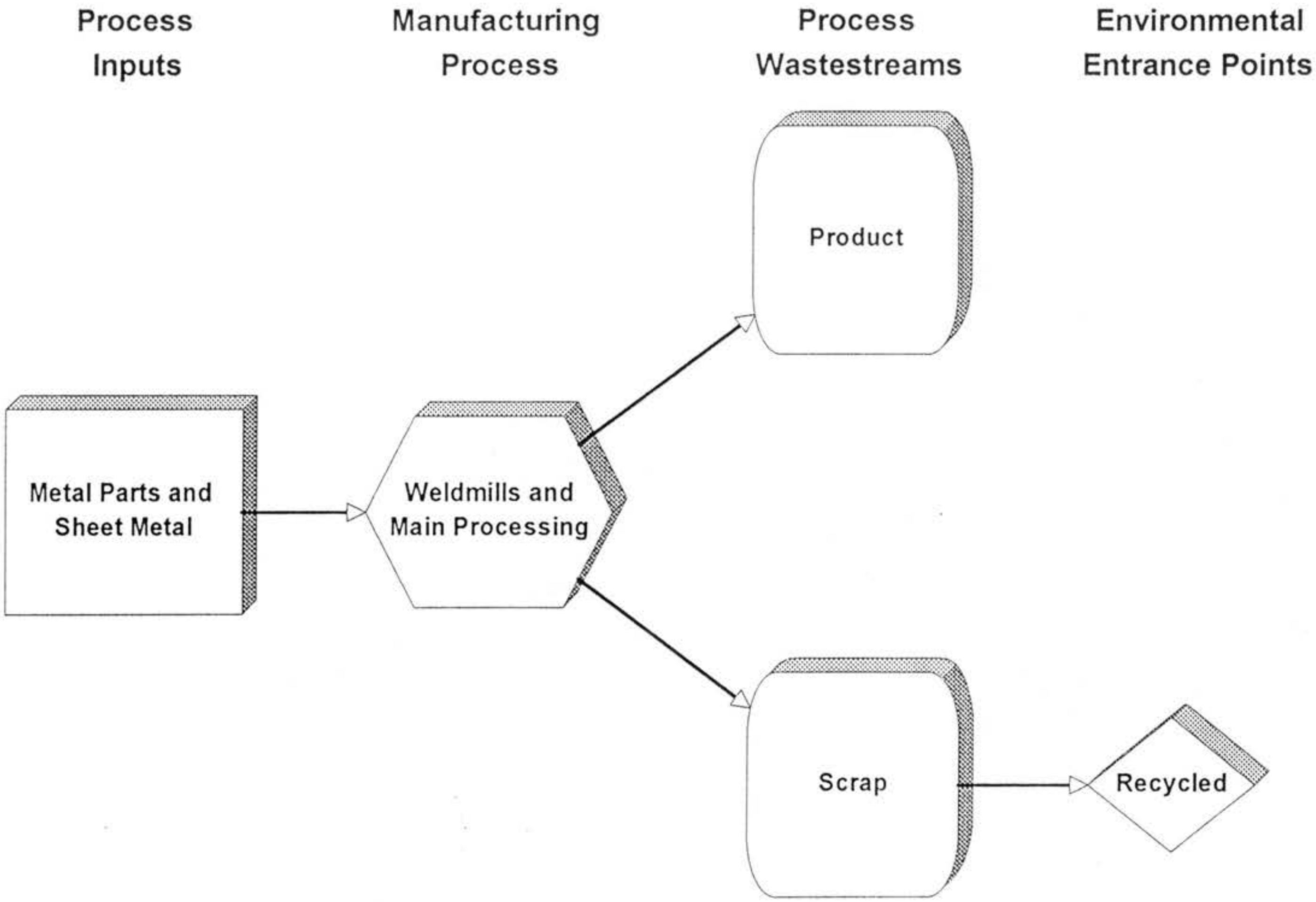
Process Wastestreams - Zinc Phosphate Coating Solution



