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Ranking of Chemical Facilities Based on the Potential to Cause Harm to the Public

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Foreword

This report was prepared by the Mary Kay O'Connor Process Safety Center (MKOPSC) at Texas A&M University. Founded in 1995, the MKOPSC conducts programs and research activities that enhance safety in the chemical process industries. Educational activities of the MKOPSC promote *safety as second nature* to everyone in the industry. In addition, the MKOPSC develops safer processes, equipment, procedures, and management strategies to minimize losses within the processing industry.

This document was prepared by the staff of the Mary Kay O'Connor Process Safety Center and may or may not represent the opinions of the MKOPSC Consortium members, various committees, or their employers, or any other individuals/organizations participating in the various activities of the Mary Kay O'Connor Process Safety Center. The authors of this document hope that the findings presented herein are used and viewed as intended. It must be noted that the calculations or the ranking discussed in this report do not represent risk or imminent harm. The potential to cause harm to the public (PCHP) index is, at best, a hazard index, and not a risk index. Hazard and risk are not interchangeable terms and neither does the presence of hazards indicate any type of quantification of risk. In addition, because of the inherent usefulness of chemicals, hazards will always be present in our society. The more important question is how we manage the risk associated with the hazard. The authors hope that the findings of this report will lead to a serious and sustained dialogue amongst all stakeholders, which will lead to better and improved risk management, while we continue to enjoy the benefits provided by the use of these chemicals.

1.0 Introduction

Chemical hazards and toxic substances can harm the environment as well as human health. The development of rating systems to assess the hazards of different facilities in the chemical industry is crucial for designing emergency response plans and effectively communicate to people the hazards they are exposed to when living near a facility.

The objective of this study is to develop a methodology to assess chemical process facilities on the basis of their potential to cause harm to the public. The hazard rating system described in this study is a function on the hazards associated with the chemicals processed and stored in the facilities, the maximum amount of chemicals in the facility and the population density within a two mile radius from the facility.

A literature review of current hazard rating systems was conducted by the Mary Kay O'Connor Process Safety Center (MKOPSC) and the main findings are summarized in section 2. Section 3 of this report presents the proposed approach to assess the facilities based on their potential to cause harm to the public. The preliminary results obtained from an analysis of 3,381 facilities in the state of Texas are shown in Section 4.

2.0 Literature Review of Hazard Rating Systems

2.1 Reactivity, Toxicity, and Flammability Hazards

Hazards associated with chemicals include reactivity, toxicity and flammability properties. The National Fire Protection Association (NFPA) has defined the three hazards in *NFPA 704: Standard System for The Identification of the Hazards of Materials for Emergency Response*. According to the standard, the reactivity hazard can also be referred to as instability hazard. The reactivity hazard exists because of the ability of a chemical to react with air, light or both, or its self-reaction or polymerization [6]. Toxicity hazard, which is also referred to as health hazard, is the capability of a material to cause injury via inhalation, dermal exposure, or ingestion [6]. Flammability hazards describe how likely it is for a material to burn [6], and the degree of flammability depends on the boiling point and flash point of the material.

2.2 NFPA 704: Standard System for the Identification of the Hazards of Materials for Emergency Response [6]

A comprehensive description of the NPFA 704 Standard is provided in this section. NFPA 704 is also commonly referred as "NFPA hazard diamond" and it assigns degrees of reactivity, toxicity and flammability hazards. The standard was developed to provide hazard information about chemicals for emergency responders, so that emergency responders are able to determine the proper immediate action to take in an emergency case. Figure 1 shows an example of the NFPA hazard diamond.

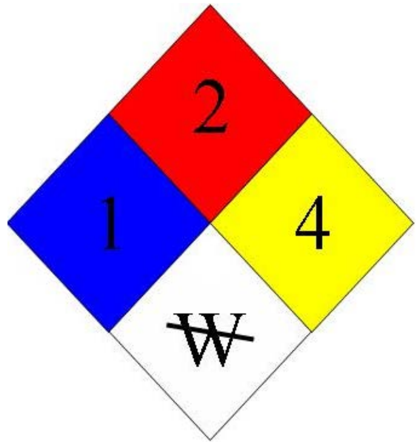

Figure 1. Example NFPA Hazard Diamond [6]

As shown in Figure 1, the NFPA diamond includes four divisions with different colors. Red represents degree of flammability (NF), blue represents degree of health hazard (NH), yellow represents degree of reactivity (NR), and white contains code for special hazards. Each division, except the division of special hazards, has a scale from 0 to 4. Criteria to determine degree for each common hazard is introduced as followed.

Degree of reactivity is decided based on the power density and the sensitivity to thermal shock at a typical temperature or pressure. For example, as shown in Table 1, a chemical whose degree of reactivity hazard is 3 will have instantaneous power density at 250°C at or above 100W/mL and below 1000W/mL, or it will be sensitive to thermal shock at elevated temperature or pressure.

Table 1. Example Degree of Reactivity Hazard [6]

Degree of Hazard	Criteria
3-Materials that in themselves are capable of detonation or explosive decomposition or explosive reaction but that require a strong initiating source or must be heated under confinement before initiation	Materials that have an instantaneous power density (product of heat of reaction and reaction rate) at 250° (482°F) at or above 100W/mL and below 1000W/mL Materials that are sensitive to thermal or mechanical shock at elevated temperatures and pressures

As for degree of toxicity hazards, there are different criteria for different phases of materials, but criteria are basically related with LC_{50}, LD_{50} and corrosiveness to body systems. LC_{50} and LD_{50} are lethal concentrations and lethal dosages to kill half the animals in a test group when the animals are exposed to the chemical by inhalation, ingestion or dermal absorption [10]. Table 2 shows an example of the criteria applied to classify a chemical as level 3 according to its degree of toxicity.

Table 2. Example Degree of Toxicity Hazard [6]

Degree of Hazard	Criteria
3-Materials that, under emergency conditions, can cause serious or permanent injury	Gas whose LC_{50} for acute inhalation toxicity is greater than 1000 ppm but less than or equal to 3000ppm Any liquid whose saturated vapor concentration at 20°C (68°F) is equal to greater than its LC_{50} for acute inhalation toxicity, if its LC_{50} is less than or equal to 3000ppm, and that does not meet the criteria for degree of hazard 4 Dusts and mists whose LC_{50} for acute inhalation toxicity is greater than 0.5mg/L but less than or equal to 2mg/L Materials whose LD_{50} for acute dermal toxicity is greater than 40mg/kg but less than or equal to 200mg/kg Materials that are corrosive to the respiratory tract Materials that are corrosive to the eye or cause irreversible corneal opacity Materials that are corrosive to skin Cryogenic fluids that cause frostbite and irreversible tissue damage

	Compressed liquefied gases with boiling points at or below -55°C (-66.5°F) that cause frostbite and irreversible tissue damage Materials whose LD_{50} for acute oral toxicity is greater than 5mg/kg but less than or equal to 50mg/kg

Degree of flammability hazards mainly depend on boiling point and flash point and how rapidly a material can burn. Table 4 shows criteria for degree of the hazard to be 3.

Table 4. Example Degree of Flammability Hazard[6]

Degree of Hazard	Criteria
3-Liquids and solids (including finely divided suspended solids) that can be ignited under almost all ambient temperature conditions. Materials in this degree produce hazardous atmospheres with air under almost all ambient temperatures, are readily ignited under almost all conditions.	Liquids having a flash point below 22.8°C(73°F) and a boiling point at or above 37.8°C(100°F) and those liquids having a flashpoint at or above 22.8°C(73°F) and below 37.8°C(100°F) Finely divided solids, typically less than 75 micrometers (200 mesh), that present an elevated risk of forming an ignitable dust cloud, such as finely divided sulfur Materials that burn with extreme rapidity, usually by reason of self-contained oxygen Solids containing greater than 0.5 percent by weight of a flammable or combustible solvent are rated by the closed cup flash point of the solvent

Overall, the NFPA hazard diamond is a useful rating system, indicating criteria to determine degrees of hazards explicitly, and provide sufficient information for emergency responders. However, this standard only takes into account the properties of the chemicals for emergency response planning but do not take into account the amount of chemicals. Also, the standard is intended for use for emergency response planning, and its applicability to rate the potential harm caused to the public is limited. This is even more significant when considering the fact that for the public around a facility where an accidental release could occur, inhalation hazards are more dominant than dermal exposure and ingestion.

Along with consideration of the applicability of NFPA ratings, other methods to rate reactivity, toxicity, and flammability hazards are reviewed, and are introduced in Sections 2.3, 2.4 and 2.5.

2.3 Emergency Exposure Limits

In order to describe conditions resulting in different degree of health effects, there are several exposure limits, which are boundary airborne concentrations to make people suffer different severities of health effects, including emergency response planning guideline (ERPG), the Acute Exposure Guideline Level (AEGL), and Temporary Emergency Exposure Limit (TEEL). All these exposure limits have 3 levels, which correspond to mild, median, and severe health effects. The major difference in these exposure limits is that they are based on different time periods of exposure.

2.3.1 Emergency response planning guideline (ERPG) values [8]

Emergency response planning guideline (ERPG) values is the estimation for majority of the people who will begin to experience health effects when they are exposed to the hazardous airborne chemicals for one hour. The ERPG values are defined into three different thresholds:

ERPG-1 is the maximum concentration of airborne chemicals that almost every individual could experience for up to one hour without experiencing mild temporary health effects.

