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**ANALYSIS OF EMISSIONS TEST RESULTS
AND RESIDUAL BY-PRODUCTS FROM
FACILITIES USING TIRES AS A FUEL
SUPPLEMENT**

**CALIFORNIA INTEGRATED WASTE
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EXECUTIVE SUMMARY

Why was this analysis completed?

The objective of this analysis was to compare the differences in air emissions from industrial processes operating with and without tires as a fuel supplement. The goal of this analysis is to assess (in a quantifiable manner) the potential for changes in air emissions when using tire-derived fuel and its potential impact on air quality and health risk.

What is tire-derived fuel?

Tire-derived fuel refers to using scrap tires as a fuel in combustion processes in much the same way that coal and wood chips are used as fuel. Tire-derived fuel can be in the form of whole scrap tires, shredded tires, or crumb rubber from used tires.

Tires have several properties that make them attractive for potential energy usage. They have a slightly higher heating value than coal, ranging from 12,000 to 16,000 Btu per pound. Tires also have a lower moisture content than coal which remains constant. Tires may also have a lower sulfur content than some coal, depending upon the source of the coal, which could lead to lower sulfur dioxide emissions.

What are the air emissions and how are they measured?

The air pollutants of concern in this report are separated into two groups: criteria pollutants and toxic air contaminants. Criteria pollutants include nitrogen oxides, sulfur dioxide, and inhalable particulate matter. Toxic air contaminants are categorized as: cancer-causing (carcinogenic) and short-term (acute) and chronic non-cancer compounds. This analysis addresses both categories of pollutants but focuses primarily on carcinogenic toxic air emissions associated with cement kilns.

The air emissions are measured by source testing the emission stacks during normal operations followed by analytical analysis of the collected samples. Source tests are typically completed using a detailed set

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of testing requirements, high-quality equipment, experienced testing teams, technical observation by the local regulatory agency, and regulatory-approved laboratories.

What are toxic air contaminants?

Regulatory agencies have identified hundreds of different chemicals as potential toxic air contaminants, each with varying degrees of toxicity. Toxic air emissions in the environment result from both natural and anthropogenic, or man-made, sources. The primary natural sources of toxic air contaminants are particulate emissions from windblown dust and wildfires. Anthropogenic sources of toxic air contaminants include mobile sources, such as exhaust from automobiles, aircraft, or ships; area sources, such as agricultural pesticide use, waste burning, and architectural coating or consumer product use; industrial sources such as refineries, chemical plants, and chrome plating operations; and commercial sources such as dry cleaners and gasoline stations.

How do toxic air emissions affect health risk?

The location and concentration of toxic emissions affect the extent to which the emissions pose public health risks. For example, toxic emissions from many mobile, area, and natural sources occur on a regional scale. Other toxic emissions, particularly those from a point source (i.e., an individual facility) or certain mobile sources, could have more localized effects and a greater potential to contribute to an air toxic "hot spot." Specifically, toxic emissions from area and mobile sources in combination with toxic emissions from point sources in the same location could produce a cumulative effect on public health (CARB, 1990).

Toxic air emissions also differ in their potency (toxicity) and consequently in their relative hazard to public health. Among the more potent or toxic organic substances are benzene, certain polycyclic aromatic hydrocarbons (PAHs), 1,3-butadiene, and formaldehyde. Among the more toxic types of particulate matter are arsenic, cadmium, chromium (hexavalent), nickel, and lead. Both the relative emissions and the relative toxicity of these and other substances must be considered in evaluating the effects of toxic air emissions.

How were the pollutant emissions compared?

The following five steps summarize our technical approach for completing this analysis:

1. Complete a data collection effort that significantly increases the previous databases.
2. Review the data reports to determine if adequate source testing and analytical procedures were used.
3. Develop a database of the collected test data.
4. Complete a statistical comparison of the data.
5. Develop conclusions.

In addition to the comparison of test data, this report provides background information on tire recycling programs, tires as a fuel supplement, and the risk assessment process.

What are the results of this comparison?

The results of this comparison are summarized below.

- The analysis is based on air emission measurements at 28 facilities out of which cement kilns located in California comprised the largest data set.
- The change in health risk due to toxic air emissions from facilities using tires as a fuel supplement is not significantly different from the same facilities using typical fuels, such as coal.
- Greater variability in health risk occurs between different facilities, combustion practices, and air emission control systems.
- This comparison of health does not include the incremental increase in health risk if the tires are landfilled or stockpiled. This incremental health risk would be associated with the use of typical fuels for landfill operation if the tires were landfilled or the risk of catastrophic fires if stockpiled.

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How do these results relate to health risk assessments?

Each risk assessment for toxic air contaminants is unique to the emission source(s) being assessed. The differences in risk assessments at each site are due to variations in many parameters influencing the risk assessment results. Examples of site-specific conditions that influence the risk assessment results include height of the emission stack, fuel type, temperature of the exhaust, terrain, and meteorology to name a few. However, the toxic air contaminant emission rates at any given source are directly related to calculated downwind health risk. In other words, variability in the emission rates of these compounds is directly related to the variability in health risk at a given site. It should be noted that emission rates are only one factor in deriving risk. Thus, variations in emission rates between facilities do not necessarily directly relate to variations in risk between these facilities.

1.0 INTRODUCTION

This report presents a quantitative comparison analysis of air emissions from combustion processes using tires as a fuel supplement to typical or baseline fuels. This analysis is based on review and assessment of existing air emission test data, primarily as the pollutant emissions affect human health risk. The technical approach used to complete this work effort is summarized below.

1. Complete a data collection effort that significantly increases the previous databases.
2. Review the data reports to determine if adequate source testing and analytical procedures were used.
3. Identify outliers and discrepancies in the data.
4. Develop a database of the pertinent collected test data.
5. Normalize the emission rate data between the different sources.
6. Develop risk-weighted values of pollutant emission rate and associated toxicity.
7. Complete a statistical comparison of the data.
8. Develop conclusions.

In addition to the comparison of test data, this report provides background information on tire recycling programs, tires as a fuel supplement, and the risk assessment process.

Approximately 242 million tires were discarded nationally in 1990 and over 2 billion waste tires have been accumulated in stockpiles or waste dumps across the country (EPA, 1991). In California, approximately 29.5 million passenger/light truck tires were discarded in 1995 which equates to 37.6 million passenger tire equivalents (CIWMB, 1996).

These waste tires are either illegally dumped, landfilled, stockpiled in tire dumps, exported, burned for energy, used in whole tire applications or processed into usable products. Land filling, stockpiling, or illegal disposal accounted for 78 percent of all waste tires in 1990, while 5 percent were exported and 17 percent were used for new products or energy production (EPA, 1991).

Analysis of TDF Emission Results

Tires as a source of energy have a heating value of from 12,000 to 16,000 British Thermal Units per pound (BTU/lb), with less than 2 percent of moisture. Their sulfur content is generally from 1 to 2 weight percent. All of these qualities compare favorably with coal, which has a heating value between 11,000 and 13,000 BTU/lb. For this and other reasons, tires have viewed and used as an energy source, generally called Tire Derived Fuel, or TDF.

1.1 BACKGROUND

The California Integrated Waste Management Board (CIWMB) is the primary agency responsible for nonhazardous waste management in California. Under the California Tire Recycling Act enacted in 1989¹, the CIWMB is required to develop a permit program for waste tire facilities; create a tire recycling program; and periodically report to the Legislature on the status and technical feasibility of the various recycling programs. The CIWMB's first report concerning the feasibility of using tires as a fuel supplement for cement kilns, pulp and paper, and other industrial processes, was issued to the State Legislature in January of 1992². The CIWMB recommended that support be provided for the use of tires as fuel in cement kilns. However, there was a lack of data regarding the impact of burning tires on air emissions, resulting in the CIWMB recommending that funding for further source testing be provided to support air quality permitting efforts at facilities proposing to use scrap tires as fuel.

1.1.1 Scope of Work

The analyses presented in these earlier reports used information from a small database that was potentially not representative of actual conditions. The CIWMB issued a contract to compile, analyze, and report on emissions test results and residual by-products from facilities in California and other states or regions (as funds permitted) that use tires or tire rubber as a fuel supplement. Emissions test results at facilities combusting tires would be evaluated and compared to baseline emissions test results (air emission tests using typical fuel). Residual by-products from baseline conditions would be compared with residual by-products while combusting tires or tire rubber.

¹ Assembly Bill 1843 (Chapter 35, Statutes of 1990, now codified as Public Resources Code §42800 *et seq.*)

² 1992 "Tires As A Fuel Supplement: Feasibility Study" (CIWMB, 1992)

This report is a review of the available information on the emissions from facilities that have used or are using tires or tire rubber as a fuel supplement. The primary focus of the report is on cement manufacturing facilities as they are the largest potential user of waste tires. The report provides an analysis and compares the differences in emissions from facilities who are using or have used tires as a fuel supplement. It has been written in consultation with the California Integrated Waste Management Board.

1.2 TECHNICAL APPROACH

Dames & Moore's technical approach to this project was developed from preliminary meetings with the CIWMB and separated into 3 general areas:

- data collection;
- technical analysis of the data, conclusions, and recommendations; and
- prepare technical report and prepare educational literature.

A brief overview of the key aspects of these three main areas are described in this section.

1.2.1 Data Collection

Dames & Moore conducted a two-part data collection effort. The initial data collection effort included collection and cataloging of data from the CIWMB, the California Cement Manufacturers Environmental Coalition (CCMEC), members of the California Air Resources Board, air pollution control districts, other state control agencies, and the United States Environmental Protection Agency. Based on the initial data, a second data collection effort was implemented to acquire additional information.

Each organization or agency was requested to provide information concerning type of fuel, corresponding operating parameters, emission control equipment, and technologies used for emission control in these applications. We requested emission test data for particulate matter both total particulates (PM) and particulates less than 10 microns in diameter (PM₁₀), sulfur oxides, oxides of nitrogen (NO_x), carbon monoxide (CO), volatile organic compounds (VOCs), metals, formaldehyde, dioxins/furans, polycyclic aromatic hydrocarbons (PAHs), hydrogen chloride (HCl) and benzene. We also requested information concerning the analysis of residual by-products.

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1.2.2 Analysis of Emission Test Results

The submitted data were reviewed for validity and entered into a common data base sorted by industrial source such as cement kiln, power source, paper and pulp, etc. The data were analyzed for variability and the reports were examined for relevant comments concerning the data. It was not in the scope of work of this report to validate the analytical data that were submitted for review. The work effort was organized into the following steps:

1. Review the data reports to determine if adequate source testing and analytical procedures were used.
2. Identify outliers and discrepancies in the data.
3. Develop a database of the pertinent collected test data.
4. Normalize the emission rate data to provide a method for comparing the emissions between sources with different emission rates.
5. Develop risk-weighted values of pollutant emission rate and associated toxicity.
6. Complete a statistical comparison of the data.
7. Develop conclusions.

1.2.3 Develop Final Report and Educational Documents

There are two work outputs of this project, one being this report and the second an educational brochure. This report reviews the technical information found to date concerning the air impact from the use of tire derived fuel. The educational brochure will summarize the information in a shorter format for a more general audience.

2.0 OVERVIEW OF TIRES AS SUPPLEMENTAL FUEL

There is significant interest in many industries concerning the use of tires and TDF for fuel. This study was able to examine emissions data from four industries that were using tires and TDF for fuel. This section provides a description of the operational aspects of using tires for fuel.

2.1 COMBUSTION OF TDF VERSUS COAL

Tires have several properties that make them attractive for potential energy usage. They have a slightly higher heating value than coal, ranging from 12,000 to 16,000 Btu per pound. Tires also have a lower moisture content than coal which remains constant. Tires may also have a lower sulfur content than some coal, depending upon the source of the coal, which could lead to lower sulfur dioxide emissions.

Tires are burned either whole or shredded, with whole tire combustion requiring less expense to process the tires. Certain combustion types, such as boilers, require tires to be shredded and have the steel present in tires removed so that the melted metal does not clog the combustion process. Other combustion types, such as cement kilns, can use the tires whole as they can incorporate the steel into their process.

The economics of using tires as a fuel, with no other cost considerations such as permitting issues, are similar to the usage of other fuels. The quality, availability, and costs to handle the tires all need to be taken into consideration when comparing costs. The amount of energy available to be recovered from the tires being currently disposed of in California has been estimated to be equivalent to more than 700,000 barrels of oil (NEOS, 1991). The favorable economics for the use of tires in cement kilns is due to a large extent on the characteristics of existing systems to accommodate tire-derived fuel without significant modifications. Other types of combustion processes with recycling options typically require significant facility modifications to use tires.

2.2 OPERATION DESCRIPTIONS

The main potential users of tires for fuel examined by this study are:

Cement Kilns

Energy Services

Pulp and Paper Plants

Miscellaneous

2.2.1 Cement Kilns

Cement kilns are large cylinders that tilt slightly downward to one end and rotate slowly, so that feed materials travel to the far end by gravity. They are fired by the injection of fuel at the lower end where the combustion zone operates at very high temperatures (~3,000 °F) and with long residence times. Temperatures decrease along the length of the kiln allowing different chemical processes to occur at different stages. These conditions are optimum for the complete combustion of organic materials, such as tires. In addition, iron oxide is usually required in the cement manufacturing process, so the steel present in the tires is used in the production process.

Powdered limestone, alumina, iron, and silica are heated together to produce the clinker, which is later ground with gypsum to produce Portland cement. The raw feed is sent into the upper, cooler part of the kiln where it is rotated towards the hot end, gradually increasing the temperature of the feed until it reaches the flame zone. Chemical reactions occur along the length of the kiln changing the raw product to clinker.