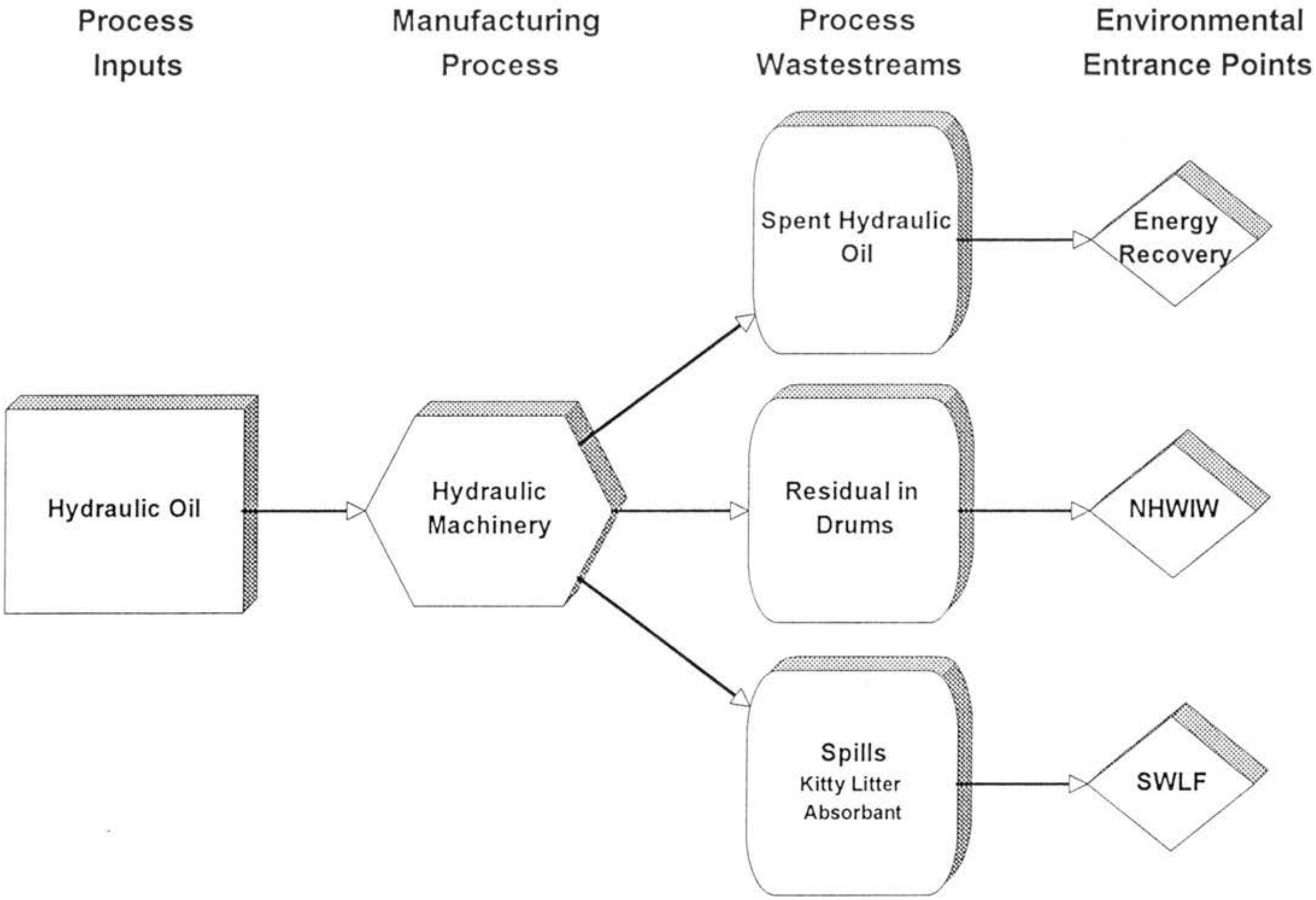
Process Wastestreams - Neutralizer



Process Wastestreams - Sodium Stearate



Process Wastestreams - Metal Parts and Sheet Metal



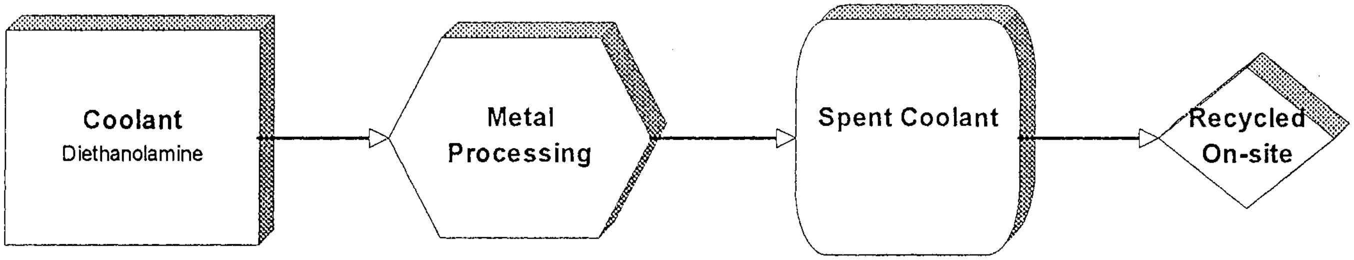
Process Wastestreams - Hydraulic Oil

Process Inputs