ERPG-2 is the maximum concentration of airborne chemicals that nearly all people could experience for up to one hour without feeling serious health effects and losing the ability to take protective action.

ERPG-3 is the maximum concentration of airborne chemicals that most people could experience for up to one hour without experiencing life-threatening health effects.

2.3.2 The Acute Exposure Guideline Level (AEGL) values [8]

The development of Acute Exposure Guideline Levels (AEGL) is aimed at describing the potential risk for people who are rarely exposed to hazardous airborne chemical releases.

AEGL-1 is the airborne concentration of a substance above which it is predicted that the general population, could experience notable discomfort, irritation, or certain asymptomatic, non-sensory effects. However, these effects are not disabling and are transient and reversible upon cessation of exposure.

AEGL-2 is the airborne concentration of a substance above which it is predicted that the general population, could experience irreversible or other serious, long-lasting, adverse health effects or an impaired ability to escape.

AEGL-3 is the airborne concentration of a substance above which it is predicted that the general population, could experience life-threatening adverse health effects or death.

2.3.3 Temporary Emergency Exposure limit (TEEL) values [8]

Temporary Emergency Exposure Limit (TEEL) determines the maximum concentration that the people begin to experience health effects when they are exposure to a hazardous chemical release for certain duration of time. The thresholds of TEEL can be grouped into three categories:

> **TEEL-1** is the airborne concentration of a substance above which it is predicted that the general population, when exposed for more than one hour, could experience notable discomfort, irritation, or certain asymptomatic, non-sensory effects. However, these effects are not disabling and are transient and reversible upon cessation of exposure.
>
> **TEEL-2** is the airborne concentration of the substance above which the general population, when exposed for more than one hour, can experience irreversible or other serious, long-lasting, adverse health effects or an impaired ability to escape.
>
> **TEEL-3** is the airborne concentration of a substance above which the general population, when exposed for more than one hour, can feel life-threatening advises when exposed for more than one hour.

2.3.4 Protective Action Criteria (PACs) Values [4]

ERPG, AEGL, and TEEL are not always available for chemicals. Protective Action Criteria (PACs) values is another exposure limit system which is based on ERPG, AEGL and TEEL, and are commonly used as the guideline for emergency response to concentration of the accidental releases of the hazardous chemicals. Thus the PAC values also can be used to evaluate toxicity hazards of chemicals. Similarly with exposure limits mentioned previously, the PACs values categorize the emergency response to three benchmark threshold levels. They are mild, which is temporary health effect (PAC-1), median which is serious health effect that could impair an individual's abilities to take protective action (PAC-2), and severe which is life-threatening health effect (PAC-3). The benchmark threshold in the PACs can be used to evaluate the potential hazard and risk during an emergency response to chemical release. Therefore, people can decide and take corresponding protective actions.

Since PAC values are developed based on AEGLS, ERPGs and TEELS, there is a hierarchy to determine which values to be used as PAC values.

The hierarchy is explained below:

- Use AEGLs (including final or interim values) if they are available.
- If AEGLs are not available, use ERPGs.
- If neither AEGLs nor ERPGs are available, use TEELs

2.4 Dow's Fire and Explosion Index [3]

Dow's Fire and Explosion Index (FEI) was developed for rating chemicals based on their flammability and reactivity, and is further applied in risk analysis to estimate the maximum probable property damage in a process plant.

The equation to calculate FEI index is

FEI = F1*F2* MF-- Eqn.1

Where F1 is general process hazard factor

F2 is special process hazard factor

MF is material factor

General process hazard factor (F1) and special process hazard factor (F2) are determined by considering particular conditions of a process unit. Penalty values are assigned for these particular conditions. F1 and F2 are determined separately by summing up relevant penalty values.

Material factor (MF) is a measure of the intensity of energy release from a chemical compound, mixture of compounds, or substance. MF is determined by considering both flammability and reactivity. The method to determine ratings for flammability are exactly the same as the NFPA's rating for flammability (NF), while ratings for reactivity is different with NFPA's rating for reactivity (NR) for some cases. Dow's rating for reactivity is derived from reactive chemicals calculations and experimental data such as adiabatic temperature of decomposition and peak temperature of DTA/DSC scan. Only MF values for 300 common chemicals are provided in Dow's FEI hazard classification guide.

2.5 Dow's Chemical Exposure Index (CEI)[2]

The Chemical Exposure Index (CEI) provides a method of rating the relative acute health hazard to the people in neighboring plants or community from possible chemical release accidents. In order to develop CEI, detailed information are required, such as an accurate plot plan of the plant and the surrounding area, a simplified process flow sheet showing vessels, piping, and chemical inventories, and ERPG values of related chemicals. Multiple scenarios need to be studied to calculate possible airborne quantities of a chemical, and finally maximum airborne quantity and corresponding ERPG-2 is used to derive the CEI.

2.6 Summary

Even though NFPA hazard diamond has been developed to provide sufficient hazard information about chemicals for emergency responders to use in determining proper immediate actions, its applicability to rate the potential harm caused to the public is limited. The NFPA ratings only take properties of materials into account, without taking quantity of chemicals into account. In addition, when considering the potential to cause harm to the public around the facility, inhalation hazards are more dominant than dermal exposure and ingestion.

When considering other hazard rating systems, Dow's FEI are determined by both reactivity and flammability hazards, and degree of the hazards are similar to NFPA's ratings. Thus it can be concluded that NFPA's NF and NR can be applied to determine potential to cause harm to the public around facilities. On the other hand, Dow's CEI takes details about particular conditions into account, which makes the index to be estimated accurately, but it is not feasible when scope of the study is a big database. Considering that the PAC values are airborne exposure concentrations, which reflect toxicity hazard to be exposed via inhalation, PAC values can be used to modify NFPA's NH.

3.0 Methodology

In order to rank facilities based on the potential to cause harm to the surrounding public, this study proposes a simple functionality which takes into account four factors. The four factors are the material inherent property represented by Material Hazard Index, quantity of the material stored in the facility, population around the facility, and the accident history of the facility. Thus, the function is represented as follows in Eqn.2

Hazard Index

= f (Material Hazard Index, Quantity, Population Density, Accident History) --------- Eqn.2

Based on Eqn.1, a similar formula was created to incorporate material hazard index (MHI), quantity, population density, and accident history. The formula to calculate overall facility index for the potential to cause harm (PCHP Index) to the public is

$$\text{PCHP Index} = \text{MHI} * \prod F_i \quad \text{-----Eqn. 3}$$

Where F_i represents penalty values for i = quantity, population density, accident history.

A guideline to determine penalty values is described later.

3.1 Material Hazard Index

Different chemicals have different inherent properties, which represent the inherent hazard of the chemicals. Material inherent properties include flammability, which may lead to fires or explosions, reactivity which represents the instability of the chemicals in certain conditions, and toxicity which will cause harm to human health and environment.

By considering the availability of the information of chemicals involved in the study and comparing different rating systems to rate these inherent properties, NFPA's rating standards are determined to be used to rate flammability and reactivity. NFPA ratings for a chemical can be found based on CAS number from variable sources. The main sources used in the study are *Sittig's Handbook of Toxic and Hazardous Chemicals and Carcinogens*[7] *and Hazardous materials guide for first responders*[5]. If NFPA ratings can not be found in these two sources, then Material Safety Data Sheet are used. Materials such as Titanium and Zinc have different NFPA ratings for solid metal and powder. Phases of the materials are clear, thus in order to keep consistent, higher NFPA ratings are used for these materials.

In order to evaluate health hazard to the public around facilities in chemical releasing events, inhalation hazards are more dominant than dermal exposure and ingestion. Therefore, PAC values, which are maximum airborne concentrations, are utilized in this study to modify the NFPA's NH values for toxicity. PAC values are found from the PAC database, Rev. 27.

The following relative logic is used for determining the priority order for the dangerous chemicals:

> Chemicals, which are rated 4 in one property rating and 0s in other two property ratings, are the most dangerous, followed by
>
> Chemicals, which have a rating of 3 in one property's rating and 1 in one property's rating along with 0 with the other property ratings, followed by

Chemicals, which have a scale of 2 in one property rating and 1s in the other two property ratings

Thus, the formula for calculating the Material Hazard Factor (MHF) proposed in this study is as follows (Eqn. 4).

$$MHF = 2^{NF} + 2^{NR} + 2^{Modified\ NH}$$ --Eqn.4

Where NF and NR are NFPA ratings and a modified NH is determined from PAC-3 values. Since PAC-3 is the maximum airborne exposure resulting in most severe consequence, which is life-threatening effects, only PAC-3 values are used to modify the NH value. Criteria to determine modified NH are developed and shown in Table 5.

Table 5. Modified NH Determination Guide

PAC-3 ranges (mg/m^3)	Modified NH
[0,100)	4
[100, 1000)	3
[1,000, 10,000)	2
[10,000, …)	1

By considering two extreme cases, where all values of NF, NR are 0s and Modified NH are 1 and where all values of NF, NR and Modified NH are 4, we can conclude the range of MHF is from 4 to 48. MHF can be classified to generate four levels of MHI, which is shown in Table 6.

Table 6. MHI Determination Guide

Material Hazard Factor (MHF)	Material Hazard Index (MHI)
[4,12)	1
[12,24)	2
[24,36)	3
[36,48)	4

3.2 Quantity

Besides of the inherent hazard the chemical possess, the amount of chemicals stored in the facility also factors into the calculation for the potential to cause harm to the public. Since the quantity that the facilities have for each chemical varies, a systematic method is developed to determine the quantity penalty for the facility hazards. A guideline to determine penalty values for different range of quantities are developed, and shown in Table 7.