Tires or TDF can be used to supplement the kiln fuel and/or the precalciner fuel. When TDF is added to the kiln fuel mix, it is often added at the burner (lower) end of the kiln, near, but not mixed with, the coal feed. More often, TDF is added at the feed end (high end) of the kiln. Whole tires cost less and are easier to handle, but can release too much heat if too many large tires are introduced too closely spaced together.

2.2.2 Energy Services

The main dedicated tire-burning power plant reviewed by this study was the Modesto Energy Project Tires-to-Energy facility in Westley, California, which has been in operation since 1987. This is a 14-megawatt (MW) power plant that was specifically designed to combust tires. It was built to process the Filbin tire pile, which is estimated to have over 35 million tires.

At full capacity, approximately 6,400 pounds of discarded whole tires are incinerated per hour in each of the facility's two identical boilers. The steam produced supplies a single General Electric turbine and generator which produces electricity. A portion of the electricity is consumed by the facility and the majority of the electricity is sold to Pacific Gas and Electric. The facility is currently reviewing the economics of operating the facility with the changing electrical rates from power deregulation.

Tires from the stockpile are transported to a carousel-type roller system by a conveyor belt and roller arrangement. The tires are admitted to the charging chute of either boiler. As the heat content of the tires vary by size, the tire feed rate needs to be adjusted to maintain constant heat input to each boiler. The tires burn as they are moved by a reciprocating stoker grate located along the floor of each furnace. The grate configuration allows the slag and ash to filter down to a conveyor system for possible by-product sales to off-site users.

The air pollution control equipment installed at the facility consists of a thermal deNO_x (ammonia injection) system for controlling oxides of nitrogen emissions, a fabric filter baghouse for controlling particulate matter emissions and a lime slurry wet scrubber for controlling sulfur dioxide and other acid gas emissions. Waste products from this operation include bottom ash, fly ash and scrubber ash residue.

2.2.2.1 Other Utility Facilities

TDF has been used at several utilities as a supplement to coal usage. As opposed to the Modesto Energy Project which was designed to burn whole tires, utilities have tried to utilize existing fuel handling systems as much as possible. This involves procuring TDF that is correctly sized to be used in their existing fuel handling systems. As utilities have tremendous leverage in buying fuels, TDF cost savings advantage may not be as great as other industries.

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2.2.3 Pulp and Paper Plants

Pulp and paper plants generate large amounts of waste wood products in the process of making wood chips for the pulp digester. Bark is the most common component of waste wood in the pulp and paper industry (US EPA, AP-42). Many facilities use this waste material to generate heat energy for process streams and to reduce solid waste. These waste wood boilers are known as "hog fuel" boilers. The hog fuel needs to be supplemented by a base fuel because of the variation in Btu content and other fuel characteristics. Coal, gas or oil are commonly used as base fuels. Some facilities have attempted to use TDF to augment the fuel supply.

Most waste boilers are small, producing from 100,000 to 200,000 pounds of steam per hour. Boiler configurations can vary widely in hog fuel boiler applications. The spreader stoker is the most widely used configuration (CIWMB, 1996). TDF is usually added with the bark and wood waste as chips.

2.2.4 Miscellaneous

TDF can be used in other industries that have boilers used for manufacturing. These boilers either provide electricity or process steam or both. This study had results from a Monsanto facility in Sauget, Illinois. This facility manufactures a wide variety of products used in the automotive, detergents, and household products industries. They operate a powerhouse for steam and electricity to support this facility. TDF was tested at Boiler #8, a Babcock & Wilcox four-drum chain grate stoker. TDF was blended with the coal and fed with the normal fuel delivery system.

3.0 TOXIC AIR CONTAMINANTS OVERVIEW

Toxic air contaminants is a general term used to describe those chemicals that, when dispersed in the atmosphere, have the potential to result in adverse health effects to exposed individuals. Adverse health effects resulting from exposure to toxic air contaminants are typically classified into three groups: carcinogenic, or cancer-causing, effects; non-carcinogenic chronic health effects; and non-carcinogenic acute health effects. Several terms, including Toxic Air Contaminants (TACs), Hazardous Air Pollutants (HAPs), and Acutely Hazardous Materials (AHMs) are used to describe toxic air contaminants, although these terms refer to specific groups of chemicals that are regulated under local, state, or federal air quality programs.

3.1 TYPES AND SOURCES OF TOXIC AIR CONTAMINANTS

Regulatory agencies have identified hundreds of different chemicals as potential toxic air contaminants, each with varying degrees of toxicity. Toxic air emissions in the environment result from both natural and anthropogenic, or man-made, sources. The primary natural sources of toxic air contaminants are particulate emissions from windblown dust and wildfires. Anthropogenic sources of toxic air contaminants include mobile sources, such as exhaust from automobiles, aircraft, or ships; area sources, such as agricultural pesticide use, waste burning, and architectural coating or consumer product use; industrial sources such as refineries, chemical plants, and chrome plating operations; and commercial sources such as dry cleaners and gasoline stations.

3.1.1 Factors Affecting Toxic Air Contaminants Health Effects

The location and concentration of toxic substance emissions affect the extent to which the emissions pose public health risks. For example, toxic emissions from many mobile, area, and natural sources occur on a regional scale. Other toxic emissions, particularly those from a point source (i.e., an individual facility) or certain mobile sources, could have more localized effects and a greater potential to contribute to an air toxic "hot spot." Specifically, toxic emissions from area and mobile sources in combination with toxic emissions from point sources in the same location could produce a cumulative effect on public health (CARB, 1990).

Toxic air substances also differ in their potency (toxicity) and consequently in their relative hazard to public health. Among the more potent or toxic organic substances are benzene, certain polycyclic

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aromatic hydrocarbons (PAHs), 1,3-butadiene, and formaldehyde. Among the more toxic types of particulate matter are arsenic, cadmium, chromium (hexavalent), nickel, and lead. Both the relative emissions and the relative toxicity of these and other substances must be considered in evaluating the effects of toxic air contaminants.

3.1.2 Assessing Relative Health Risk

In order to account for the variation in the relative potency of a substance, agencies that regulate or analyze health risk have developed "potency slope factors," or "unit risk factors." These values, which differ for each compound, may be used in quantitative risk analyses to calculate the probability or risk of adverse health effects with a given exposure. Table 3-1 shows unit risk factors for some common air toxic compounds.

TABLE 3-1
Unit Risk Factors for Common Toxic Air Compounds

Compound	Unit Risk Factor ($\mu\text{g}/\text{m}^3$)
Acetaldehyde	2.70×10^{-6}
Benzene	2.90×10^{-5}
1,3 Butadiene	1.70×10^{-4}
Cadmium	4.20×10^{-3}
Hexavalent Chromium (Chromium VI)	1.50×10^{-1}
Formaldehyde	6.00×10^{-6}
Lead	1.20×10^{-5}
Perchloroethylene	5.90×10^{-6}

1. Unit risk values are for carcinogenic risk (Air Toxics "Hot Spots" Program Revised Risk Assessment Guidelines, October, 1993). Some of the compounds listed may also cause non-carcinogenic chronic or acute health effects; factors used for evaluating these types of health effects are different than those presented in this table.

Health effects from exposure to toxic air contaminants may take a number of forms: carcinogenic health effects; long-term, chronic non-carcinogenic health effects; or short-term, acute non-carcinogenic effects. Unit risk factors such as those presented above are used to assess carcinogenic health risk. To assess non-carcinogenic chronic and acute health effects, various methods may be used. The National Institute for Occupational Safety and Health (NIOSH) and the Occupational Safety and Health Administration (OSHA) have developed Permissible Exposure Levels (PELs) for a number of compounds to address

exposure to toxic air contaminants in the workplace. PELs represent the highest allowable concentration of a given compound in the workplace atmosphere, measured over an eight-hour day.

Typically, unit risk factors are multiplied by a chemical concentration (in micrograms per cubic meter, or $\mu\text{g}/\text{m}^3$), and the result indicates a potential risk of suffering adverse, carcinogenic health effects; higher values indicate greater health risk. As can be seen by the selected data presented above, risks associated with different compounds can vary dramatically. An exposure to $100 \mu\text{g}/\text{m}^3$ of benzene over a given period would produce a risk of contracting cancer at 2.9×10^{-3} , or 0.0029, while exposure to the same concentration of hexavalent chromium for the same period would produce a risk of 15.0, a value about 5,000 times greater than the value for benzene. While the "risk values" are largely insignificant as presented in this study, this example does indicate the widely varying relative risk associated with different compounds.

EPA and the California Air Pollution Control Officers Association (CAPCOA) have developed Reference Exposure Levels (RELs) to address acute (one-hour) and chronic non-cancer effects from exposure to emissions from industrial facilities. RELs are highly conservative values used in mathematical health risk modeling, and are designed to protect the most sensitive individuals in the population by including margins of safety (CAPCOA, 1993). Health risk assessments rely on source tests or emission estimates combined with air dispersion modeling to estimate ambient downwind concentrations. These estimated ambient concentrations are compared with RELs to evaluate the acute or chronic non-carcinogenic hazard from a source of emissions.

3.1.3 Types and Sources of Toxic Air Emissions

In most urban areas, sources of toxic air emissions may be classified as generated either by industrial, motor vehicle, commercial, area, or natural sources. Table 3-2 presents general types and sources of toxic air emissions, and summarizes relative exposure, duration of emissions, and relative risk among the source types.

Analysis of TDF Emission Results

TABLE 3-2.

Types and Sources of Toxic Air Emissions

Source Type	Example Sources	Typical Exposure	Duration of Emissions	Estimated Percent of Ambient Relative Risk
Industrial	Refineries, chemical plants, power plants	Highest concentrations at close proximity to source	Typically steady.	Estimated at 20 percent for California, up to 50 percent in some cities.
Motor Vehicle Exhaust	Automobiles, trucks, ships, trains	Distributed along transportation corridors; concentrations decrease with distance from corridor.	Fluctuates over the course of a day based on vehicle volume, vehicle operating mode, and average speed.	Accounts for the largest portion of public risk, between 50 and 80 percent.
Commercial and Area	Crop dusting, wood stoves, hair spray, roadway dust, gas stations, building construction	Widely and uniformly distributed throughout large regions.	Typically steady.	Estimates vary widely, depending on data availability; probably 20 to 35 percent.
Natural Sources	Wind blown dust, wildfires, volcanic eruptions	Widely and uniformly distributed throughout large regions.	Typically steady.	Probably less than 5 percent.

Industrial Sources

Large industrial sources of toxic air emissions include refineries, chemical plants, and power plants. Industrial facilities generally emit toxic air emissions through exhaust streams (i.e., via facility stacks) or through fugitive emissions, such as vapors escaping through valves or seals. Because industrial facilities are sources of large quantities of toxic air emissions, and because such facilities generally operate under well-controlled conditions, regulation of toxic air contaminants has largely focused on eliminating, reducing, or minimizing exposure to toxic air emissions from industrial facilities. Because of this extensive regulation, a substantial body of information regarding quantified toxic air emissions from industrial facilities is available.

Relative risk estimates indicate that industrial facility toxic air emissions account for a large percentage of health risk to the public, estimated at 20 percent in California overall, and up to 50 percent in some cities (EPA, 1989). Generally, industrial facilities emit toxic air emissions continuously or routinely from fixed points, and their emissions do not fluctuate substantially.

Motor Vehicle Sources

Automobiles, trucks, ships, and other means of transportation are also major sources of toxic air emissions. The toxic air emission rate (and the resulting health risk) from most vehicles depends on the operating mode of the vehicle. Toxic air emissions are a function of vehicular exhaust, which in turn depends on the fuel combustion efficiency. Vehicles burn fuel least efficiently during acceleration and deceleration, and at low speeds. Because vehicular toxic air emissions are emitted along roadways, human beings are physically much closer to vehicular emission sources than to industrial emission sources (e.g., an industrial stack), therefore toxic air concentrations can be much higher in the vicinity of an automobile than at the property line of an industrial facility. Individual vehicles emit relatively small amounts of toxic air contaminants to the atmosphere; however, mobile sources in general contribute up to 90 percent of various toxic air emissions to the atmosphere, often generating between 50 and 80 percent of total ambient risk (EPA, 1989).

Commercial and Area Sources

The "commercial and area source" category covers a wide array of potential sources, along with a wide array of toxic air compounds. Commercial sources may include small dry cleaning operations, photo developing shops and gas stations. These sources are usually considered small point sources of toxic air emissions; individually their emissions are not substantial, but the sum of many commercial source emissions make up a significant portion of aggregate ambient risk. Commercial sources with substantial toxic air emissions, such as dry cleaners and gas stations, are typically required to comply with air quality regulations, and as a result of this regulatory procedure those commercial point source emissions are known and quantified.

"Area" sources of toxic air emissions include many small commercial sources for which regulation is infeasible, along with consumer products, residences, agricultural operations, and other miscellaneous operations that generate toxic air emissions over a large area, making emission control difficult or impossible. Typical area sources of air toxics include emissions from consumer product use, such as hair spray, chemical cleansers, painting materials, and insecticides; emissions from residential wood combustion (fireplaces), water heaters, and cooking equipment; emissions from agricultural activities, including crop dusting, dust-generating field work, and agricultural chemical use; and emissions from other miscellaneous activities, such as construction and demolition activities, asphalt paving, application

Analysis of TDF Emission Results

of adhesives and architectural coatings, asphalt roofing, and dust from travel on unpaved roads (CARB, 1990; CARB, 1996c).