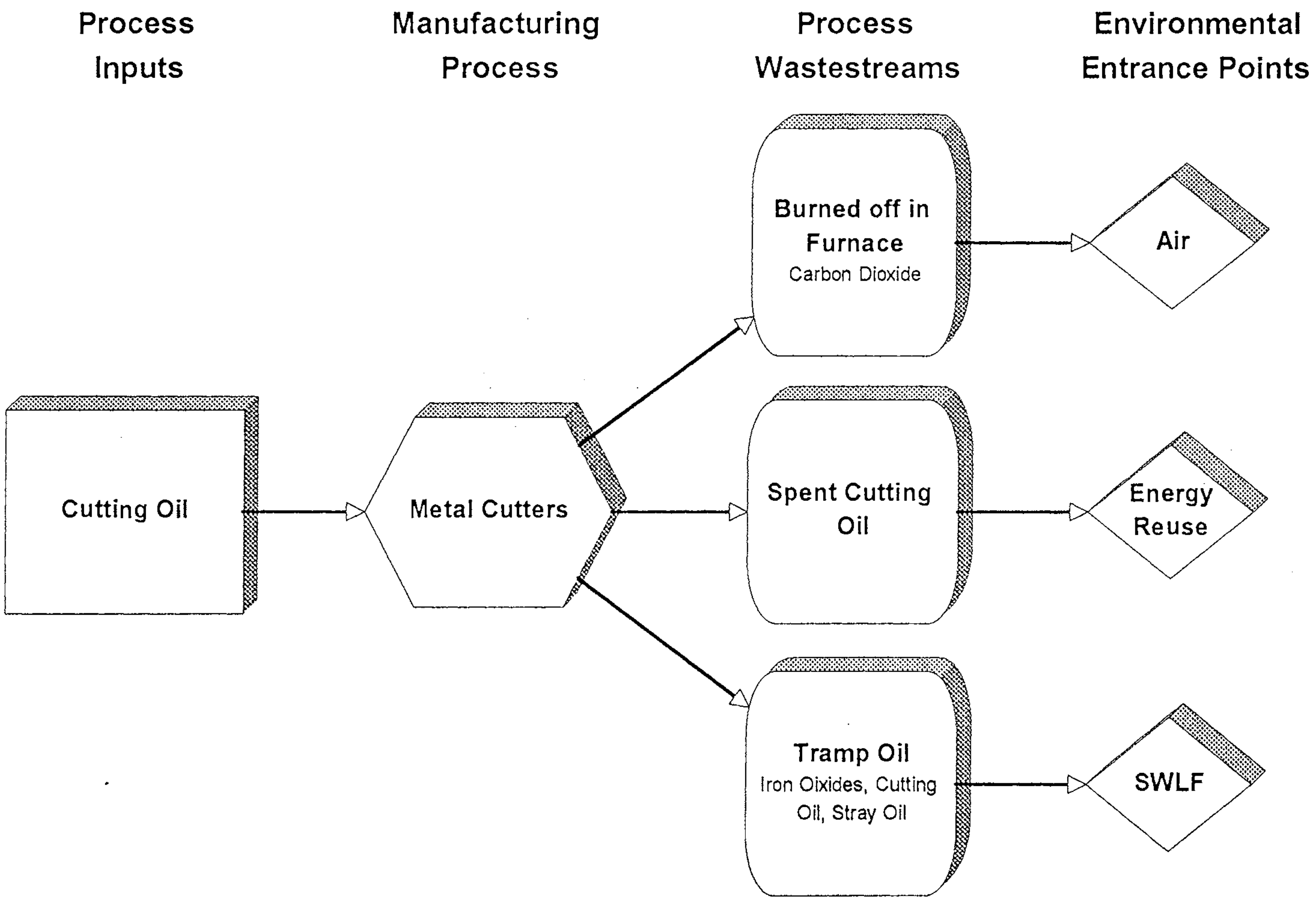
Manufacturing Process

Process Wastestreams

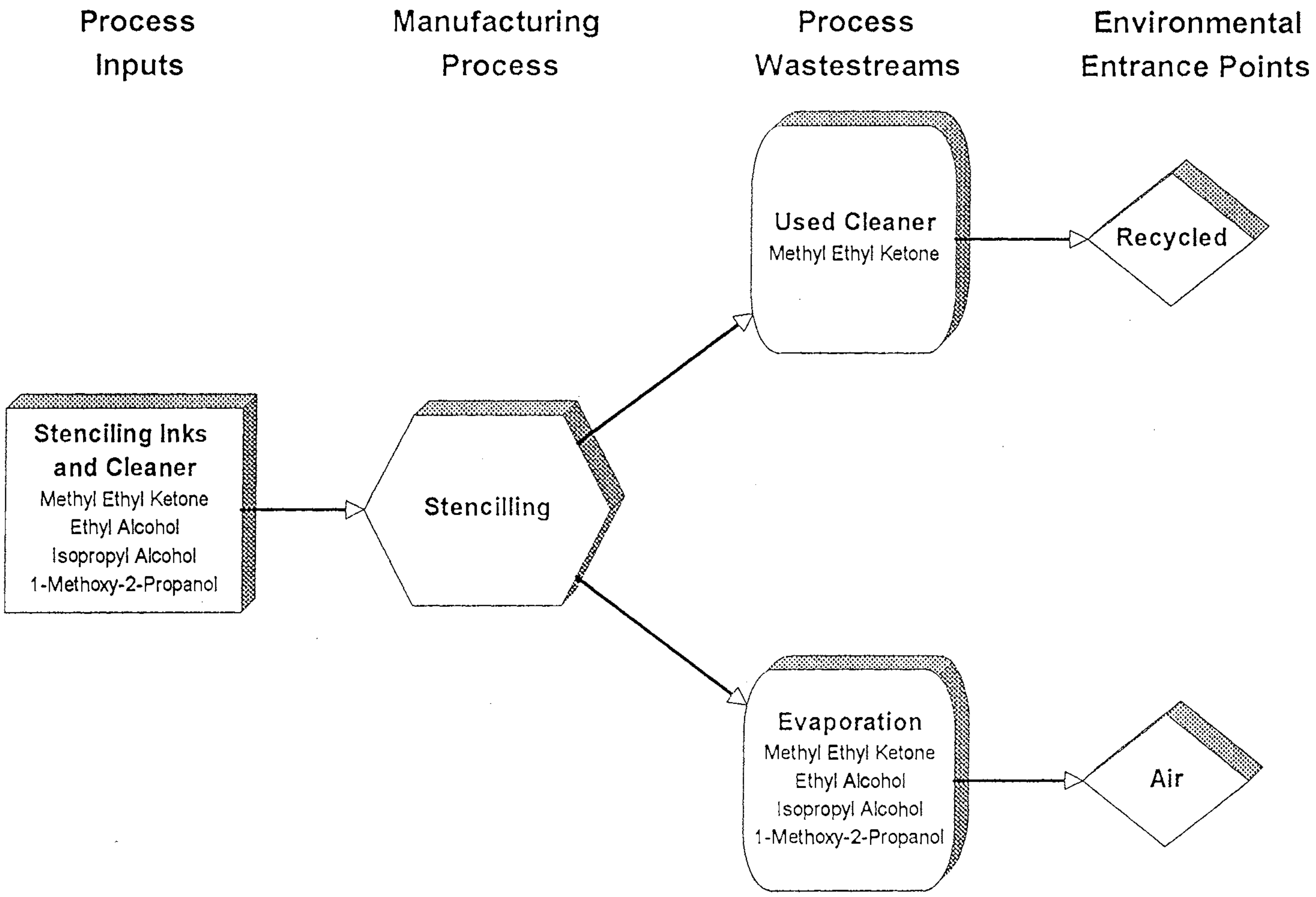
Environmental Entrance Points