Table 7. Penalty Value of Quantity Determination Guide

Quantity ranges (pounds)	Penalty Value
[1, 100)	1.2
[100, 1,000)	1.4
[1,000, 10,000)	1.6
[10,000, 100,000)	1.8
[100,000, …)	2

3.3 Population Density

Besides material hazard index and quantity of chemicals, population density around the facilities is also considered. Given coordinate or address of a facility, information about the population in a radius of two miles near the facility can be found by using LandView, which is a geographic information system software displaying information database available from the U.S. Environmental Protection Agency and the U.S. Geological Survey. A guideline to determine penalty values for different range of populations was developed, and is shown in Table 8.

Table 8. Penalty Value of Population Density Determination Guide

Population in 2-mile radius	Penalty Value
[10, 100)	1.2
[100, 1,000)	1.4
[1,000, 10,000)	1.6
[10,000, 100,000)	1.8
[100,000, …)	2

3.4 Accident History

The accident history of a facility takes into account the accident history of the facility and thus is an indicator of how likely the facility is to have an accidental chemical release. Since the information about accident history is not available so far, the study thus far does not reflect the inclusion of the accident history factor in the PCHP Index calculations. But similar methods can be used to assign penalty values based on number of accidents during a fixed time period, for example, number of releases reported in the last five years.

4.0 Results

This section provides the results obtained with the application of the proposed methodology. The analysis is based on calculations on a representative set of 2,581 facilities in the state of Texas. The PCHP index for facilities with known location was calculated. For facilities with multiple chemicals, the PCHP Index was estimated by selecting the chemical with known values of MHI and quantity that has the highest PCHP Index.

For developing the MHF the flammability, reactivity and toxicity hazards were taken into account. Table 9 provides example calculations of MHF based on the different combinations of values of flammability, reactivity and toxicity hazards.

Table 9. MHF calculations

NF	NR	Modified NH	MHI
4	0	0	18
3	1	0	11
2	1	1	8
4	1	0	19
3	2	0	13
2	2	1	10
4	1	1	20
3	2	1	14
4	2	1	22
3	3	1	18
3	2	2	16

Figure 2 shows the distribution for MHI for the 2,581 facilities. For most chemicals, the MHI is 2 and for a few chemical, the MHI is 1, 3, or 4. The distribution explains the reality that most chemicals are relatively safe, and small portion of chemicals are extremely hazardous chemicals.

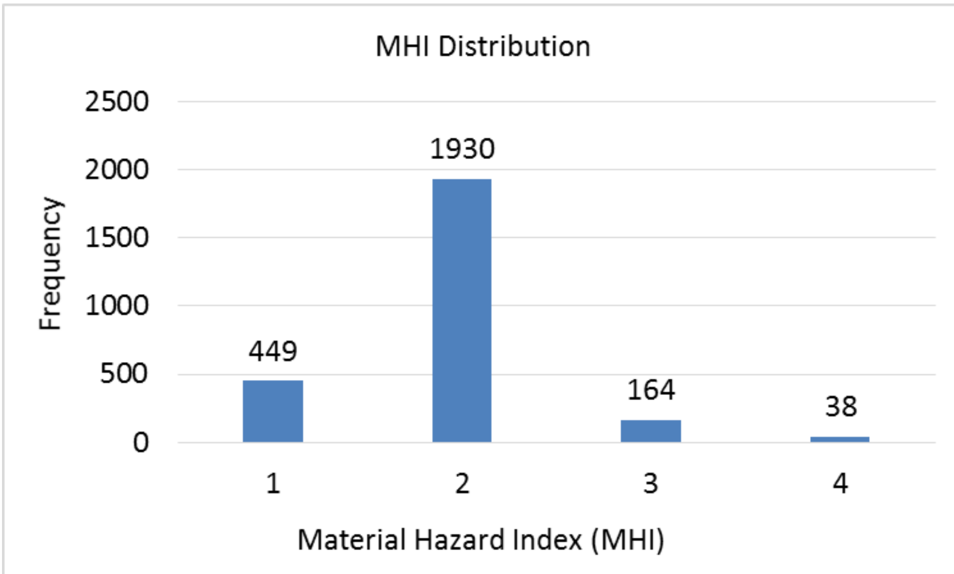

Figure 2. MHI Distritbuion

Similar to the MHI distribution, the distribution of penalty values of population density and quantity are shown in Figure 3. Both distributions reflect the reality well, where more common cases have a higher frequency and less common cases have a lower frequency.

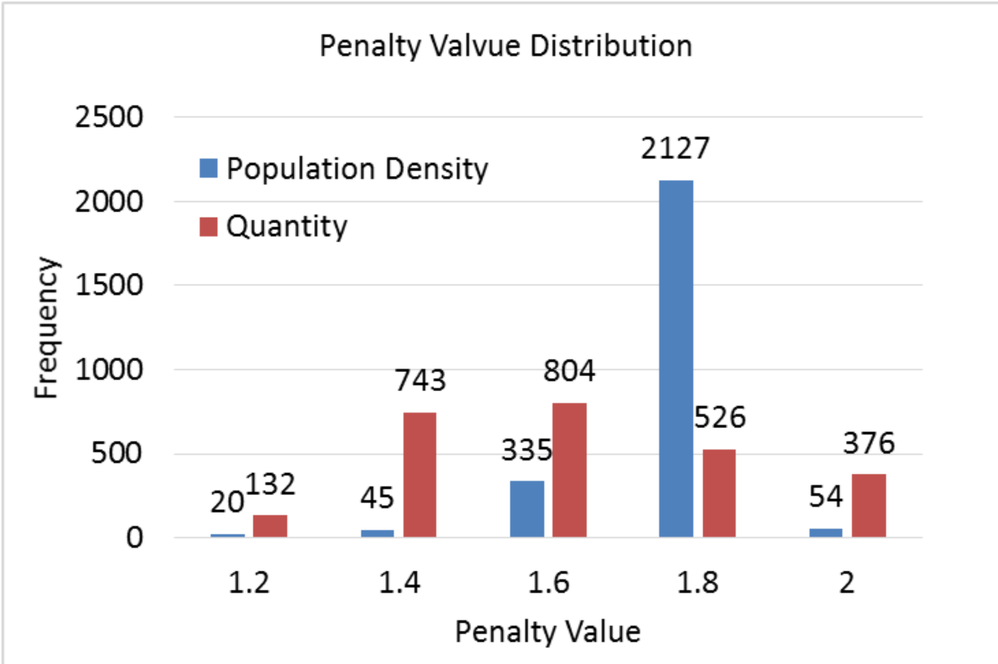

Figure 3. Penalty Value Distribution

Finally, the PCHP Index is calculated for each facility. Since a facility can have multiple chemicals with variable quantities, the PCHP Index is first calculated for each chemical. Then for a facility with multiple chemicals, the final PCHP Index for the facility is determined by the highest PCHP Index. The distribution of the PCHP Index for the 2,581 facilities is shown in Figure 4. The results in Figure 4 can be summarized as

- 56 facilities are in highest range (10-16) with regard to potential to cause harm to the public
- 596 facilities are in medium range (6-10) with regard to potential to cause harm to the public, and
- 1,929 facilities are in lowest range (0-6) with regard to potential to cause harm to the public

List of the facilities in highest range (10-16) with regard to potential to cause harm to the public is in Appendix.

Of course, it must be noted that the calculations shown here do not take into consideration the accident history. Since the 2,581 facilities represent a statistically representative sample of the all the facilities in Texas, it can be concluded that calculations for the remaining facilities will show similar results and conclusions.

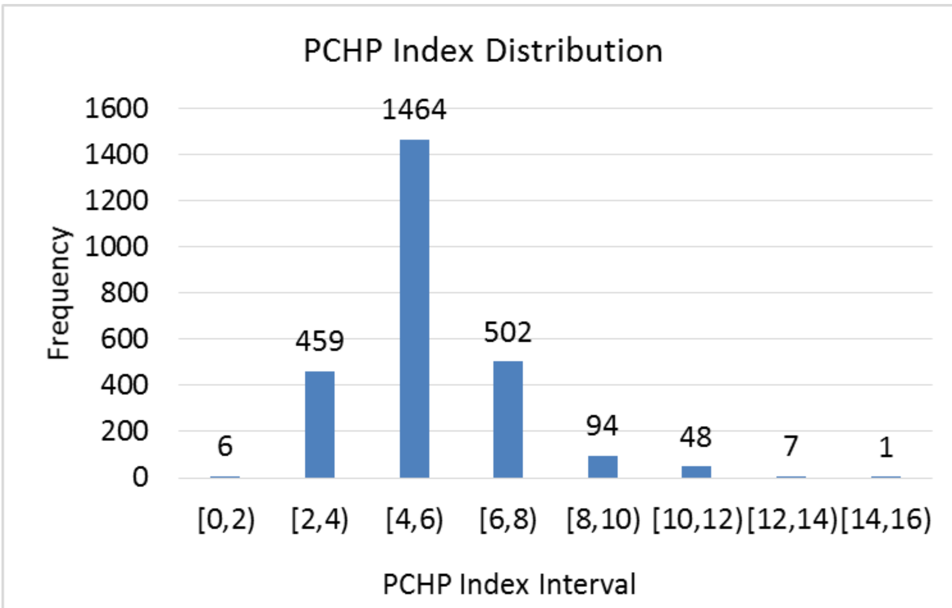

Figure 4. PCHP Index Distribution

The following results provide more details of the range of values of the MHI, population density and quantity penalty factors for each PCHP Index interval.