While it is well known that many of these activities are sources of toxic air emissions, characterization and quantification of toxic air emissions from area sources is difficult, due to the number and variety of source types, the variety of emittants from these sources, and the variability of emission generation. Various studies have concluded that small point and area sources figure prominently in aggregate ambient risk; however, estimates of this risk are not readily available.

Natural Sources

Many compounds that are considered toxic air contaminants occur naturally in the atmosphere. Major natural sources of toxic air contaminants include wind blown dust, which contains metals and other compounds, and wildfires and forest fires, which also generate substantial particulate emissions and combustion emissions. Plants are often sources of toxic air contaminants: acetaldehyde, for instance, is an intermediate product of plant respiration, and can be found in ripening plants; methyl iodide occurs naturally as a product of marine algae; and acetone occurs in nature as a metabolite in vegetation and insects. Volcanic eruptions can place large quantities of toxic compounds in the atmosphere, including lead, chromium, and other particulates. Sea and salt lake aerosols generate lead emissions; coal tar and animal waste emit phenol; and crude oil and plant volatiles naturally generate benzene emissions (CARB, 1996c).

Natural sources of toxic air compounds, as with anthropogenic area sources, are difficult to quantify, and the resulting relative risk associated with these emissions is not easily estimated. Windblown dust, forest fires, and wildfires are often included in discussions of ambient air toxic levels, while emissions from other sources mentioned above are generally not considered to contribute substantially to ambient risk.

3.2 REGULATION OF TOXIC AIR CONTAMINANTS

3.2.1 Industrial Sources

Both state and federal governments have developed programs to address toxic air emissions from industrial sources. Most air toxics programs have a risk-based approach, meaning that decisions on what

sources and pollutants to control and the degree to which to control them have been based on the results of health risk assessments (HRAs). An HRA is an analysis in which human health exposure to toxic substances is estimated, and is then considered, together with information regarding the toxic potency of the substances, to provide quantitative estimates of health risks. Most air toxics programs consists of three major elements:

- A program to control emissions from new and modified sources;
- A program directed at existing sources requiring retrofits for categories of sources;
- A program directed at existing sources which is based on facility-specific analyses.

Toxic Air Contaminants New Source Review

As part of the permitting process for new and modified sources, a control agency reviews potential toxic air emissions from industrial facilities. A health risk screening analysis or health risk assessment must be performed for each permit; the results of this analysis determine the need for and degree of toxic emissions control required. Where health risks exceed specified health-based significance levels, sources must use the Best Available Control Technology for Toxics (T-BACT). The significance level for T-BACT is an individual cancer risk of one in one million, or an ambient concentration above a reference exposure level. After controls are applied, if residual health risks still exceed established significance levels for project acceptability, either more risk reduction measures may be required or the permits may be denied.

Retrofit Requirements for Categories of Existing Sources

State measures, such as the Tanner Act and the Risk Reduction Act, require the development of retrofit air toxics control measures in California. The act establishes a process for identifying toxic air contaminants (TACs), and for preparing retrofit toxic control measures. Retrofit control measures are developed by CARB, and are implemented and enforced by local air districts. Recent federal air toxics legislation outlines Maximum Achievable Control Technology (MACT) requirements for a number of sources; MACT standards will be promulgated on a schedule extending through the year 2000.

Analysis of TDF Emission Results

Air Toxics "Hot Spots" Program

Another state program, the Air Toxics "Hot Spots" Information and Assessment Act (AB2588) requires plants emitting TACs to prepare inventories of toxic air emissions from their entire facility. Air districts are then required to prioritize these facilities based on the quantity and toxicity of these emissions, and the facility's proximity to areas where the public may be exposed.

Each facility that is put into a "high priority" category as a result of this review is required to prepare a comprehensive facility-wide HRA. AB2588 requires that exposed individuals then be notified of any "significant health risks" identified in the HRA. The health risk levels used for public notification in the "hot spots" program are set by each individual air district, but most use a maximum individual cancer risk of 10 in one million, or an ambient concentration above a non-cancer reference exposure level, as the threshold of notification.

3.2.2 Mobile Sources

Toxic air emissions from mobile sources, primarily motor vehicles, are regulated at the state and federal levels through vehicle exhaust emission standards. Most vehicular exhaust emission limitations apply to common emission types such as "total organic gases" (TOG) or "particulates," of which some components are considered to be toxic air contaminants. California's recently implemented reformulated gasoline program will substantially reduce organic toxic air emissions (benzene, 1,3-butadiene, and acetaldehyde) on a gram per mile basis. The oxygenated fuel program, another California program, which was designed to decrease carbon monoxide emissions from automobiles, resulted in slightly increased formaldehyde emissions on a gram per mile basis. In general, however, trends in state and federal regulation indicate that toxic air emissions from motor vehicles will continue to decline (BAAQMD, 1996).

3.2.3 Area / Commercial / Consumer Product Sources

Commercial sources such as dry cleaners and gas stations are regulated in the same way as industrial facilities. Toxic air emissions from area and consumer product sources are directly regulated at state and federal levels through limiting the TOG content of consumer products, and through requiring that less toxic substances be substituted, where feasible, in products such as pesticides or herbicides. Area and commercial source toxic air emissions are indirectly controlled through means such as emission control

programs (vapor recovery at gasoline stations) and waste minimization programs (recycling of perchloroethylene by dry cleaners).

4.0 AIR EMISSIONS MONITORING FROM TDF COMBUSTION

This section provides a summary of the collected data. A detailed compilation of the data is provided in the appendices to this report.

Dames & Moore contacted federal, state, county, and industry representatives to acquire emissions data pertaining to whole tire or TDF burning. Twenty-eight facilities representing four major categories submitted relevant source testing data. The emissions and residual by-product results of baseline and TDF testing were compiled and compared.

Table 4-1 lists the facilities that responded for this study. And summarizes the important information concerning the facilities such as fuel type, air pollution control system, baseline and TDF fuel rates, production rates and dates of test. Some of the information was not present in the data we received and is reported as "unknown" where appropriate.

4.1 FACILITIES THAT CONDUCTED MONITORING STUDIES

Dames & Moore contacted federal, state, county, industrial groups and facilities requesting information for an emissions evaluation study for the California Integrated Waste Management Board. We received responses from twenty-eight facilities, with many facilities reporting results from several different test programs. Collection dates for the test data submitted ranged from 1987 to 1996.

Facilities were coded and grouped according to the following four categories:

- Cement Manufacturer
- Energy Services
- Pulp and Paper
- Miscellaneous

TABLE 4-1
Facilities Responding to Information Request

Company Name	Unit	Heat Input (Mbtu/hr)	Fuel	TDF (ton/hr)	Prod. Rate (Ton/hr; Base/TDF)	Steam Output (k-lb/hr; Base/TDF)	Control Device	Date of Test
Abitibi-Price Corporation	Boiler	47	Unknown	Unknown	NA	Unknown	Unknown	4/91
Ash Grove Cement Company	Kiln	98	Whole/Coal/Oil	0.64	15.6/15.6	NA	ESP	8/93
Boise Cascade Lime Kiln	Kiln	87	TDF/Gas	0.4	275	NA	V Scrubber	5/94
Boxcrow Cement Company	Kiln	435	Chip/Coal	4.1	127.1/111.2	NA	Unknown	10/91
Calaveras Cement Company	Kiln	--	Whole TDF/Coal	2.7	93/93	NA	Baghouse	Unknown
California Portland Cement Co.	Kiln	460	Shred TDF/Coal	0.78	136/160	NA	Baghouse	1/95
Central Power & Lime, Inc.	Kiln	212	Shred TDF/Coal	Unknown	80/80	NA	Unknown	9/90
Champion International	Boiler	677	Chip/Oil/Bio/Coal	1.5-3.5	NA	480	ESP	10/89
Champion International Facility	Boiler	272	TDF/Coal/Bio	0.48-2.4	NA	235/271	V Scrubber	87-90
Crown Zellerbach	Boiler	171	Shred/Hog/Oil	Unknown	NA	90/90	V Scrubber	6/86
Dow Corning	Boiler	--	Chip TDF	Unknown	NA	Unknown	ESP	Unknown
EPI Pilot Test	Boiler	--	Coal	Unknown	NA	Unknown	Unknown	Unknown
ESSROC Cement Plant	Kiln	--	Whole/Coal/Oil	Unknown	28.3/27.1	NA	Unknown	11/91
Florida Crushed Stone Company	Kiln	228	Whole TDF/Coal	1.2	77.5/77.5	NA	Unknown	11/91
Great Southern Paper Company	Boiler	--	Unknown	Unknown	NA	Unknown	Unknown	Unknown
Holnann Incorporated Industries	Kiln	258	Chip/Coal/Coke	0.95-1.2	Unknown	NA	ESP	10/90
Illinois Cement Company	Kiln	196	Shred TDF/Coal	1.4	Unknown	NA	Baghouse	7/91
Jackson Valley Energy	Boiler	--	Chip/Coal	6.4	NA	Unknown	Unknown	Unknown
Kaiser Cement Corporation	Kiln	540	Shred/Coal/Coke	2.0-2.2	Unknown	NA	Baghouse	1/96
Mitsubishi Cement Corporation	Kiln	436	Whole TDF/Coal	2	Unknown	NA	Baghouse	10/93
Modesto Energy Limited Partnership	Boiler	--	Whole TDF	6.42	NA	259.4	Baghouse	87-96
Monsanto Company	Boiler	92	Chip/Coal	0.6	NA	74.4/71.2	ESP	12/90
Nekoosa Packaging	Boiler	459	Shred/Wood/Coal	1.5	NA	347.6/328.8	ESP	8/89
Port Townsend Paper Company	Boiler	239	Shred/Hog/Oil	0.525	NA	141/148	V Scrubber	2/86
Riverside Cement Company	Kiln	133	Whole TDF/Coal	1.1-1.2	24.2/19.5	NA	Baghouse	4/95
RMC Lonestar	Kiln	325	Whole TDF/Coal	2.5	Unknown	NA	ESP	12.90
RMC Lonestar	Kiln	291	Chip/Coal	2.4	Unknown	Unknown	ESP	9/92
Southwestern Portland Cement Co.	Kiln	344	Whole TDF/Coal	2.3	224/218	NA	Baghouse	4/91
Wheelabrator Shasta Energy Co.	Boiler	280	Chip/Hog/Gas	1.0	NA	170	ESP	5/94

Analysis of TDF Emission Results

4.2 POLLUTANT DATA

In our request for information, we requested summary information pertaining to baseline and tire derived fuel testing data, corresponding operating parameters, emission control equipment, and technologies used for emission control in these applications. We specifically asked for the following data:

Particulate Matter (PM, PM ₁₀)	Metals
Sulfur oxides (SO _x)	Dioxins/Furans
Oxides of nitrogen (NO _x)	Polycyclic aromatic hydrocarbons (PAHs)
Carbon monoxide (CO)	Formaldehyde
Volatile Organic Compounds (VOC)	Benzene
Hydrogen chloride (HCl)	

We also asked for relevant chemical information on fly ash, bottom ash and scrubber residues. This information was grouped into the following categories:

1. Carcinogens
2. Criteria Pollutants
3. Dioxin/Furans
4. Metals
5. Organics
6. PAH's
7. PCB's
8. Ash

4.3 EMISSION RESULTS

After receipt, the data were entered into a common database, checked for accuracy and then grouped. The test data within each group were characterized to determine the relative differences for each pollutant. The data with tires or TDF were compared to the data without tires or TDF. Finally, the cement industry was broken out and compared to the overall averages to determine if there were any significant differences.

4.3.1 Results of Carcinogenic Air Emissions

Carcinogenic pollutants are cancer-producing substances such as a physical agent or a chemical compound. There are numerous published lists of chemicals with carcinogenic potential that have been compiled using different evaluative criteria applied to the same data. The lists generally divide into identifying known human carcinogens and then identifying suspected or reasonably anticipated to be human carcinogens. (NTP, 1994).

The submitted data were specifically examined for results associated with known or suspected carcinogens. Specific known carcinogen elements and compounds reviewed were:

- Arsenic
- Hexavalent chromium
- Benzene
- Vinyl chloride

Specific suspected carcinogen elements and compounds reviewed were:

- Acetaldehyde
- Furans
- 1,3 – Butadiene
- Lead
- Cadmium
- Methylene chloride
- Carbon tetrachloride
- Total PCB's

Data pertaining to carcinogenic emissions were received for twenty-seven facilities, fifteen of which were cement manufacturers. Several facilities sent data for more than one test condition, resulting in data from thirty-nine test runs. As seen in Figures 4-1 and 4-2, there are a number of pollutants showing increased emissions when the facilities were using tires or TDF as compared to baseline results, while others show a decreasing trend for TDF versus baseline fuels.