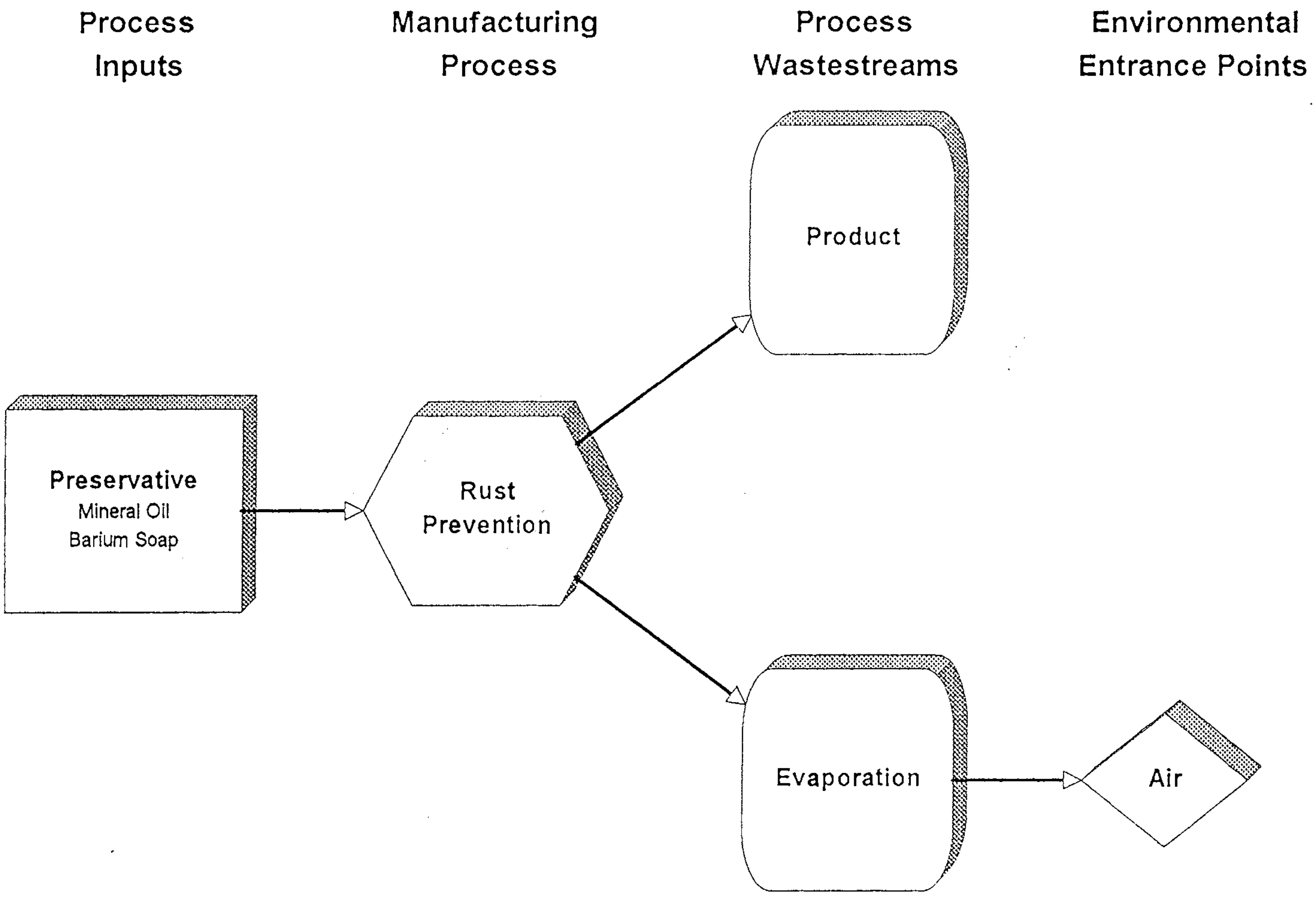
Process Wastestreams - Coolant



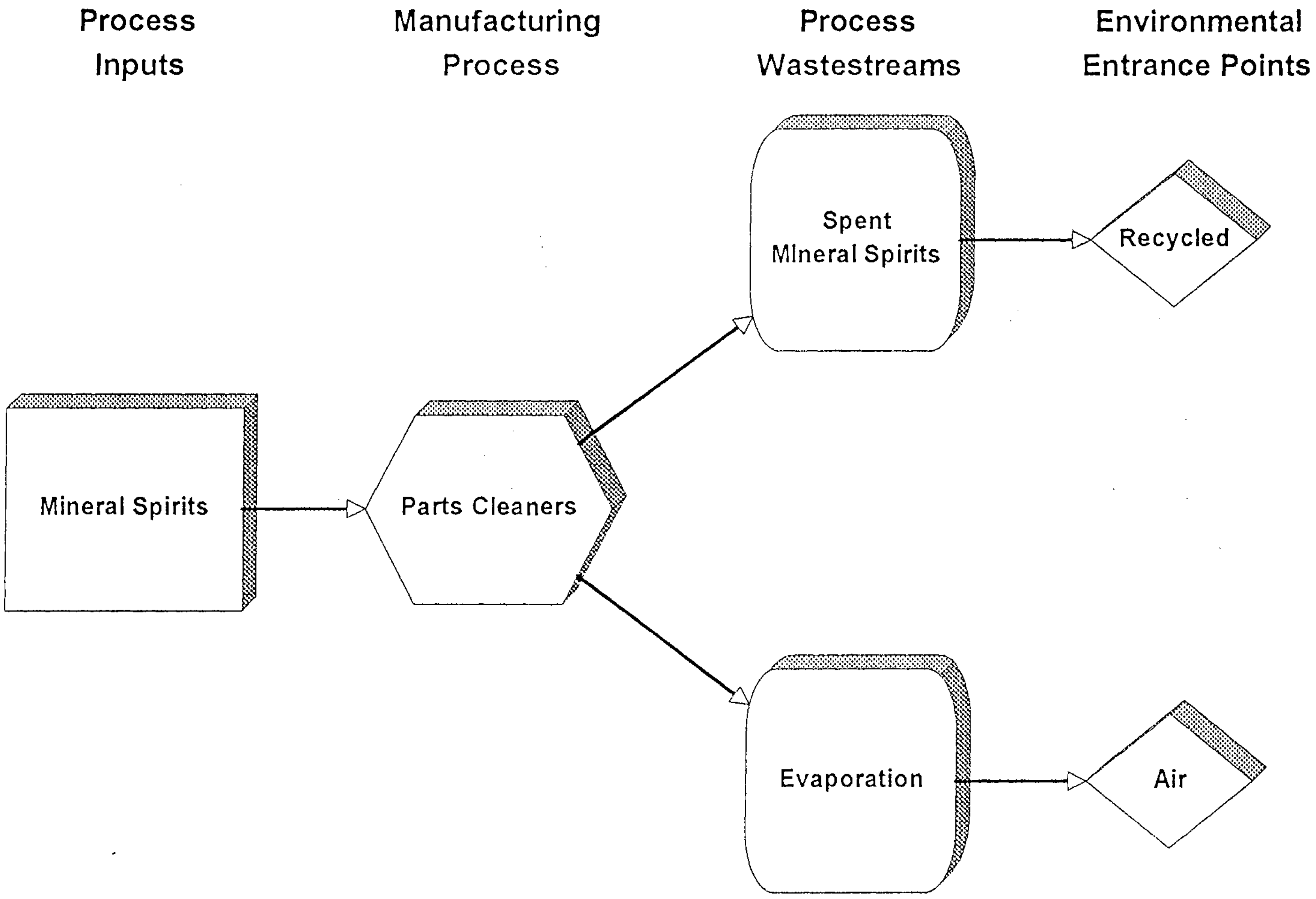
Process Wastestream - Cutting Oil