The results show that there are 6 facilities that fall in the lowest PCHP Index interval. For each one of these facilities the value of the MHI is 1. As explained in previous sections, the MHI is a function of the NFPA reactivity (NR) and flammability (NF) values and the modified toxicity (Modified NH) values. A MHI value of 1 indicates that the NF, NR and modified NH values fall between 0-2 as shown in Table 10 for each facility with a PCHP Index value between 0-2. The population density penalty values based on the population in 2 miles radius are 1.4 and 1.6 and the assigned penalty values given the amount of these chemicals in the facilities are 1.2 and 1.4.

Table 10: MHI, NF, NR and Modified NH for facilities with PCHP Index between 0-2

Facility Name	NF	NR	Modified NH	MHI	Penalty Values	
					Population Density	Quantity
American National Carbide Co.	0	0	1	1	1.6	1.2
Jacinto Port No. 2 Production Facility	1	0	2	1	1.6	1.2
Osage #1 Production Faciilty	1	0	2	1	1.6	1.2
State Lease 108750 #1 Production Facility	1	0	2	1	1.6	1.2
Swilley No. 2 Production Faclity	1	0	2	1	1.6	1.2
IBM Kurland	2	0	2	1	1.4	1.4

There are 8 facilities with the highest PCHP Index values (intervals 12-14 and 14-16) as shown in Table 11. For these facilities the obtained MHI values correspond to the highest rating. The penalty values for population density are larger than or equal to 1.6 and for quantity the penalty values are larger than or equal to 1.8.

Table 11: MHI, NF, NR and Modified NH for facilities with high PCHP Index intervals

Facilities	NF	NR	Modified NH	MHI	Penalty Values	
					Population Density	Quantity
PCHP Index Interval: 12-14						
Akzo Nobel Polymer Chemicals, LLC	4	3	4	4	1.6	2
Dow Chemical Company-Freeport	2	4	4	4	1.6	2
Equistar Chemicals, LP	4	3	4	4	1.6	2
Ashland Inc.	4	3	4	4	1.8	1.8
Axiall Corporation (company) Eagle US 2 LLC (facility)	3	4	4	4	1.8	1.8
DEGESCH AMERICA INC HOUSTON DIVISION	4	2	4	4	1.8	1.8
Gulf Coast Waste Disposal Authority-Washburn	2	4	4	4	1.8	1.8
PCHP Index Interval: 14-16						
Akzo Nobel Polymer Chemicals LLC (TXT2# 67410)	2	4	4	4	2	1.8

Most of the facilities fall in the PCHP index intervals, which are 2-4, 4-6, 6-8, 8-10 and 10-12. Figures 5-9 show the distribution of the MHI value for each PCHP Index interval.

From the figures, it can be observed that the value of MHI for the chemicals increases along the different intervals, a description of this increment is provided in Table 12.