FIGURE 4-1

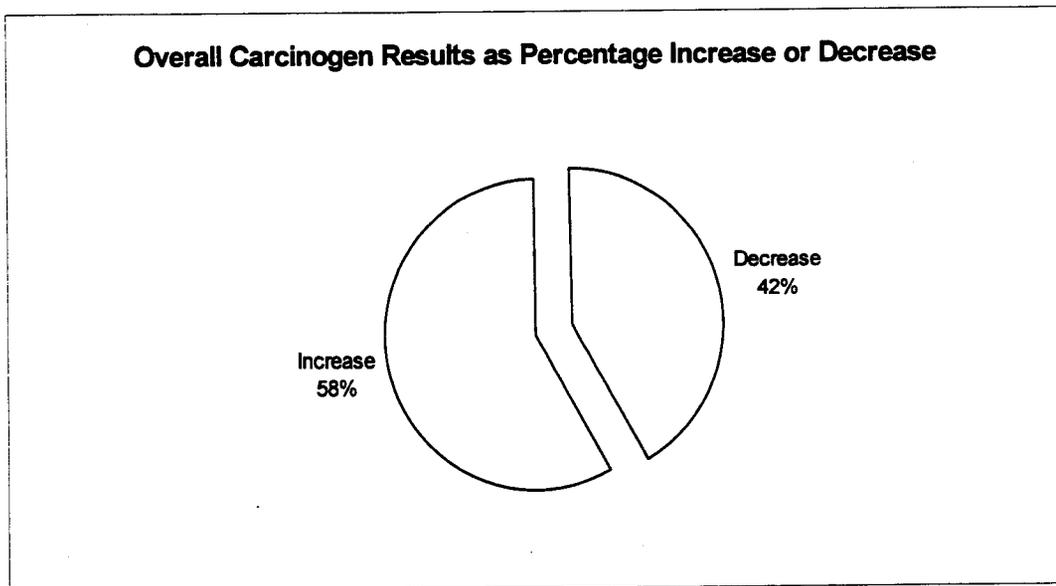
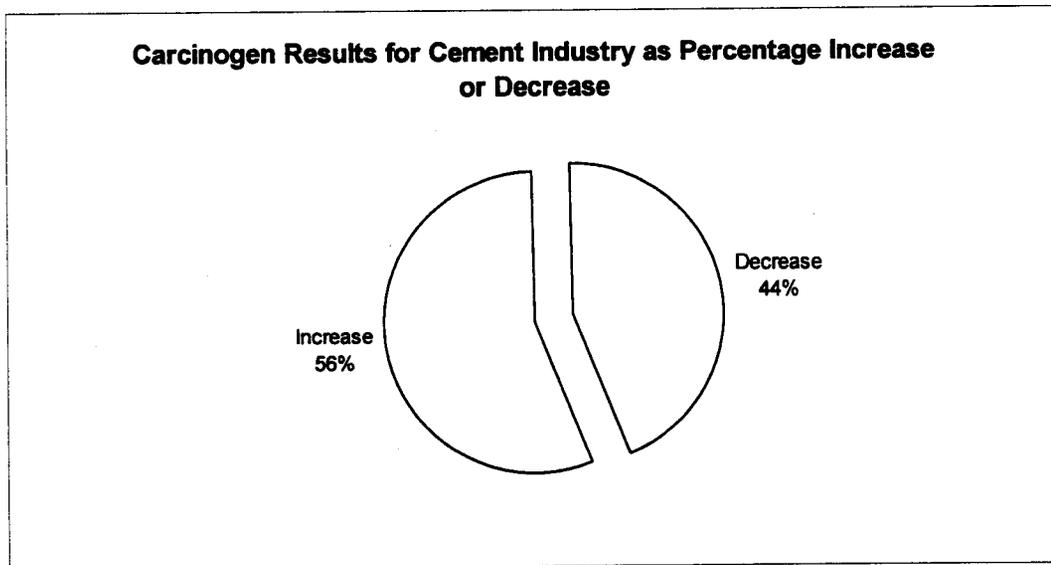


FIGURE 4-2



There were, however, significant differences in emissions between sources. For instance, the range of reported emission rates for PCDD (TEQ) was from 8.30×10^{-8} to 3.15×10^{-12} lb/hr for baseline results and 5.84×10^{-8} to 2.62×10^{-11} lb/hr for TDF. This is a difference of from 1,000 to 10,000 between sources. In both cases, the higher reported emissions rates were from Southwestern Portland Cement Company. Table 4-2 shows the range of values reported for each element and compound for carcinogens.

TABLE 4-2
Maximum and Minimum Reported Emissions for Carcinogens

Compound/Element	Units	Baseline Results		TDF Results	
		Max	Min	Max	Min
PCDD (TEQ)	lbs/hr	8.30E-08	3.15E-12	5.84E-08	2.62E-11
PCDF (TEQ)	lbs/hr	6.17E-07	9.19E-10	8.92E-07	1.86E-10
Arsenic	lbs/hr	4.00E-03	3.00E-05	4.00E-03	6.19E-06
Beryllium	lbs/hr	7.18E-04	7.22E-06	8.73E-04	9.85E-06
Cadmium	lbs/hr	9.13E-03	2.90E-05	1.67E-02	4.00E-06
Hexavalent Chromium	lbs/hr	1.29E-02	4.06E-05	3.58E-02	1.83E-05
Lead	lbs/hr	1.30E-01	3.80E-06	1.73E-01	3.60E-06
Nickel	lbs/hr	1.47E-01	1.27E-05	2.83E-02	1.50E-05
Methylene Chloride	lbs/hr	2.00E-01	9.19E-03	5.50E-02	3.08E-03
1,3-Butadiene	lbs/hr	3.31E-03	3.10E-04	1.16E-03	2.00E-04
Acetaldehyde	lbs/hr	3.42E-02	1.11E-02	1.10E+00	3.83E-03
Benzene	lbs/hr	3.82E+00	1.31E-03	3.26E+00	5.95E-04
Carbon Tetrachloride	lbs/hr	1.60E-02	1.60E-02	1.50E-02	1.50E-02
Formaldehyde	lbs/hr	9.40E-02	7.00E-03	1.80E+00	4.60E-03
Vinyl Chloride	lbs/hr	1.63E-02	6.40E-03	4.00E-02	3.40E-04
Total PAHs	lbs/hr	6.97E-03	3.23E-07	2.62E-03	3.56E-07
Total PCBs	lbs/hr	4.05E-05	1.81E-05	3.00E-04	9.13E-06

Analysis of TDF Emission Results

As expected, large differences in the toxic air emission rates were seen in the test data results. Mean toxic air emission rates ranged from 40.6 lb/hr for hydrogen fluoride to 5.39×10^{-10} lb/hr for 1,2,3,7,8,9-HxCDF (one of the furan compounds), which is expected due to the variety and make-up of the compounds. Large differences, however, were also observed within most of the compounds between test results. For instance, the mean reported baseline emission rate for PCDD (TEQ) was 1.31×10^{-8} lb/hr, however, the emission rates ranged from 8.30×10^{-8} to 3.15×10^{-12} lb/hr for baseline results. Similar results were seen for TDF-derived emission rates of the same compound, which had a mean value of 6.38×10^{-9} lb/hr and ranged from 5.84×10^{-8} to 2.62×10^{-11} lb/hr.

The large differences in the range of reported values within the compounds may arise for a variety of conditions, including variations in stack flows, operating conditions, process requirements, analytical methods, and source testing conditions. For the purposes of this study, only increases and decreases were compared between baseline and TDF test runs, relative differences between sources were outside of the scope of the project.

Covariance analyses were conducted on the comparable test data between the baseline and TDF test results for each air toxic compound as well as classes of compounds (i.e., dioxins, furans, PAHs, PCBs, etc.). These analyses show the correlation between combinations of baseline and TDF results from the various facilities, which factors out the variability between test result combinations. The correlation coefficient (r) is the measure of this variability and ranged from 0.410 to 0.996 for the different classes of toxic air compounds. Metal toxic air contaminants exhibited the lowest correlation as a class, while the non-metal toxic air contaminants had the highest correlation.

Individual plots of the differences between TDF and baseline results for carcinogenic compounds/elements versus source can be found in Appendix B.

4.3.2 Criteria Pollutant Results

National Ambient Air Quality Standards (NAAQS's) have been established for six criteria air pollutants - five primary, or directly emitted, and one secondary pollutant (ozone), because it is formed in the lower atmosphere by chemical reactions among primary pollutants. The five primary criteria pollutants are

Analysis of TDF Emission Results

particulate matter less than 10 μm in diameter (PM_{10}), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), and particulate lead.

Data pertaining to criteria pollutant emissions were received for twenty-two facilities, twelve of which were cement manufacturers. Several facilities sent data for more than one test condition, resulting in data from thirty-five test runs. When comparing all criteria pollutants together, Figures 4-3 and 4-4 show no trends in either increases or decreases of emissions when the facilities were using tires or TDF as compared to baseline results. As can be seen from Table 4-3 and Figure 4-5, carbon monoxide and particulate matter emissions tended to rise with the use of TDF. Mean CO and PM emission rates for all reported facilities were 146 lb/hr and 16.4 lb/hr, respectively, during baseline condition and increased to 215 lb/hr, and 20.5 lb/hr for the two pollutants during the TDF testing. These data had fairly good correlation with the corresponding r being 0.79 and 0.78 for CO and PM (perfect correlation is 1.0; no correlation is 0.0; and inverse correlation is -1.0). The CO emission rates between facilities did vary greatly with standard deviations of 178 lb/hr and 350 lb/hr for the baseline and TDF cases, respectively. This was also true for the PM emission rates which showed high standard deviations (16.5 lb/hr - baseline; 20.7 - TDF).

Similar increasing trends (although less significant) were shown for SO_2 with the use of TDF. The mean SO_2 emission rates from the reported facilities were 207 lb/hr (using baseline fuels) versus 214 lb/hr for TDF fuel use test results. These results were in good agreement between the two fuel types (having a correlation coefficient of 0.96), even though the emissions between sources experienced large variability in emission rates (standard deviations of 302 lb/hr and 284 lb/hr for the baseline and TDF data sets).

Mean NO_x emission rates showed a decrease when using TDF with values of 243 lb/hr and 192 lb/hr for baseline and TDF test results, respectively. The NO_x results between source type, however, varied widely having standard deviations of 215 lb/hr for the baseline data and 152 lb/hr for the TDF data results. As with the other criteria pollutants, the overall NO_x data sets (Baseline vs TDF) were in good agreement, having a correlation coefficient of 0.96, indicating that the reductions were fairly consistent even though there was a wide variation in the emissions rates for each source category. Figure 4-6 displays the nitrogen oxide emission rates for both cases for the data reported.

FIGURE 4-3

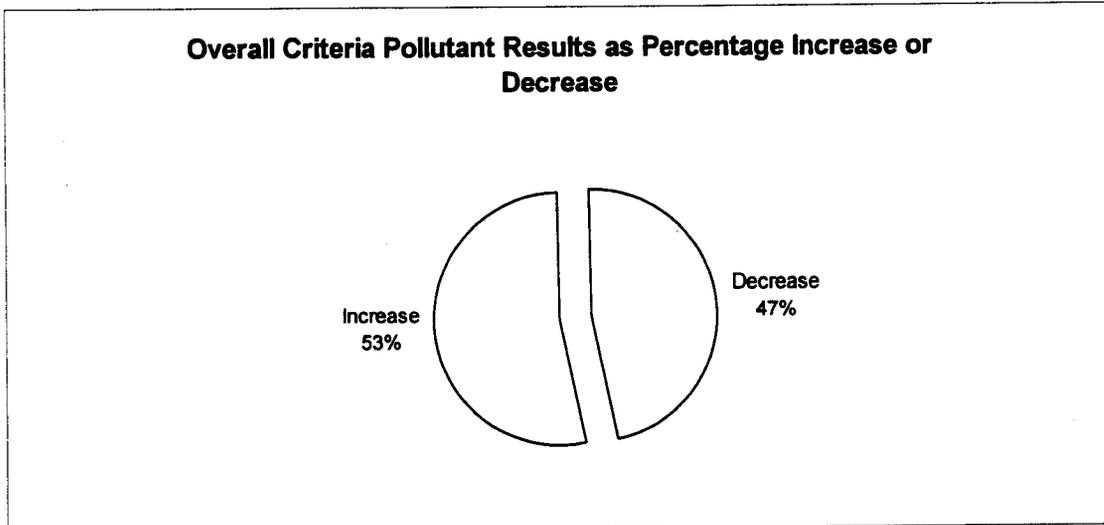


FIGURE 4-4

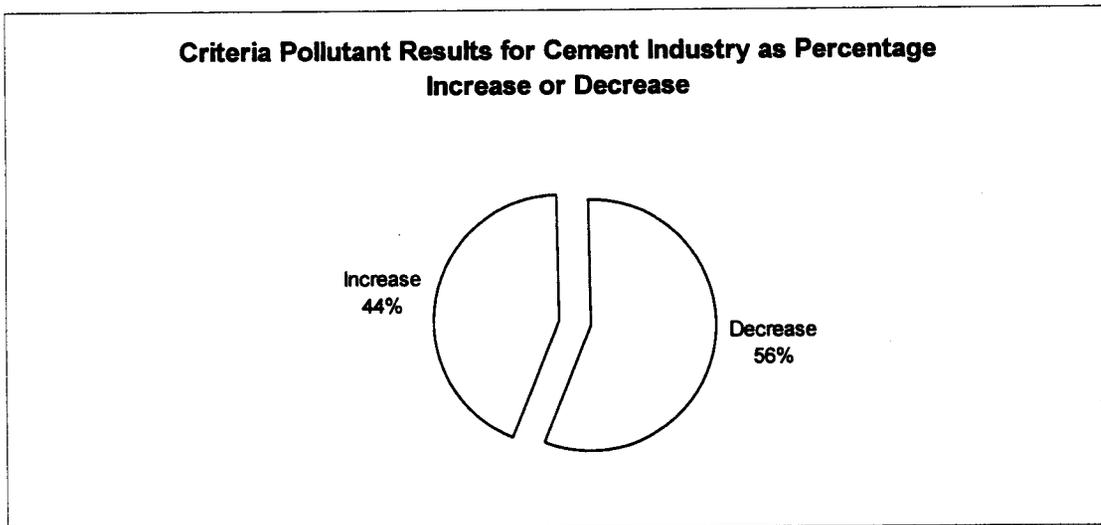


TABLE 4-3
Maximum and Minimum Reported Emissions for Criteria Pollutants

Compound	Units	Baseline Results		TDF Results	
		Max	Min	Max	Min
Carbon Monoxide	lbs/hr	781	0.4	1,485	0.5
Oxides of Nitrogen	lbs/hr	972	19.6	606	8.3
Particulate Matter	lbs/hr	56.8	0.1	258	0.1
Sulfur Dioxide	lbs/hr	1,406	0.3	1,380	0.3
Nitrogen Dioxide	lbs/hr	0.0	0.0	12.0	12.0
Oxides of Sulfur	lbs/hr	45.1	45.1	37.0	37.0
PM ₁₀	lbs/hr	2.1	0.4	1.9	1.0