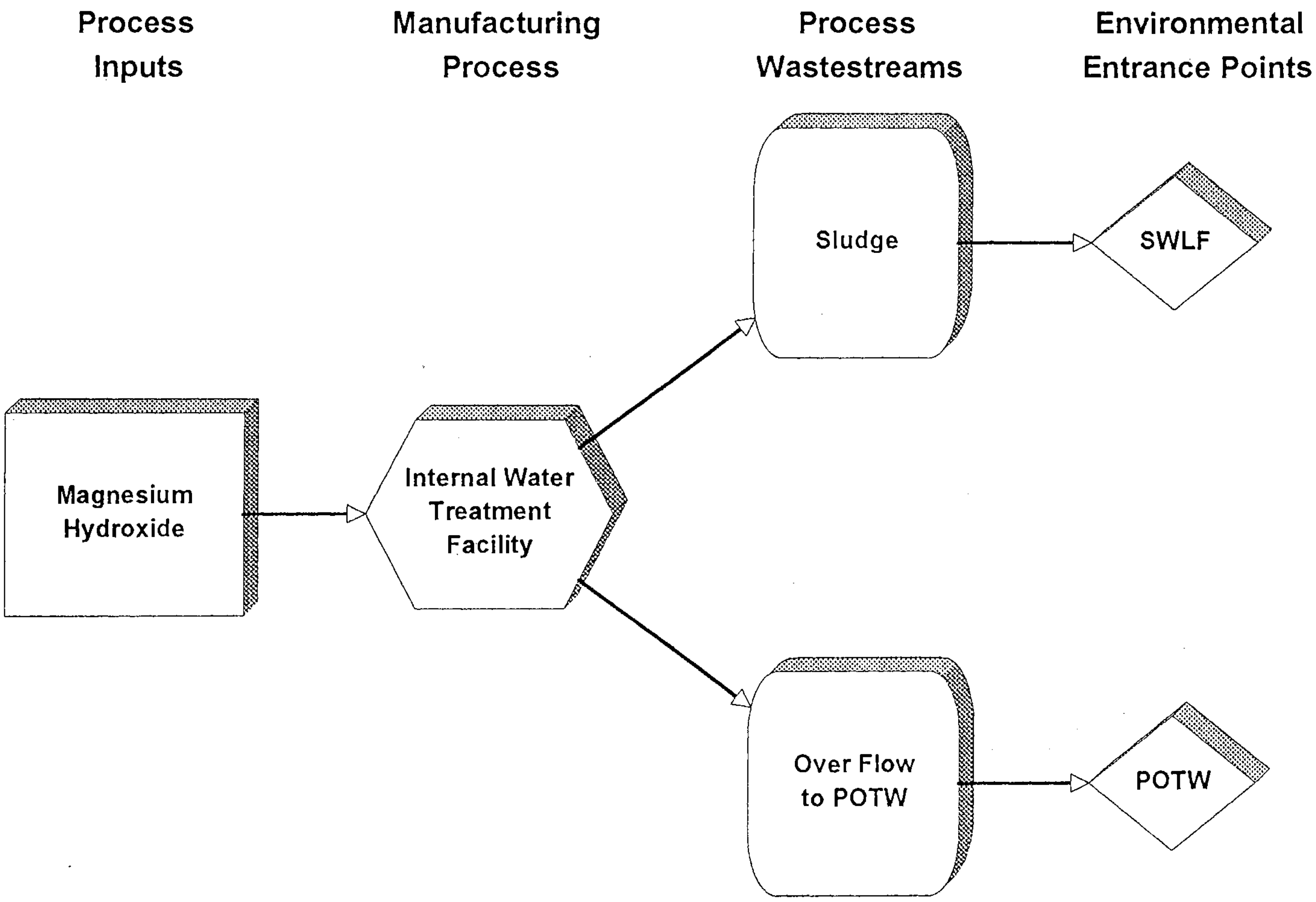
Process Wastestreams - Stenciling Inks and Cleaner



Process Wastestreams - Preservative



Process Wastestreams - Mineral Spirits



Process Wastestreams - Magnesium Hydroxide

2

# VITA

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