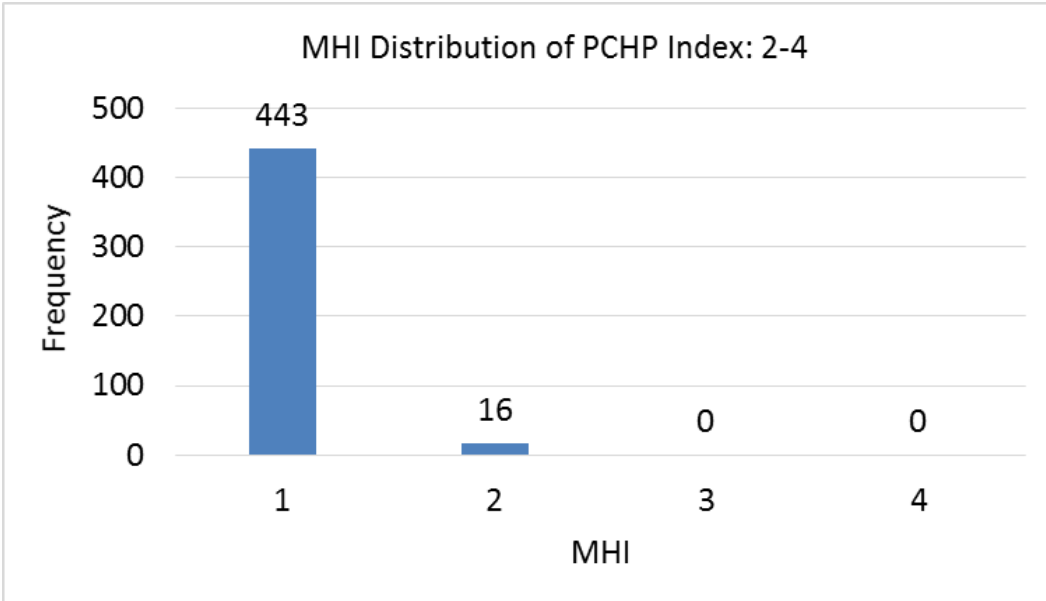

Figure 5. MHI distribution of 2-4 PCHP Index Interval

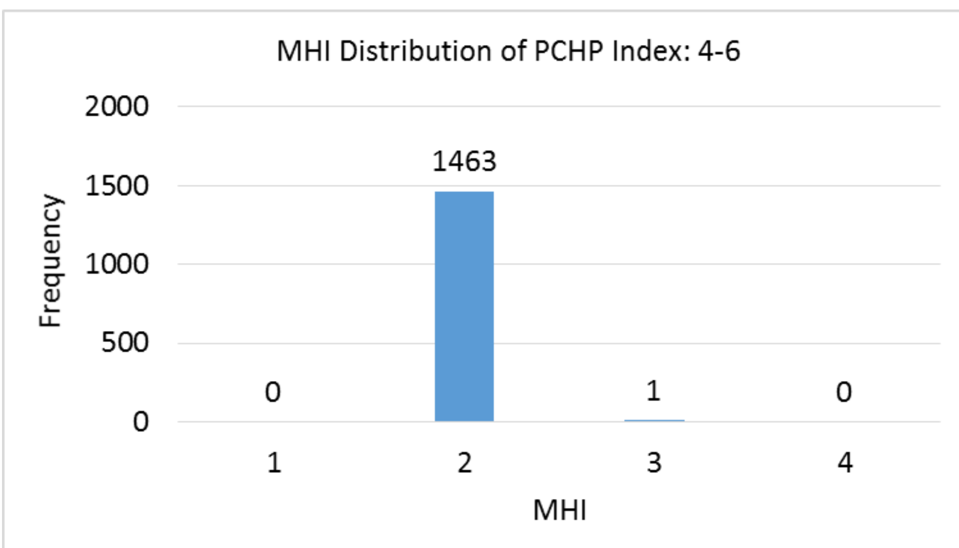

Figure 6. MHI distribution of 4-6 PCHP Index Interval

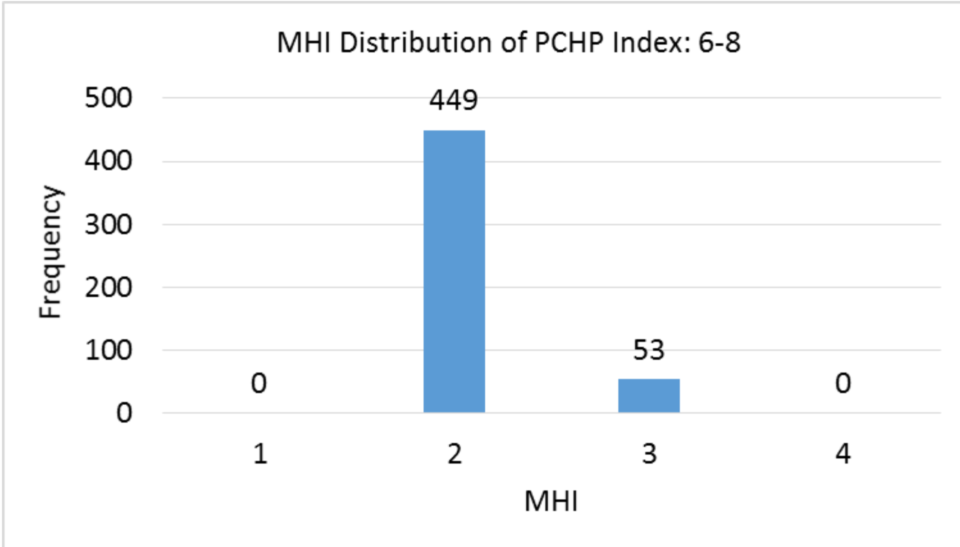

Figure 7. MHI distribution of 6-8 PCHP Index Interval

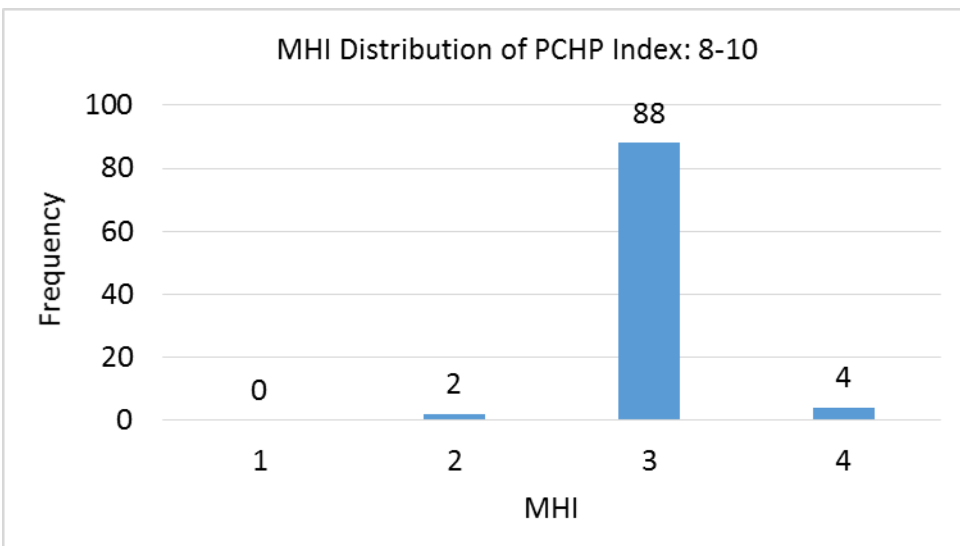

Figure 8. MHI distribution of 8-10 PCHP Index Interval

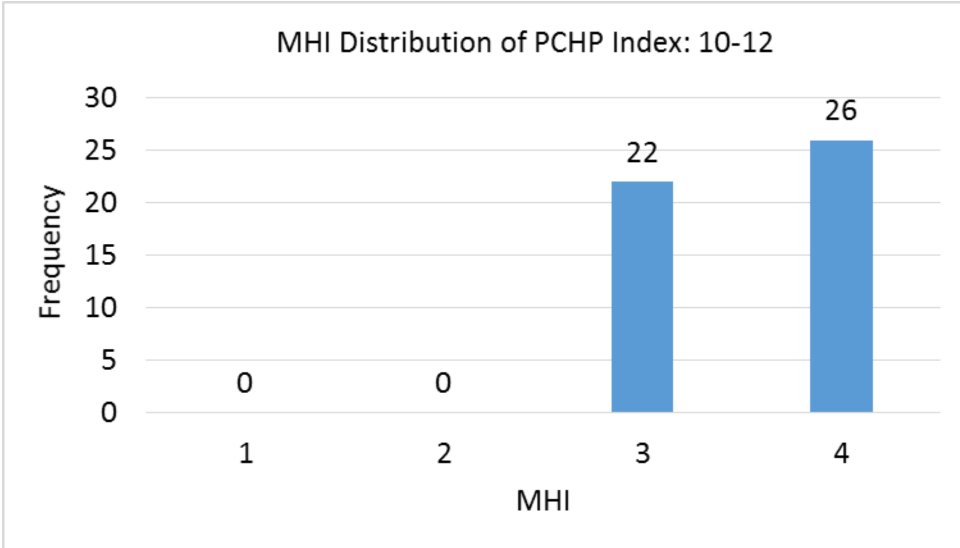

Figure 9. MHI distribution of 10-12 PCHP Index Interval

Table 12. MHI Increment Description

PCHP Index Interval	MHI Description
2-4	The majority of the facilities have an MHI of 1.
4-6	The majority of the facilities have an MHI of 2.
6-8	The majority of the facilities have an MHI of 2 but there is an increment on the number of facilities having an MHI of 3 compared to the previous PCHP Index interval.
8-10	The majority of the facilities in this interval have a MHI of 3.
10-12	A considerable number of facilities have an MHI of 3. However, the majority have an MHI value of 4.

Figure 10 shows the degree of flammability (NF), reactivity (NR) and health (Modified NH) hazards of the chemicals in the facilities with 2-4 PCHP Index. The x-axis contains the ratings (0-4) for NF, NR and the Modified NH and the number of facilities that have chemicals with those hazard ratings is shown in the y-axis. From the graph it can be observed that for flammability hazard, a total of 229 facilities have a rating of 0, 111 have a rating of 1, 83 facilities have a rating of 2, 35 facilities have a rating of 3 and 1 facilities have a rating of 4. For reactivity hazard, a total of 445 facilities have a rating of 0, 7 facilities have a rating of 1, 7 facilities have a rating of 2 and 0 facilities have 3 and 4 ratings. For health hazards, a total of 112 facilities have a rating of 1, 149 facilities have a rating of 2, 193 facilities have a rating of 3 and 5 facilities a rating of 4. Similar information can be found in Figures 11-14 for the remaining PCHP Index Intervals.

The value that appears most often in a set of data is known as the "Mode". For example, in the 2-4 PCHP Index Interval the mode for NF is the rating of 0 with a total of 229 facilities out of 459. The mode values for the NF, NR and Modified NH values of each set of PCHP Index are summarized in Table 13.

Table 13. NF, NR and Modified NH Mode values

PCHP Index Interval	Total number of facilities	NF		NR		NH	
		Rating Mode	Facilities	Rating Mode	Facilities	Rating Mode	Facilities
2-4	459	0	229	0	445	3	193
4-6	1464	0	1303	0	746	4	710
6-8	502	0	293	0	254	4	230
8-10	94	4	55	0	47	4	52
10-12	48	4	27	3	21	4	38