FIGURE 4-5

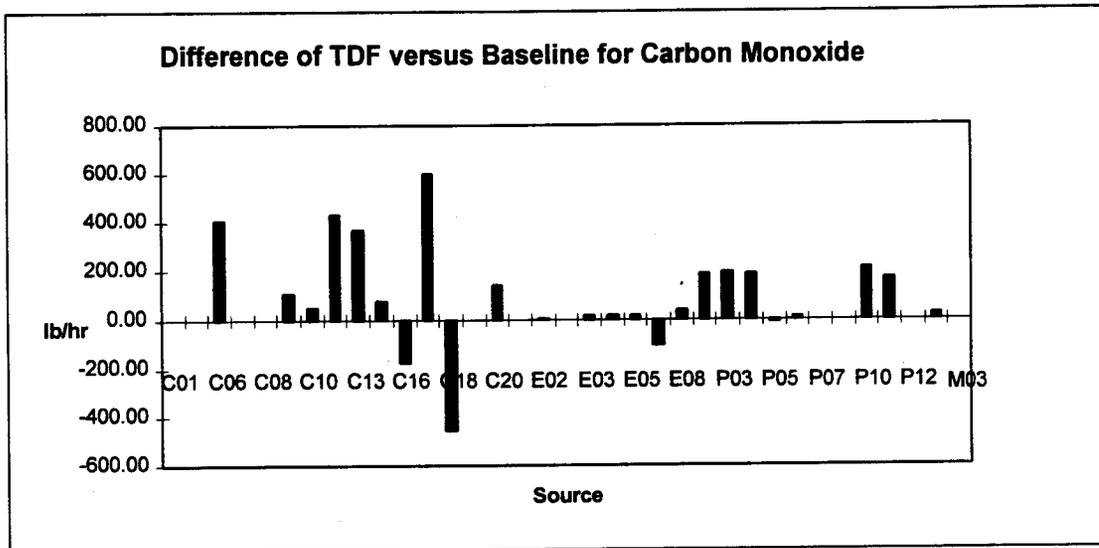
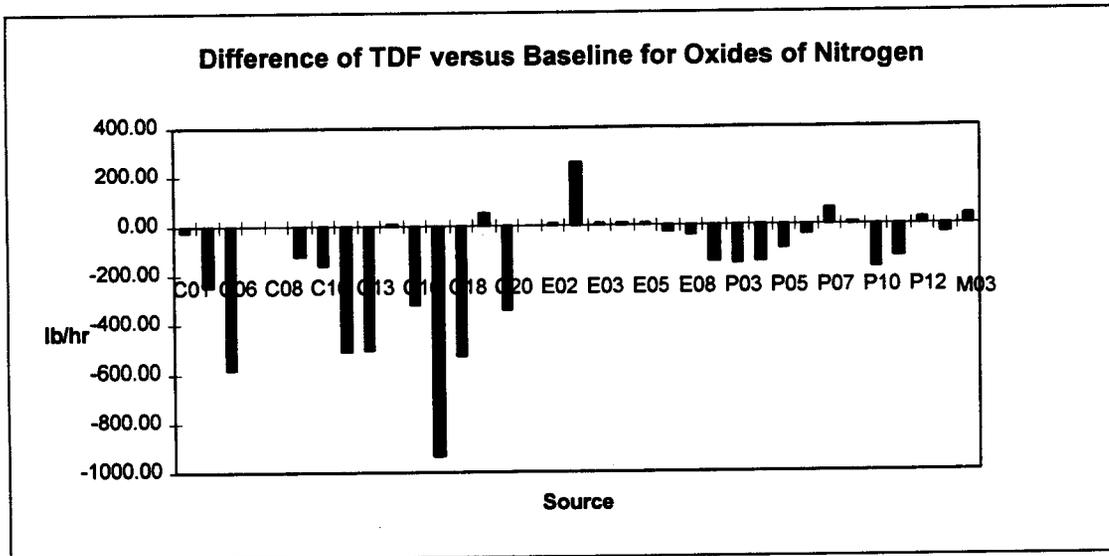


FIGURE 4-6



4.3.3 Dioxin/Furan Results

Polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) are chemically classified as halogenated aromatic hydrocarbons. Dibenzodioxins and dibenzofurans have similar physical and chemical properties and have similar structure. There are 75 individual compounds comprising the PCDDs and 135 different PCDFs. Only 7 of the 75 congeners of PCDDs are thought to have dioxin-like toxicity. Only 10 of the 135 possible congeners of PCDFs are thought to have dioxin-like toxicity. These data hold true for bromine substituted congeners also.

The reference compound for these classes of compounds is 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). These compounds have been assigned individual toxicity equivalence factor (TEF) values as defined by international convention (EPA, 1989). TEFs are estimates of the toxicity of dioxin-like compounds relative to the toxicity of TCDD, which has a TEF of 1.0. Concentrations of dioxin and related compounds are reported as toxic equivalents or TEQs. TEQs are determined by summing the products of multiplying concentrations of individual dioxin-like compounds times the corresponding TEF for that compound.

PCDDs and PCDFs are generated as by-products from various combustion and chemical processes when chlorine donor compounds are present. They can be formed as by-products from the manufacture of chlorine and chlorinated compounds. Dioxin-like compounds can also be formed through the chlorination of phenolic compounds such as those present in wood pulp during chlorine bleaching processes in the manufacture of bleached pulp and paper.

At present, TCDD and related compounds are regarded as potent toxicants in animals with the potential to produce a spectrum of effects. Some of these effects may occur in humans at very low levels and some may result in adverse impacts on human health. The Science Advisory Board (SAB) of the Environmental Protection Agency reported that in general human data are "limited," and that dioxin is a "probable" human carcinogen under some conditions of exposure (SAB, 1995).

Data were received for eleven facilities, seven of which were cement manufacturers. Several facilities sent data for more than one test condition, resulting in data from eighteen test runs. As can be seen in Figures 4-7 and 4-8, increases and decreases of emission ranges with specific dioxins/furans occurred when the facilities were using tires or TDF and baseline fuels. However, the overall mean dioxin emission rate was higher for the baseline data set (8.13×10^{-8} lb/hr) as compared to the data derived from TDF, which had an overall mean emission rate of 3.36×10^{-8} lb/hr. Although this trend did not occur in all specific dioxin compounds, this overall agreement was generally good, with the data having a correlation coefficient of 0.75. There were also large differences in emission rates between sources. For instance, the range of reported emission rates for PCDD (TEQ) was from 8.30×10^{-8} to 3.15×10^{-12} lb/hr for baseline results and 5.84×10^{-8} to 2.62×10^{-11} lb/hr for TDF. The overall furan emission rates showed slightly higher rates for the TDF cases than the baseline data sets with mean emission rates of 1.92×10^{-8} lb/hr and 1.85×10^{-8} lb/hr, respectively. This is a very small increase (approximately 4 percent) and is in the range of natural variation. The overall furan data do compare well between the baseline and TDF cases, having an overall correlation coefficient of 0.92. Table 4-4 shows the range of values reported for each compound for dioxin/furans. There was little difference between the maximum and minimum values from the baseline results as compared to the TDF results.

FIGURE 4-7

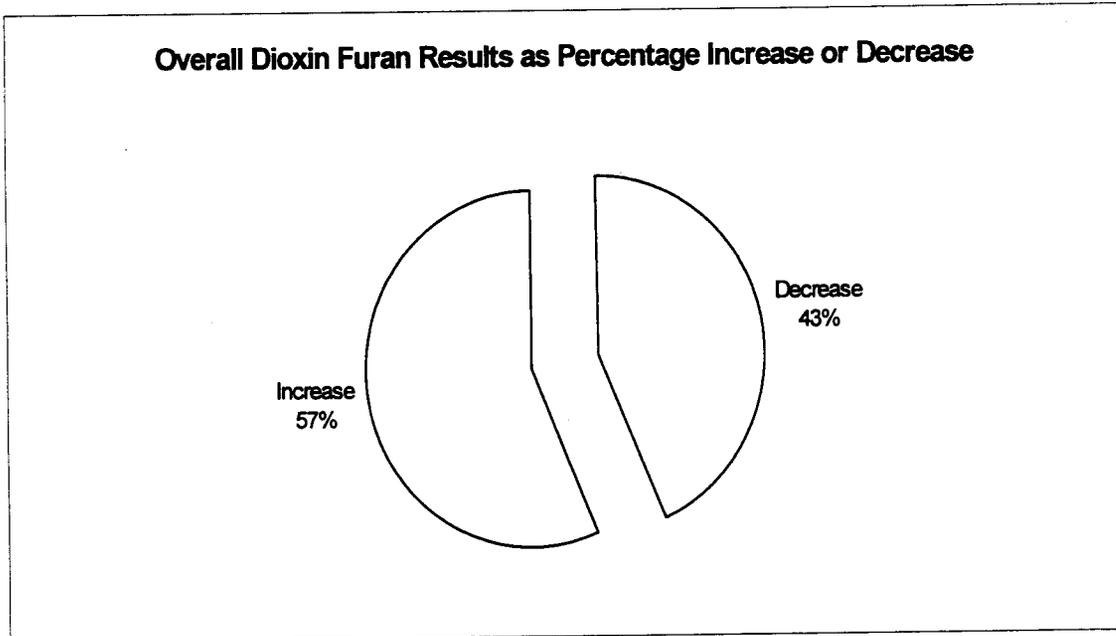


FIGURE 4-8

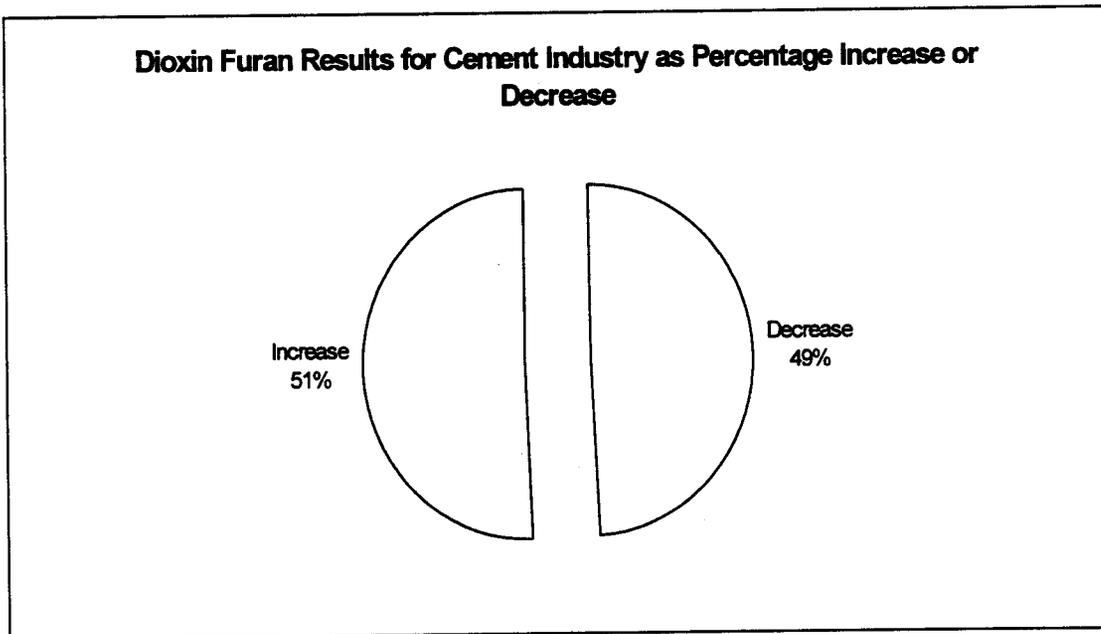


TABLE 4-4
Maximum and Minimum Reported Emissions for Dioxins/Furans

Compound	Units	Baseline Results		TDF Results	
		Max	Min	Max	Min
1,2,3,4,6,7,8-HpCDD	Lbs/hr	1.21E-06	1.80E-10	1.07E-07	1.70E-10
1,2,3,4,7,8-HxCDD	Lbs/hr	4.80E-08	8.86E-11	2.24E-08	1.70E-10
1,2,3,6,7,8-HxCDD	Lbs/hr	1.25E-07	8.20E-11	2.43E-08	8.10E-11
1,2,3,7,8,9-HxCDD	Lbs/hr	8.40E-08	1.09E-10	3.49E-08	4.00E-11
1,2,3,7,8-PeCDD	Lbs/hr	3.50E-08	7.60E-11	3.31E-08	8.50E-11
2,3,7,8-TCDD	Lbs/hr	1.30E-08	1.30E-10	1.96E-08	1.25E-10
OCDD	Lbs/hr	5.22E-06	3.80E-10	1.10E-06	3.90E-10
PCDD (TEQ)	Lbs/hr	8.30E-08	3.10E-12	5.84E-08	2.62E-11
1,2,3,4,6,7,8-HpCDF	Lbs/hr	7.90E-08	5.20E-11	4.38E-08	6.50E-11
1,2,3,4,7,8,9-HpCDF	Lbs/hr	1.79E-08	4.97E-11	1.26E-08	4.40E-11
1,2,3,4,7,8-HxCDF	Lbs/hr	8.36E-08	4.60E-11	1.68E-07	4.80E-11
1,2,3,6,7,8-HxCDF	Lbs/hr	5.63E-08	3.60E-11	5.72E-08	4.90E-11
1,2,3,7,8,9-HxCDF	Lbs/hr	6.19E-09	8.58E-11	9.49E-09	1.34E-10
1,2,3,7,8-PeCDF	Lbs/hr	1.27E-07	1.10E-10	1.81E-07	1.20E-10
2,3,4,6,7,8-HxCDF	Lbs/hr	1.20E-07	2.08E-10	5.48E-08	2.93E-10
2,3,4,7,8-PeCDF	Lbs/hr	1.91E-07	1.10E-10	2.40E-07	1.30E-10
2,3,7,8-TCDF	Lbs/hr	2.90E-07	3.80E-10	4.61E-07	1.86E-10
OCDF	Lbs/hr	2.90E-07	1.63E-10	3.70E-08	2.68E-10
PCDF (TEQ)	Lbs/hr	6.17E-07	9.19E-10	8.92E-07	1.80E-10

4.3.4 Metal Results

EPA has developed a list of thirteen priority pollutant metals (40 CFR Part 261) that are defined as hazardous metals. California has expanded this list to seventeen metals (California Administrative Code, Title 22). These metals plus some additional process metals were analyzed from twenty-five facilities,

Analysis of TDF Emission Results

fourteen of which were cement manufacturers. Several facilities sent data for more than one test condition, resulting in data from thirty-five test runs.

Metals are not destroyed by a combustion process. The metals in the fuel are typically passed through this combustion process and become components of the fly ash, as material captured by a control device or as air emissions.

Metals emissions overall tended to increase with TDF as can be seen in Figure 4-9. However, the cement manufacturers data did not exhibit as strong a trend on metal emissions as the overall data set (Figure 4-10), reflecting the nature of their process where residual ash is incorporated into the clinker and their use of electrostatic precipitators or baghouses. Removal of metals is more efficient with baghouses and electrostatic precipitators. Scrubbers are not as effective in removing metals. This effect can particularly be seen in Figure 4-11 for zinc emissions. Zinc oxide is used in the tire manufacturing process and high zinc values have been reported with the use of TDF (EPA, 1991).

FIGURE 4-9

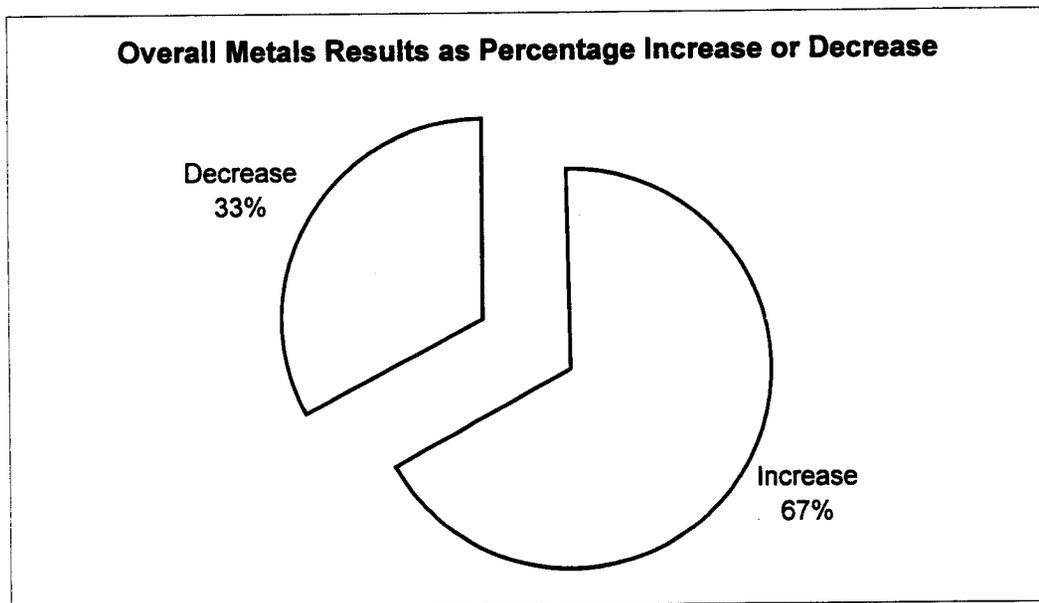


FIGURE 4-10

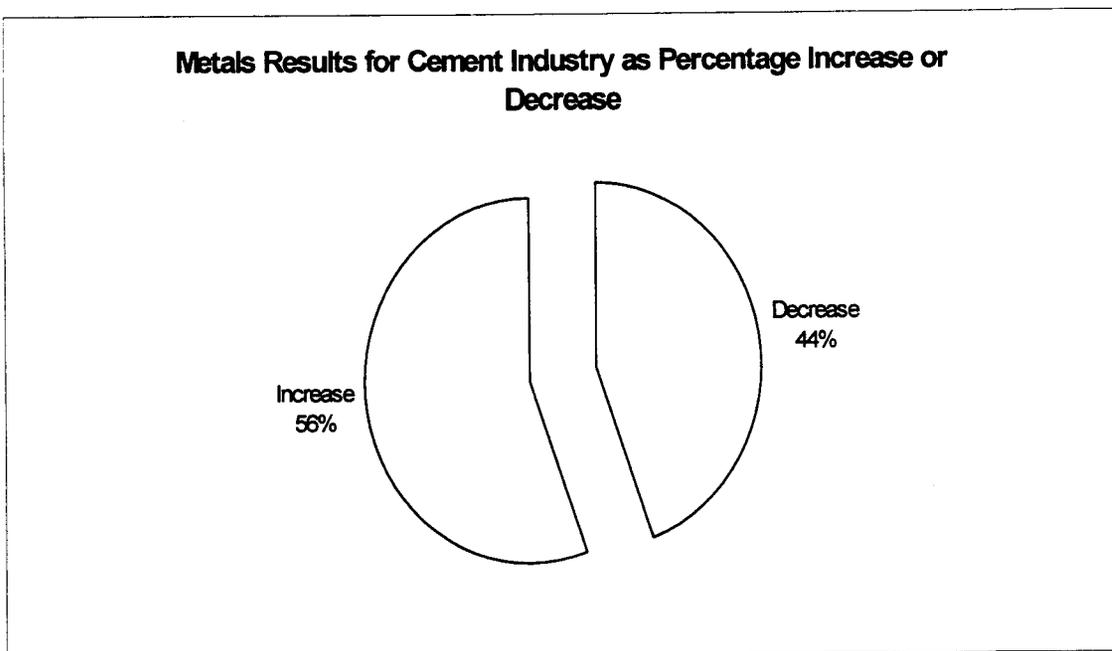
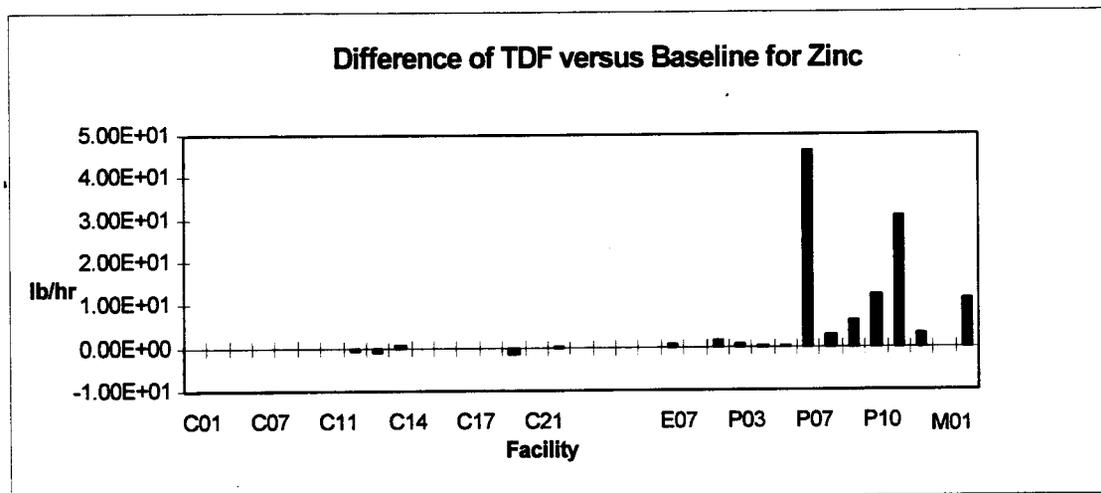


FIGURE 4-11



Analysis of TDF Emission Results

The mean air toxic metal emission rates were 0.08 lb/hr for the baseline data and 0.39 lb/hr for the TDF test results. However, it should be noted that the correlations vary widely between specific metal emission rates and that the overall correlation coefficient is less than 0.5 (0.41), which does not indicate a strong correlation between baseline and TDF data sets. Table 4-5 shows the maximum and minimum emission rate values for metals on both baseline and TDF tests.

TABLE 4-5
Maximum and Minimum Reported Emissions for Metals

Compound	Units	Baseline Results		TDF Results	
		Max	Min	Max	Min
Aluminum	lbs/hr	6.86E+00	3.49E-02	8.13E+00	7.50E-03
Antimony	lbs/hr	2.88E-05	2.88E-05	1.16E-02	3.49E-05
Arsenic	lbs/hr	4.00E-03	3.00E-05	4.00E-03	6.19E-06
Barium	lbs/hr	9.75E-02	2.39E-04	6.59E-01	8.10E-04
Beryllium	lbs/hr	7.18E-04	7.22E-06	8.93E-04	9.85E-06
Bismuth	lbs/hr			8.72E-03	2.86E-03
Cadmium	lbs/hr	9.13E-03	2.90E-05	1.67E-02	4.00E-06
Chromium (Total)	lbs/hr	4.80E-02	1.32E-05	8.50E-02	1.70E-05
Cobalt	lbs/hr	5.00E-03	5.77E-05	2.00E-03	7.86E-05
Copper	lbs/hr	3.00E-02	1.20E-05	3.00E-02	1.70E-05
Hexavalent Chromium	lbs/hr	1.29E-02	4.06E-05	3.58E-02	1.83E-05
Iron	lbs/hr	1.39E+00	1.87E-02	1.30E+00	1.51E-02
Lead	lbs/hr	1.30E-01	3.80E-06	1.73E-01	3.60E-06
Magnesium	lbs/hr	5.00E-01	8.03E-02	5.50E-01	7.73E-02
Manganese	lbs/hr	1.44E-01	1.70E-05	4.15E+00	1.90E-05
Mercury	lbs/hr	1.75E+00	1.00E-06	5.45E-02	1.00E-06
Molybdenum	lbs/hr	2.00E-02	2.19E-03	2.00E-02	4.00E-06
Nickel	lbs/hr	1.47E-01	1.27E-05	2.00E-02	1.50E-05
Phosphorus	lbs/hr	7.30E-02	7.30E-02	3.95E-02	2.45E-02
Selenium	lbs/hr	7.33E-03	1.00E-05	4.30E-03	1.00E-05
Silver	lbs/hr	9.00E-03	2.88E-05	9.00E-03	2.77E-05
Thallium	lbs/hr	1.00E-03	7.00E-05	7.39E-03	6.30E-05
Tin	lbs/hr			8.73E-02	7.50E-04
Titanium	lbs/hr	2.20E-01	6.44E-03	2.00E-01	7.46E-03
Vanadium	lbs/hr	1.92E-01	3.00E-04	2.00E-02	2.00E-04
Zinc	lbs/hr	3.15E+00	3.90E-05	4.93E-01	5.40E-05

4.3.5 Organic/Inorganic Results

Several inorganic and organic compounds were grouped together and examined for possible trends. Data from eighteen facilities, including thirteen cement manufacturing facilities were compared for twenty-nine inorganic and organic compounds for a total of twenty-five data test runs. As can be seen in Figures 4-12 and 4-13, trends for both increases or decreases of emissions were observed for TDF and baseline results. The overall mean non-metal inorganic compounds was 6.19 lb/hr for the baseline data and 6.30 lb/hr for the TDF conditions (less than 2 percent difference). However, the emission rates varied widely with the major non-metal inorganic compound, hydrogen fluoride, having a average emission rate of 40.6 lb/hr. Although these data had widely varying emission rates, the correlation was very good between the