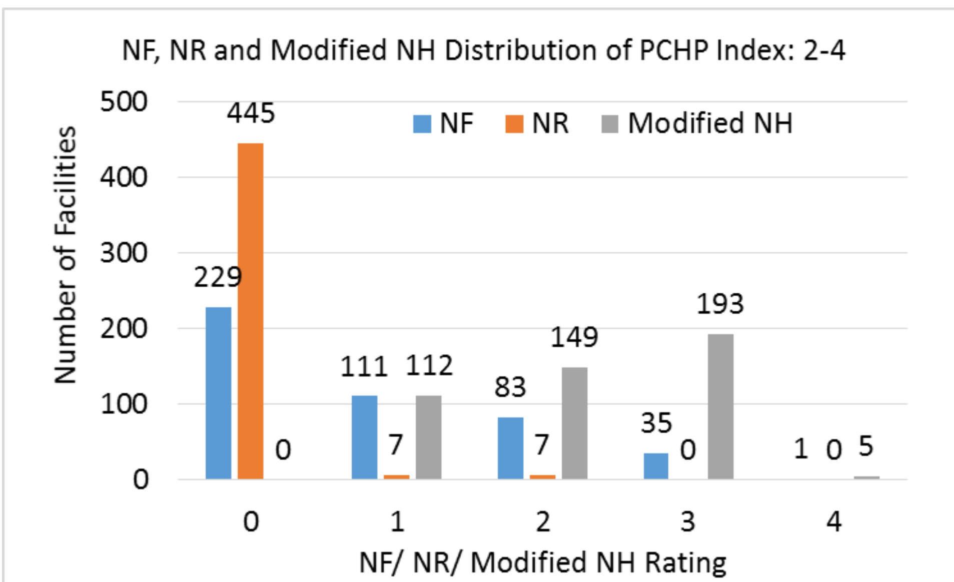

Figure 10. NF, NR and Modified NH distribution of 2-4 PCHP Index Interval

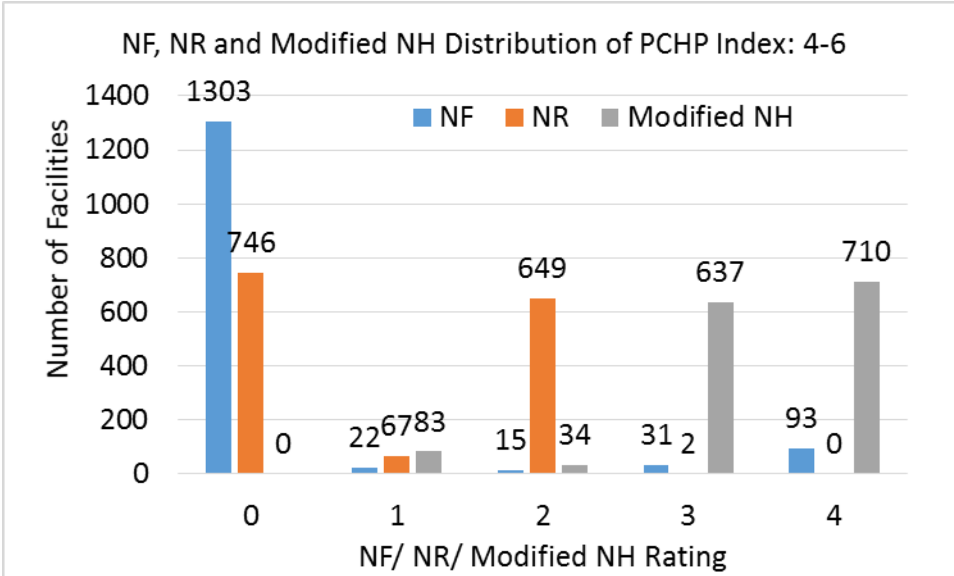

Figure 11. NF, NR and Modified NH distribution of 4-6 PCHP Index Interval

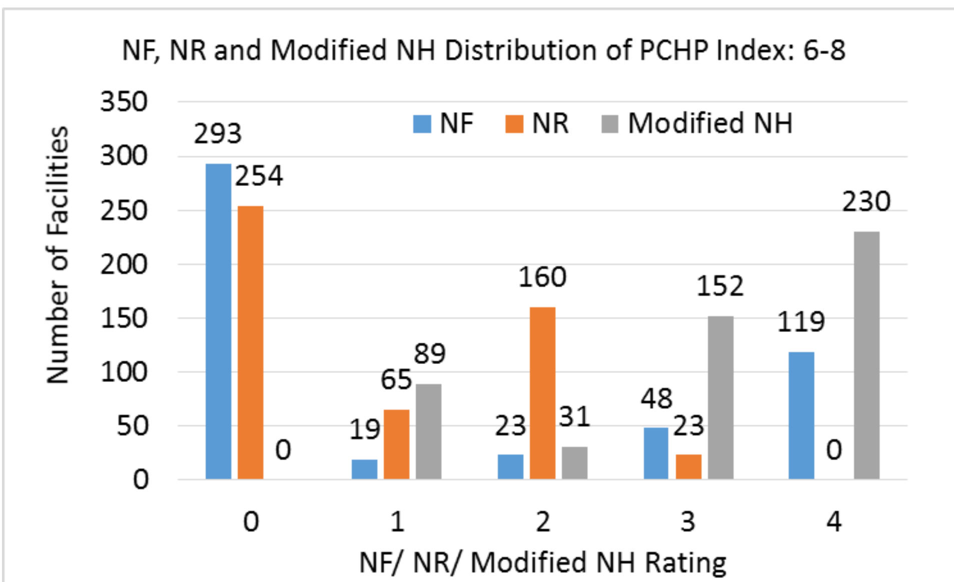

Figure 12. NF, NR and Modified NH distribution of 6-8 PCHP Index Interval

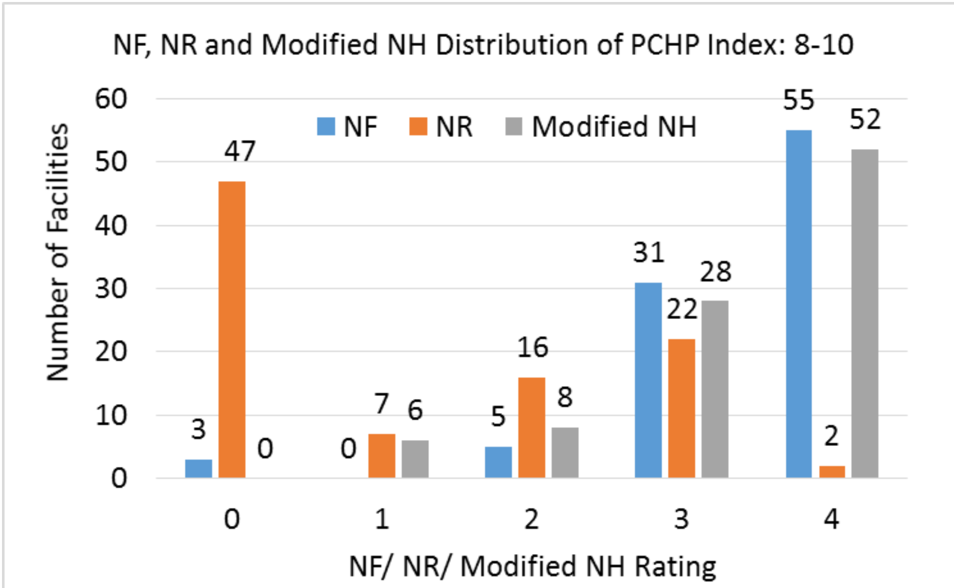

Figure 13. NF, NR and Modified NH distribution of 8-10 PCHP Index Interval

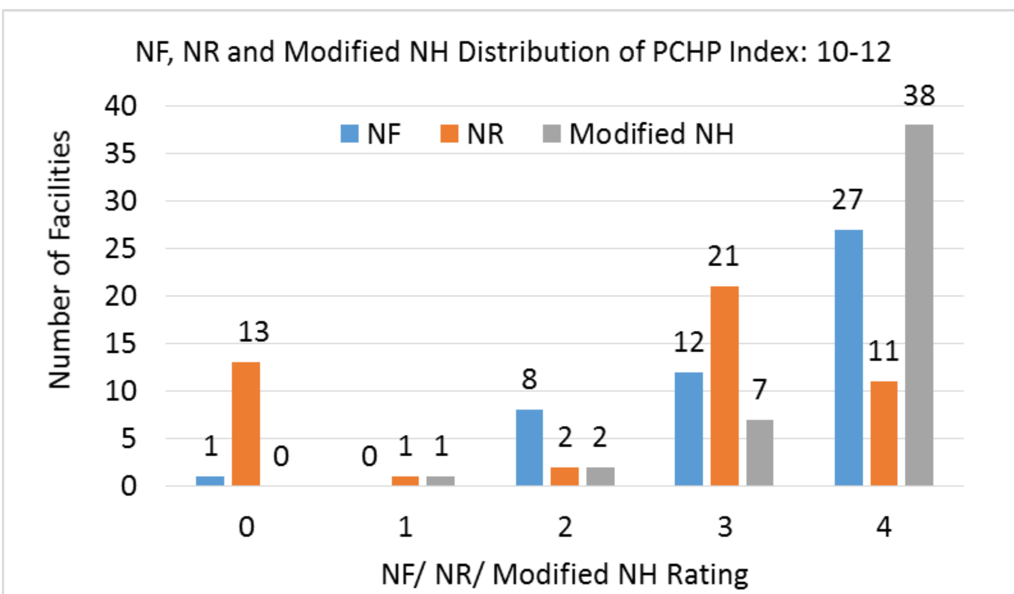

Figure 14. NF, NR and Modified NH distribution of 10-12 PCHP Index Interval

The PCHP Index is also a function of the Population Density and Quantity penalty values. Figures 15-19 show the distributions of the penalty values for the population density and quantity of material for each PCHP Index interval. The mode values for the Population Density and Quantity penalty values are summarized in Table 14.

Table 14. Mode of the Population Density and Quantity Penalty Values

PCHP Index Interval	Total number of facilities	Population Density		Quantity	
		Mode	Facilities	Mode	Facilities
2-4	459	1.8	386	1.8	192
4-6	1464	1.8	1239	1.6	753
6-8	502	1.8	416	2	221
8-10	94	1.8	51	1.8	39
10-12	48	1.8	30	2	24