FIGURE 4-12

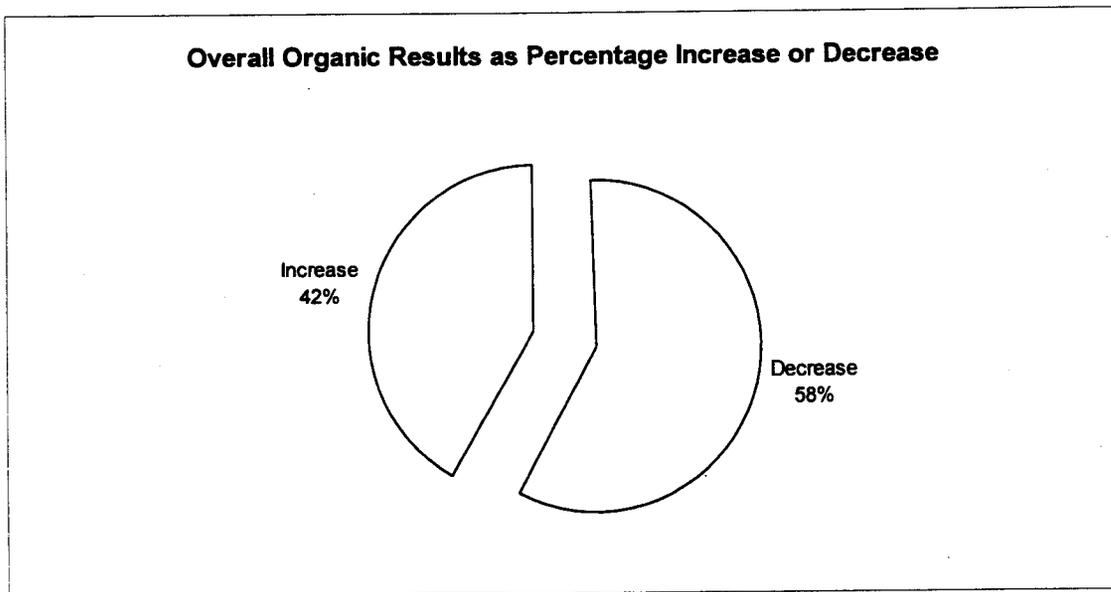
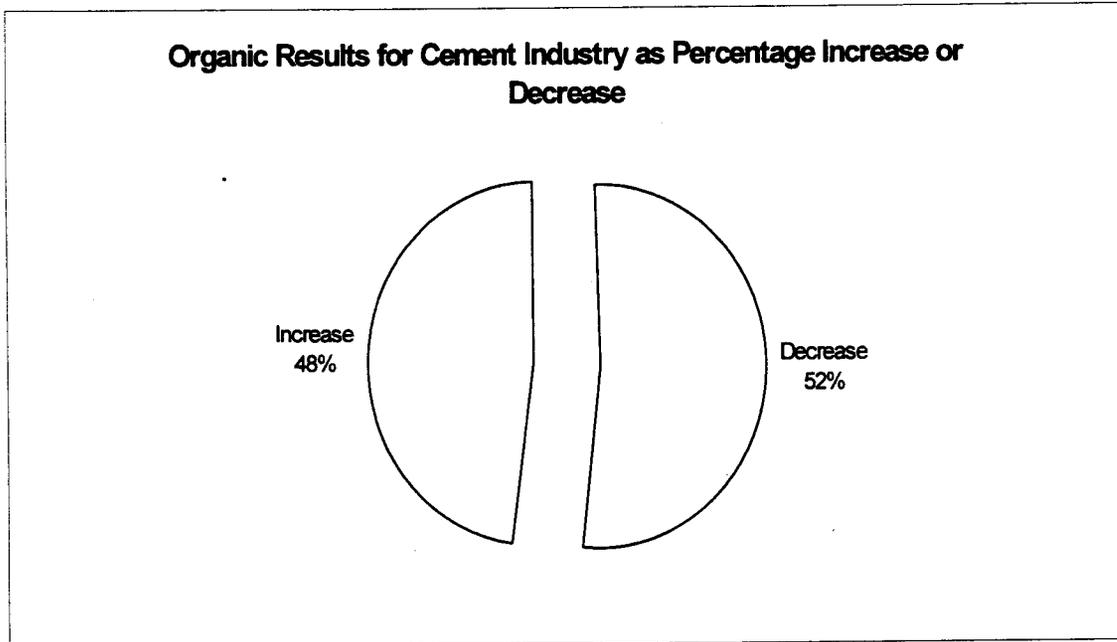


FIGURE 4-13



baseline tests and the TDF tests for each of the facilities, exhibiting an overall correlation coefficient of 0.99.

The organic compounds also showed good agreement between the baseline and TDF emission rate trends with an overall correlation coefficient of 0.93. This trend showed that the emission rates generally decreased using the TDF versus baseline fuels (0.73 lb/hr for baseline and 0.45 lb/hr for TDF). Table 4-6 shows the maximum and minimum emission rate values for Organic/Inorganic compounds for both baseline and TDF tests.

TABLE 4-6

Maximum and Minimum Reported Emissions for Organic/Inorganic

Compound	Units	Baseline Results		TDF Results	
		Max	Min	Max	Min
Ammonia	lbs/hr	2.50E+00	3.84E-03	2.66E+01	5.70E-04
Asbestos	lbs/hr			3.20E-03	3.20E-03
Boron	lbs/hr	5.00E-03	5.00E-03	6.00E-03	6.00E-03
Fluorene	lbs/hr	1.27E-05	1.27E-05	4.39E-05	4.39E-05
Hydrogen Chloride	lbs/hr	2.21E+01	3.90E-02	1.45E+01	1.96E-02
Hydrogen Fluoride	lbs/hr	1.21E+01	1.41E-02	1.36E+02	8.20E-03
Methylene Chloride	lbs/hr	2.00E-01	9.19E-03	5.50E-02	3.08E-03
1,3-Butadiene	lbs/hr	3.31E-03	3.10E-04	1.16E-03	2.00E-04
Acenaphthene	lbs/hr	4.19E-06	4.19E-06	1.41E-05	1.41E-05
Acetaldehyde	lbs/hr	3.42E-02	1.11E-02	1.10E+00	3.83E-03
Acrolein	lbs/hr			3.20E-02	3.20E-02
Benzaldehyde	lbs/hr	5.80E-02	5.80E-02	2.50E-01	2.50E-01
Benzene	lbs/hr	3.82E+00	1.31E-03	3.26E+00	5.95E-05
Carbon Tetrachloride	lbs/hr	1.60E-02	1.60E-02	1.50E-02	1.50E-02
Chlorobenzene	lbs/hr	1.24E-02	5.20E-04	1.34E-02	1.99E-03
Ethyl Benzene	lbs/hr	4.21E-01	9.91E-04	5.77E-01	7.28E-04
Formaldehyde	lbs/hr	9.40E-02	7.00E-03	1.80E+00	4.60E-03
HC as Methane	lbs/hr	2.94E-01	2.94E-01	2.82E+00	2.82E+00
Methyl Indene	lbs/hr			1.12E+00	1.12E+00
Naphthalene	lbs/hr	1.01E-01	2.23E-01	1.07E+00	4.30E-04
Phenanthrene	lbs/hr	4.64E-05	4.64E-05	1.00E-03	2.85E-04
Styrene	lbs/hr	4.33E-01	4.33E-01	7.65E-01	3.78E-04
Toluene	lbs/hr	3.31E+00	9.70E-03	4.50E+00	3.74E-03
Total VOCs	lbs/hr	3.16E+01	2.97E-02	1.77E+01	4.40E-01
Vinyl Chloride	lbs/hr	1.63E-02	6.40E-03	4.00E-02	3.40E-04
Xylene	lbs/hr	1.83E+00	6.11E-03	2.69E+00	2.16E-03

4.3.6 PAH Results

Polycyclic aromatic hydrocarbons (PAHs) are nonpolar, fat soluble compounds composed of aromatic rings. The PAHs such as benzo(a)pyrene are of concern because of their known carcinogenicity. PAHs are produced during most typical combustion processes, including vehicular exhaust and from industrial combustion products.

Analysis of TDF Emission Results

Eighteen facilities representing twenty-six test runs were examined for differences in PAH emissions from baseline conditions to TDF. PAH comparisons were limited to the six PAH's listed in the October 1993 CAPCOA Air Toxics "Hot Spots" Program Risk Assessment Guidelines. Twelve cement manufacturers were represented. Figures 4-14 and 4-15 appear to show an increase in PAH emissions as TDF is used. The overall mean PAH emission rate for the baseline data set conditions was calculated to be 3.01×10^{-5} lb/hr as compared to the computed overall mean emission rate during TDF conditions, 7.21×10^{-5} lb/hr, confirming the general increase trend. The correlation between baseline test results and TDF test results was in relative good agreement with a correlation coefficient of 0.82. Even though the data showed an overall increase trend, there was very high variability within the data sets ranging from 10^{-4} to 10^{-8} lb/hr.

FIGURE 4-14

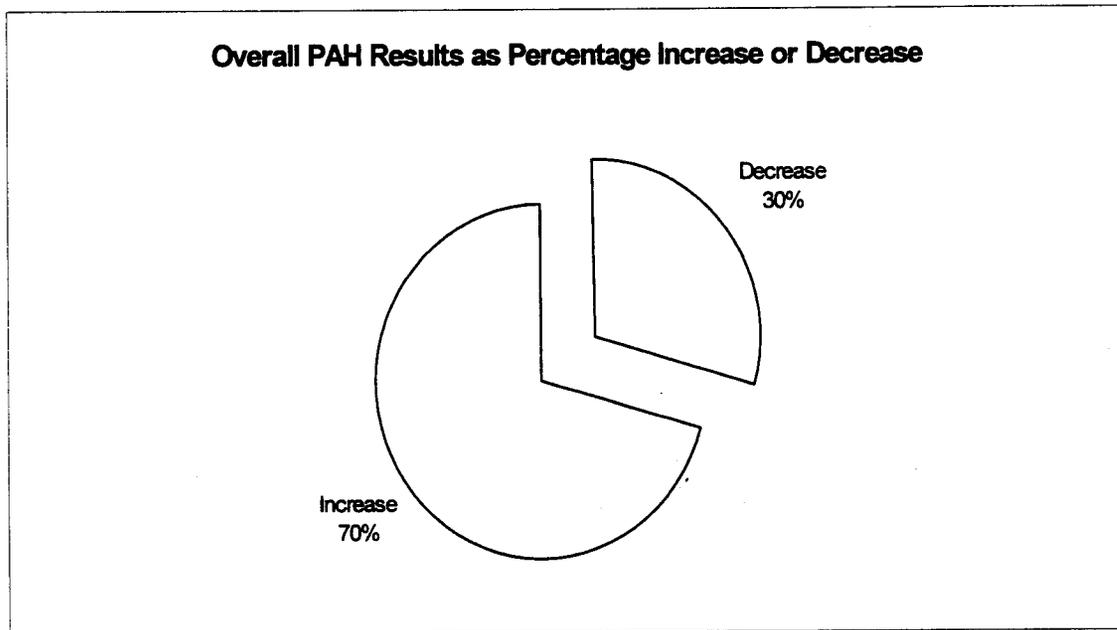


Table 4-7 shows the maximum and minimum emission rate values for PAH's for both baseline and TDF tests.

FIGURE 4-15

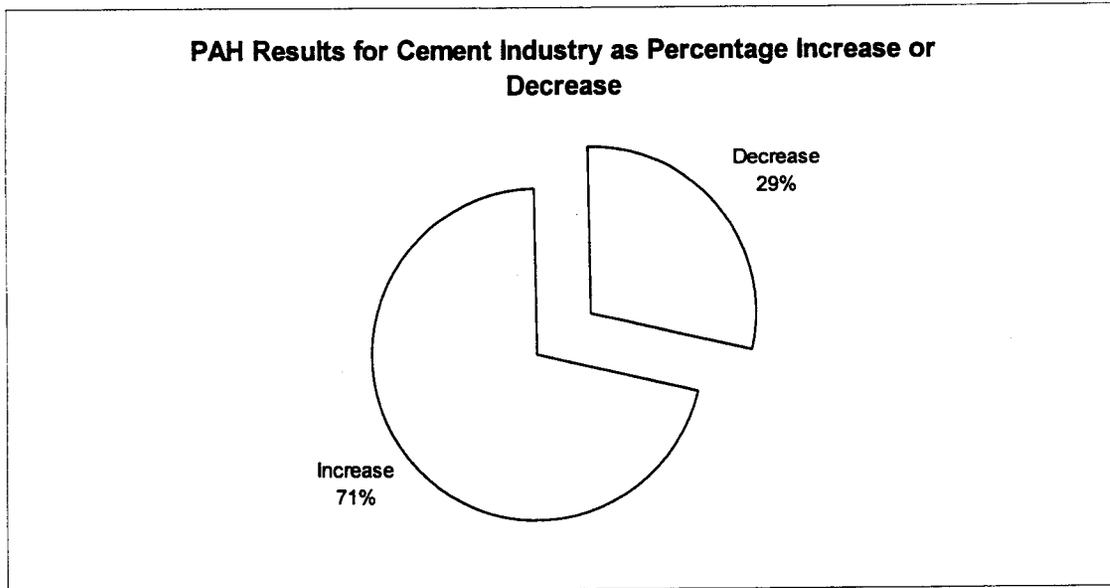


TABLE 4-7

Maximum and Minimum Reported Emissions for PAHs

Compound	Units	Baseline Results		TDF Results	
		Max	Min	Max	Min
Benzo(a)anthracene	lbs/hr	1.52E-03	4.08E-07	6.48E-04	7.87E-07
Benzo(a)pyrene	lbs/hr	1.26E-03	9.90E-08	1.84E-03	5.31E-08
Benzo(b)fluoranthene	lbs/hr	2.04E-03	7.86E-08	7.73E-04	2.80E-07
Benzo(k)fluoranthene	lbs/hr	2.16E-03	1.51E-06	5.29E-05	2.31E-07
Dibenzo(a,h)anthracene	lbs/hr	5.32E-05	4.20E-08	2.94E-04	4.10E-08
Indeno(1,2,3-cd)pyrene	lbs/hr	6.62E-05	3.10E-08	3.37E-04	3.50E-08
Total PAHs	lbs/hr	6.97E-03	3.23E-07	2.62E-03	3.56E-07

4.3.7 PCB Results

Polychlorinated biphenyls (PCBs) are also chemically classified as halogenated aromatic hydrocarbons similar to PCDDs and PCDFs. Certain of the PCBs are structurally similar to the PCDDs and PCDFs and are generally agreed to produce dioxin-like toxicity.