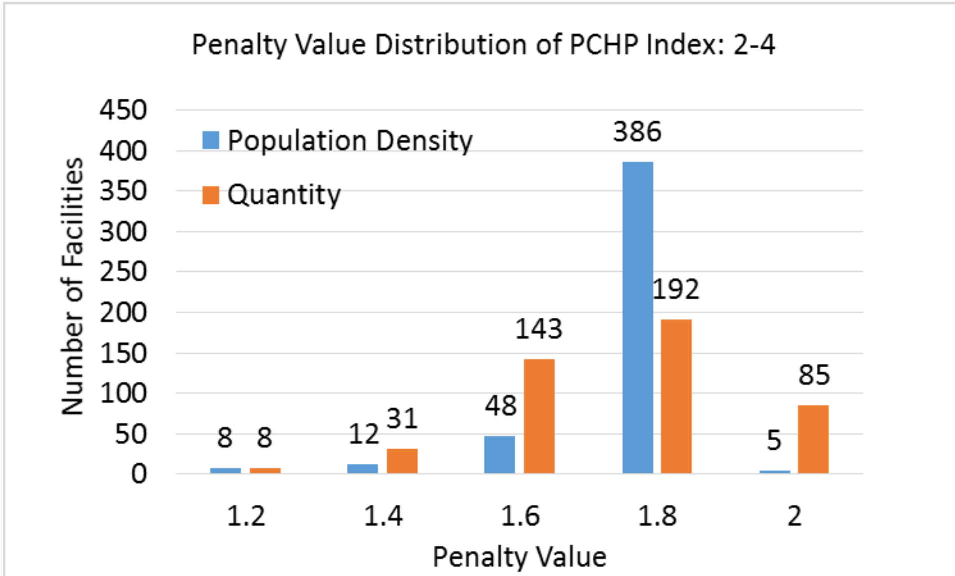

Figure 15. Population density and Quantity penalty values of 2-4 Index Interval

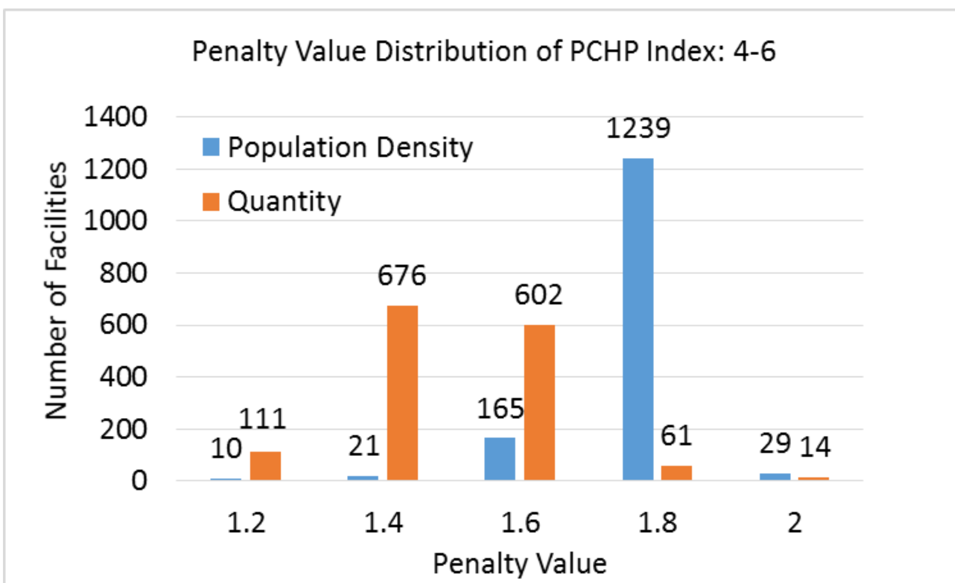

Figure 16. Population density and Quantity penalty values of 4-6 Index Interval

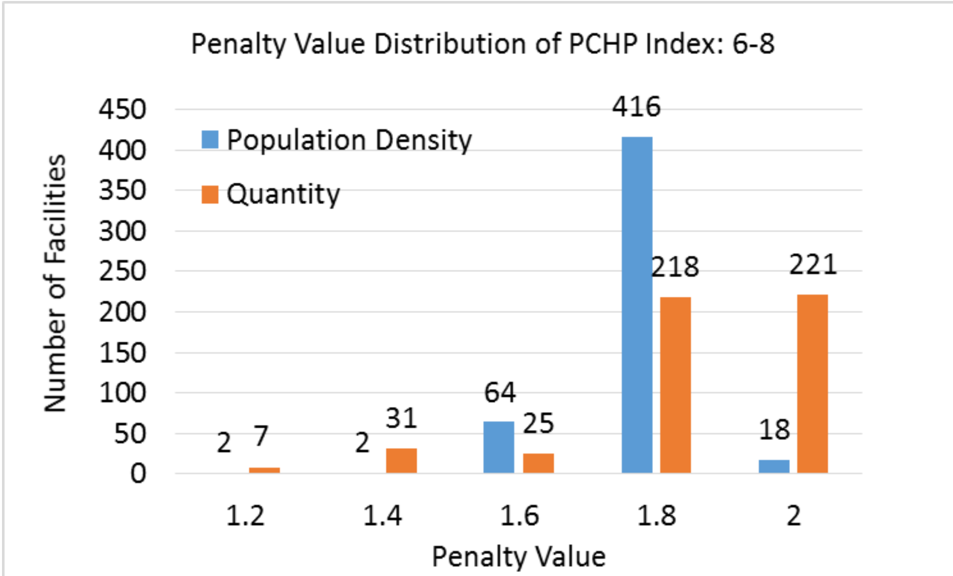

Figure 17. Population density and Quantity penalty values of 6-8 Index Interval

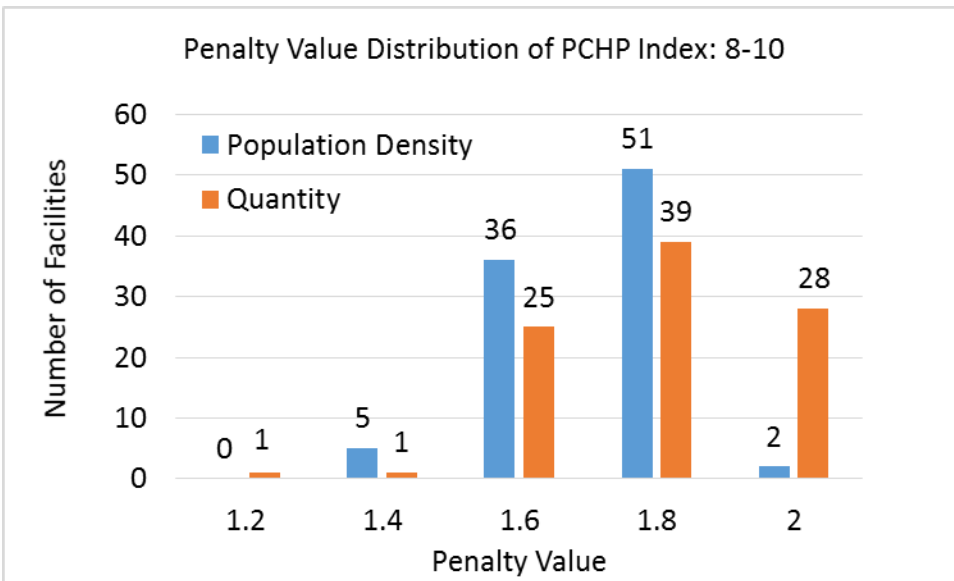

Figure 18. Population density and Quantity penalty values of 8-10 Index Interval

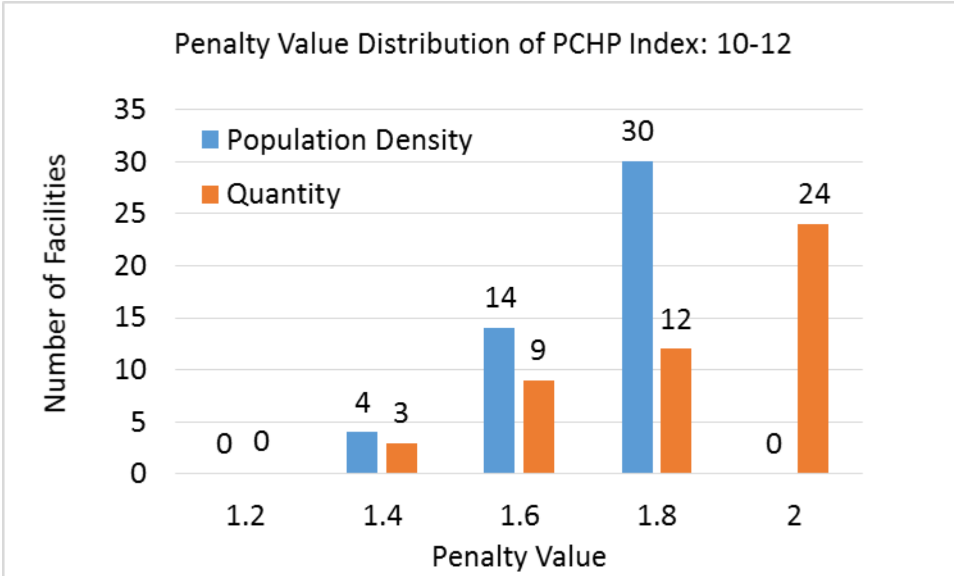

Figure 19. Population density and Quantity penalty values of 10-12 Index Interval

In order to illustrate how different hazards contribute to MHI, Figure 20-23 provide the NF, NR and Modified NH values of the facilities for each MHI value.

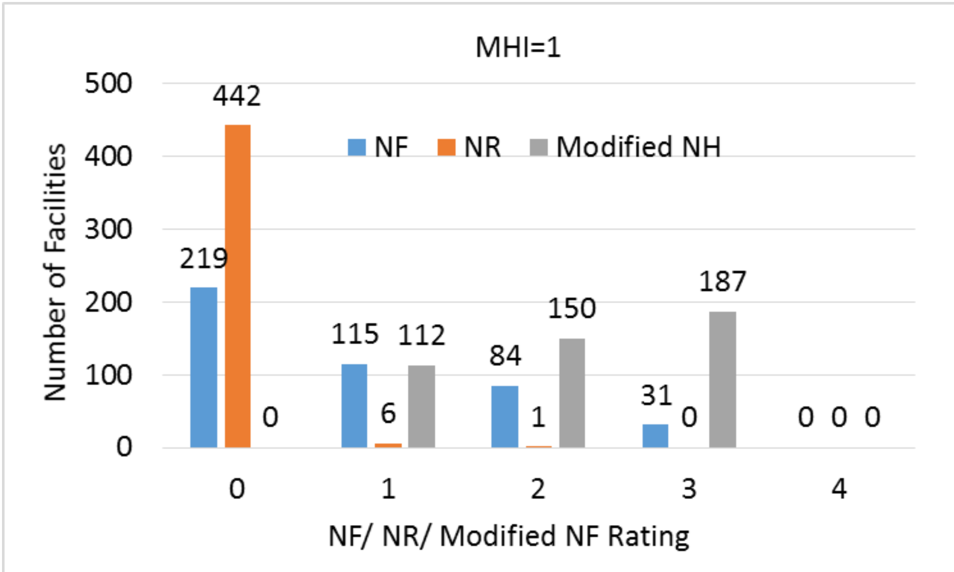

Figure 20. Distributions of NF, NR, and Modified NH for MHI = 1

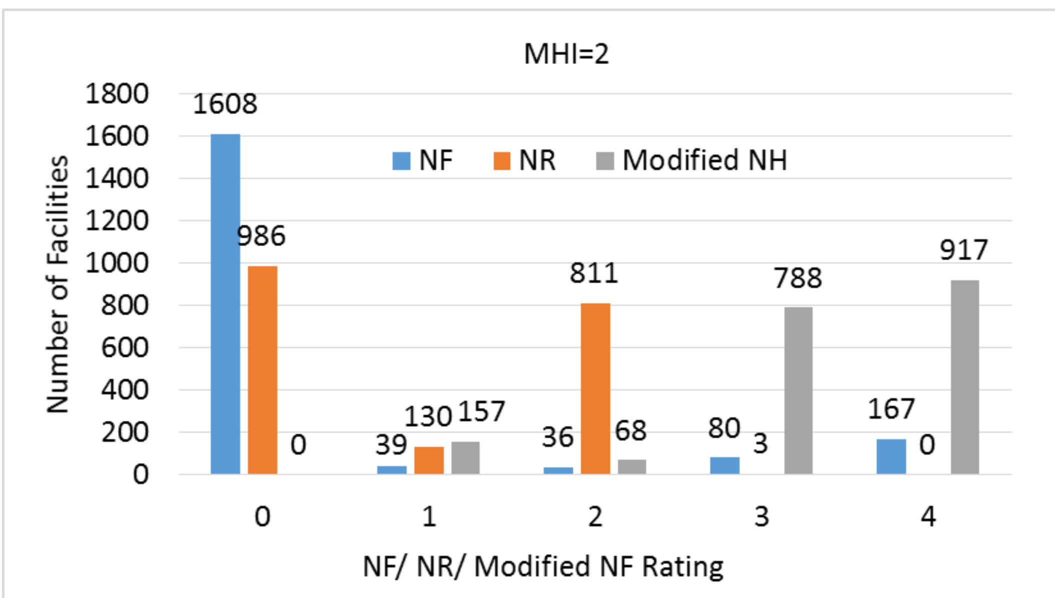

Figure 21. Distributions of NF, NR, and Modified NH for MHI = 2

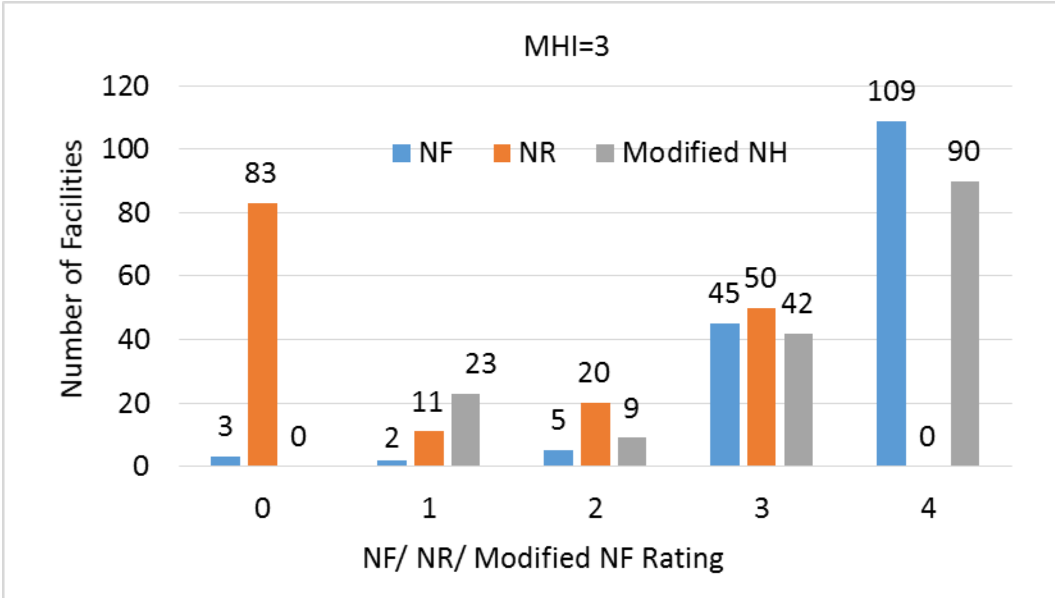

Figure 22. Distributions of NF, NR, and Modified NH for MHI = 3

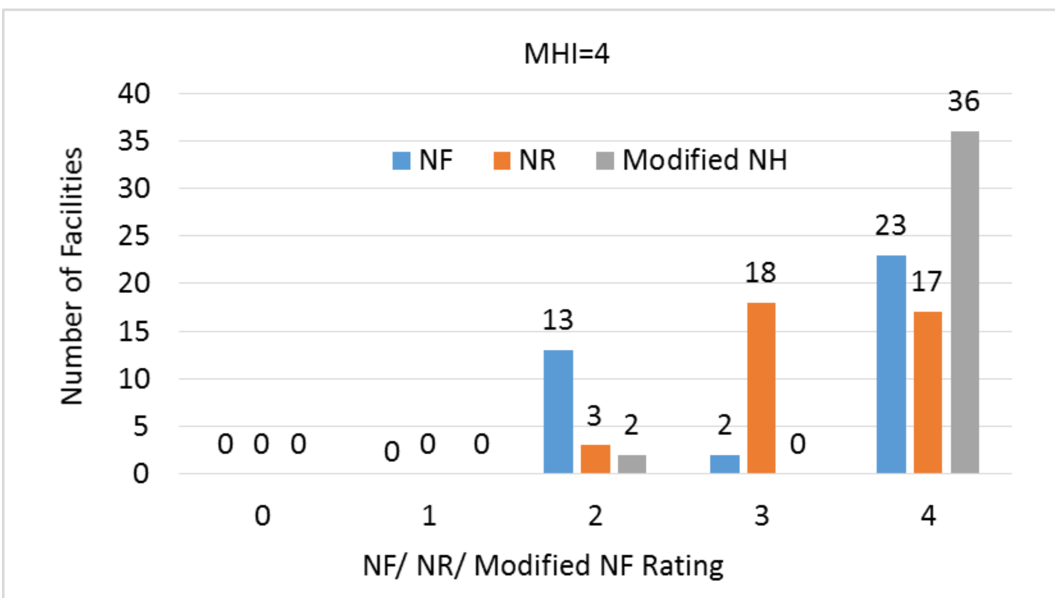

Figure 23. Distributions of NF, NR, and Modified NH for MHI = 4

5.0 References

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[2] Dow's Chemical Exposure Index Guide, first edition.

[3] Dow's Fire & Explosion Index Hazard Classification Guide, fifth edition.

[4]Emergency Management Issues Special Interest Group. Chem PACs/TEELs. https://orise.orau.gov/emi/scapa/chem-pacs-teels/default.htm

[5]Federal Emergency Management Agency, U.S. Fire Administration (1998). Hazardous materials guide for first responders.

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[7]Pohanish, R.P. (2012). Sittig's Handbook of Toxic and Hazardous Chemicals and Carcinogens: A-Z: Elsevier.

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6.0 Appendix

Table A. List of facilities in highest range (10-16) with regard to potential to cause harm to the public

Facility Name	Facility City	PCHP Index
Akzo Nobel Polymer Chemicals LLC (TXT2# 67410)	Pasadena	14.4
Gulf Coast Waste Disposal Authority-Washburn	Pasadena	12.96
DEGESCH AMERICA INC HOUSTON DIVISION	HOUSTON	12.96
Axiall Corporation (company) Eagle US 2 LLC (facility)	La Porte	12.96
Ashland Inc.	Houston	12.96
Equistar Chemicals, LP	Pasadena	12.8
Dow Chemical Company- Freeport	Freeport	12.8
Akzo Nobel Polymer Chemicals, LLC	La Porte	12.8
Exel, Inc	La Porte	11.52
TOTAL PETROCHEMICALS & REFINING USA, INC. - Bayport HDPE Plant	Pasadena	11.52
INEOS Polyethylene North America	La Porte	11.52
The Lubrizol Corporation - Bayport Facility	Pasadena	11.52
Chevron Phillips Chemical Company LP, Pasadena Plastics Complex	Pasadena	11.52
Equistar Chemicals, L.P.	LaPorte	11.52
EXXONMOBIL BAYTOWN CHEMICAL PLANT	BAYTOWN	11.52
Kaneka North America LLC SE Facility	Pasadena	11.52
Pergan Marshall, LLC	Marshall	11.52
Chevron Phillips Chemical Company LP - Cedar Bayou Plant	Baytown	11.52
R.C. TRANSPORTATION, INC.	HOUSTON	11.52
Winfield Solutions, LLC	Houston	11.52
Angelica Corporation Houston 082	Houston	11.52
Enduro Composites, Inc.- Houston	Houston	11.52
PPG Industries, Inc.	La Porte	11.52
ARKEMA Inc	Crosby	11.2
ALBEMARLE CORPORATION	Pasadena	11.2
Palmer Logistics	Houston	10.8

Facility Name	Facility City	PCHP Index
CPI Engineering, Division of The Lubrizol Corp.	Houston	10.8
Arsham Metal Industries, Inc.	Houston	10.8
LyondellBasell - Houston Refining	Houston	10.8
E.I. DuPont de Nemours and co. Inc-HMS	Houston	10.8
Baker Petrolite - Baport Facility	Pasadena	10.8
Bayport_Rohm and Haas TX	La Porte	10.8
Appleton Electric LLC	Houston	10.8
Chem One Ltd.	Houston	10.8
Cameron International Corporation	Houston	10.8
Brenntag Southwest Greens Bayou Formerly Altivia	HOUSTON	10.8
Halliburton Energy Svcs, Inc HCD	Houston	10.8
ExxonMobil Baytown Refinery	Baytown	10.8
Delta Deer Park		10.8
International Paint LLC Houston Mfg	Houston	10.8
Service Wire Company	Houston	10.8
Owens Corning Houston Roofing and Asphalt LLC	Houston	10.8
Powell Electrical Manufacturing	Houston	10.8
Market Street Recycling	Houston	10.8
Buffalo Flange, Inc.	Houston	10.8
StarpakCorp	Houston	10.8
International Paint LLC Central Distribution Center	Houston	10.8
DIXIE CHEMICAL COMPANY, INC.	Pasadena	10.24
Solvay Chemicals, Inc.	LaPorte	10.24
KMCO	CROSBY	10.24
ChemQuest Chemicals, LLC	Pasadena	10.24
MEMC Pasadena, Inc	Pasadena	10.08
Flint Hills Resources Polymers, LLC: Longview Plant	Longview	10.08
H-E-B Houston Retail Support Center Milk Plant	Houston	10.08
Ellington Field Joint Reserve Base	Houston	10.08
Freedman Food Service, Inc.	Houston	10.08