Analysis of TDF Emission Results

Six facilities representing seven test conditions reported PCB data. Three of these facilities represented cement manufacturers. Generally, PCB emission rates showed the same trend as the PAH data, however, the emission are generally a factor of 10 lower. Mean baseline PCB emission rate was calculated at 2.94×10^{-6} while the overall TDF emission rate was estimated at 4.29×10^{-6} . The data also indicated that the degree of agreement was not as strong as the PAHs, with a correlation coefficient of 0.73. Again the variability between various facilities were high.

4.4 ASH RESULTS

Ash can come from three sources: (1) material left after combustion (bottom ash), (2) material removed from a control device such as an electrostatic precipitator (fly ash) or baghouse, and (3) scrubber waste. Cement kilns generally have no ash from combustion, as the material is incorporated into the final product, clinker. Dust from the control device is generally fed back into the process (recycled dust).

Collected data on ash are provided in Appendix A. Results were reported from five facilities, with several facilities reporting results from different tests or locations. Most of the reported results deal with metal concentrations. Metals can not be destroyed by combustion, they will either be emitted as fumes or as particulate matter or they will be captured in the ash, control device waste or scrubber waste.

Some energy facilities reported higher zinc concentrations (3,520 mg/kg) from tire derived fuel than from baseline conditions. Others reported higher aluminum (6,400 mg/kg), calcium (10,300 mg/kg), and iron (3,490 mg/kg) in their bottom ash and higher aluminum (69,100 mg/kg), calcium (6,500 mg/kg), iron (1,360 mg/kg), potassium (1,100 mg/kg), and zinc (1,936 mg/kg) in their scrubber waste when using tire derived fuel. They also reported a reduction in aluminum (-1,200 mg/kg), iron (-1,200 mg/kg), sodium (-13,500 mg/kg) in their electrostatic precipitator fly ash while concentrations of calcium (7,700 mg/kg), and zinc (14,500 mg/kg) went up for tire derived fuel.

Overall, the mean metal concentration within the ash was 954 mg/kg for the baseline data. For the TDF test results, the overall mean metal concentration within the ash was 2003 mg/kg. It should be noted that there was poor correlation between the baseline and TDF data sets, having a correlation coefficient of 0.51, indicating that many of the metals tested did not show increases in concentrations.

5.0 RELATIVE RISK

5.1 POTENTIAL OF RISK OF TDF VERSUS WITHOUT TDF

The EPA's Science Advisory Board (SAB) and the National Academy of Sciences have promoted the use of quantitative risk assessment in regulatory decision making (NAS, 1994; SAB, 1995). Some groups question the use of risk assessment because of its assumption that a certain amount of risk is acceptable.

In attempting to compare risks of using TDF as opposed to baseline operations, a simplified comparison of baseline versus TDF data was performed using unit risk and toxic equivalent factors (URF's and TEF's). While some of the reports did contain references to risk assessments, the majority of the reported data did not have associated risk assessments. Using the assumptions that all of the parameters used in a risk assessment are the same for the baseline condition and the TDF condition and that the only difference is the emission rates, a relative comparison of the potential for risks can be performed. Appendix I shows this analysis for the carcinogen list.

Figure 5-1 shows a comparison of TDF versus baseline relative potential for risks for the facilities that had both. Again, the calculated numbers are proportional to the potential for risk and are valuable only in comparing a same facility under different test conditions. Comparison between facilities can not be made because of the different site-specific conditions. What can be seen by this analysis is that there is little difference between TDF and baseline conditions on the contribution to the potential for risk. This can be seen better in Figure 5-2, which subtracts the TDF factor from the baseline factor. There is no discernable trend either positive or negative in the use of TDF.

FIGURE 5-1

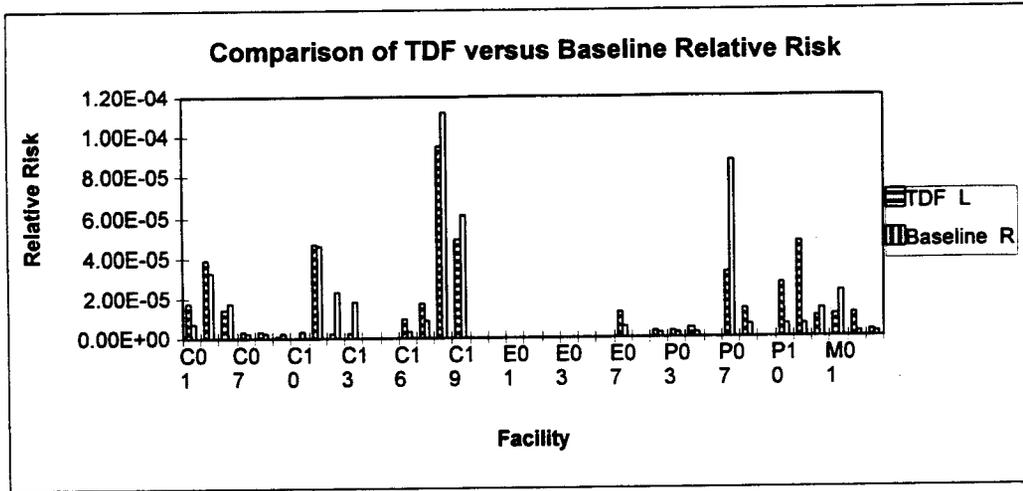
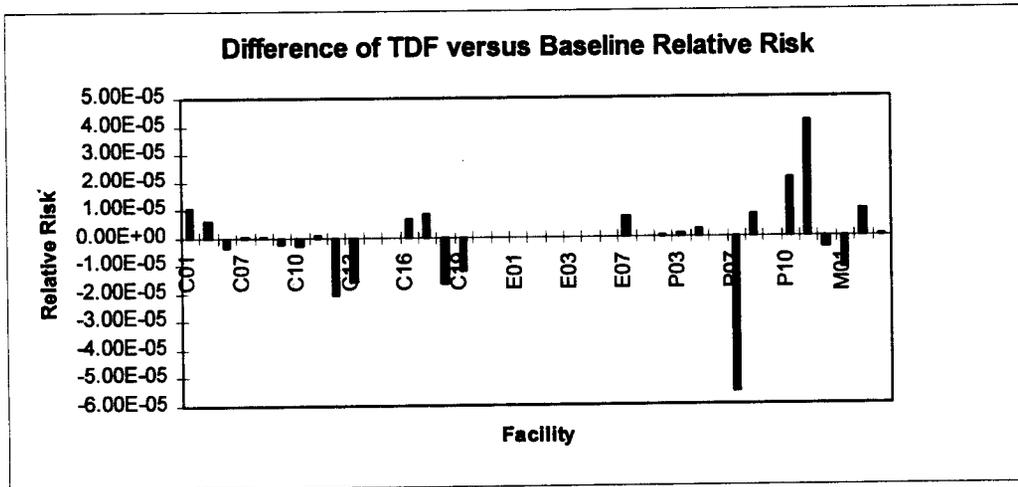


FIGURE 5-2



5.2 RELATIVE RISK POTENTIAL CONTRIBUTION COMPARISON

Carcinogenic data were examined for twenty-seven facilities involving thirty-nine test sets for the major chemical risk contributor. Normalizing the relative risk potential factors to 100%, the major risk potential contributors in baseline conditions were compared to TDF conditions. (Contributions less than

Analysis of TDF Emission Results

5 percent for individual compounds was classified and summarized in the miscellaneous category.)

Table 5-1 shows this major baseline and TDF risk potential contributions.

TABLE 5-1
Relative Potential for Risk Contributions
(Percent)

Compound	Cement Industry		Energy Industry		Pulp and Paper		Misc Industries	
	Baseline	TDF	Baseline	TDF	Baseline	TDF	Baseline	TDF
Hex Chromium	-	9.1	-	16.7	88.4	95.6	-	-
Cadmium	-	20.9	15.3	57.8	-	-	68.6	96.5
Benzene	8.1	40.6	37.2	-	-	-	-	-
PCDF	-	9.5	-	-	-	-	-	-
Lead	-	-	-	11	-	-	31.4	-
Nickel	-	-	5.1	-	-	-	-	-
Arsenic	-	6.2	-	5.4	-	-	-	-
Carbon Tetrachloride	-	-	12.9	-	-	-	-	-
Formaldehyde	-	-	7.5	-	-	-	-	-
Vinyl Chloride	-	-	9.6	-	-	-	-	-
Total PCBs	84.4	-	-	-	-	-	-	-
Miscellaneous	7.5	-	12.4	9.1	11.6	4.4	-	3.5

Changes in percent contribution to risk potential between source groups are widely varying and there do not appear to be any consistent indicators associated with TDF fuels, although there are mean increases in risk potential from hexavalent chromium and cadmium during TDF testing in three out of the four categories. In addition, risk potential from arsenic increased during TDF testing in two of the four categories. However, it is not clear that these compounds would be inherent within the TDF fuels and may likely be due to base fuel.

In summing the overall risk potential from all sources within each category during baseline and TDF testing, there is no consistent trend in risk potential. Two of the four categories had decreased total risk potential during TDF tests (cement and miscellaneous) and the other showed significant increases from the TDF test results. The data do not show any similarities in risk contributions between sources.

6.0 CONCLUSIONS

In California, approximately 29.5 million passenger/truck tires were discarded in 1995 (CIWMB, 1996). Of these, 36.6% (10.8 million) were used as fuel, and 40.3% (11.9 million) were land filled, and the remaining 23.1% (6.8 million) reused or recycled. Tires in uncontrolled stockpiles or illegal dumps present problems of being breeding grounds for insects or for being a potential fire hazard. The California Integrated Waste Management Board has supported the use of tires as fuel but had concerns on the variability in emissions from facilities using tires as fuel.

This project examined baseline and TDF source test data from four main potential users of tires for fuel: (1) Cement Kilns, (2) Energy Services, (3) Pulp and Paper Plants, and (4) Miscellaneous. The data were examined for possible trends in emissions of carcinogens, criteria pollutants, dioxin/furans, metals, organics, PAH's and PCB's. Twenty-eight facilities submitted relevant source testing data.

In examining all of the data, an overall picture emerges of no statistically significant discernable pattern of impact on emissions through the use of TDF. Good combustion practices and proper operation of effective air pollution control systems seem to maintain emissions within a normal "range" of process and measurement methodology variation.

Scrubber control systems were not as effective as baghouses or electrostatic precipitators in controlling metal emissions, particularly zinc. Zinc is generally present in TDF in higher quantities than the replaced fuel due to the use of zinc oxide as an additive in the tire manufacturing process.

Carbon monoxide emissions tended to increase in facilities using TDF probably as a result of localized fuel rich zones. Conversely, oxides of nitrogen tended to decrease probably as a result of decreasing fuel bound nitrogen and cooler flame surfaces.

The submitted data varied in quality. In some cases, baseline comparison data were performed in a completely different time period for different purposes. Detection limits between baseline and TDF conditions varied considerably in certain cases.

7.0 REFERENCES

BAAMQD, 1996. CEQA Guidelines - Assessing the Air Quality Impacts of Projects and Plans, Bay Area Air Quality Management District, April 1996.

CAPCOA, 1993. *Air Toxics "Hot Spots" Program Risk Assessment Guidelines*, California Air Pollution Control Officers Association, October 1993.

CARB, 1996. *Draft Toxic Air Contaminant Identification List Summaries*, California Air Resources Board, January 1996.

CARB, 1990. *Toxics Emission Inventory for Mobile, Area, and Natural Sources - 1989*, Technical Support Division, Toxics Emission Inventory Section, California Air Resources Board, May 1990.

CIWMB, 1992. *Tires as a Fuel Supplement: Feasibility Study*, California Integrated Waste Management Board, Publication No. 401-93-001, January 1992.

CIWMB, 1996. *Tire Recycling Program 1995 Annual Report*, California Integrated Waste Management Board, Publication No. 432-96-042, May 1996.

Cooper, C. D. and Alley, F. C., 1994. *Air Pollution Control: A Design Approach*, Waveland Press, Inc.

EPA, 1995. *An SAB Report: A Second Look at Dioxin*, U. S. Environmental Protection Agency, Science Advisory Board (SAB) 1995.

EPA, 1993. *Scrap Tire Technology and Markets*, U.S. Environmental Protection Agency, Office of Solid Waste, Clark, C., Meardon, K, Russell, D., 1993.

EPA, 1991a. *Burning Tires for Fuel and Tire Pyrolysis: Air Implications*, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, EPA-450/3-91-024, December 1991.

Analysis of TDF Emission Results

EPA, 1991b. *Markets for Scrap Tires*, U.S. Environmental Protection Agency, Solid Waste and Emergency Response, EPA/530-SW-90-074B, September 1991.

EPA, 1989. *Analysis of Air Toxics Emissions, Exposures, Cancer Risks and Controllability in Five Urban Areas, Volume I - Base Year Analysis and Results*, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, EPA-450/2-89-012a, July 1989.

EPA, 1985. *Compilation of Air Pollution Emission Factors, AP-42 Fourth Edition*, U.S. Environmental Protection Agency, Office of Air and Radiation, EPA PB86-124906, September 1985.

Godish, Thad, 1991. *Air Quality, Second Edition*, Lewis Publishers.

Kindzierski, W. B. and Fok, N. M., 1994. "Burning Scrap Tires in Cement Kilns: Should We Be Concerned About Hazardous Air Pollutants?", *Proceedings From the Air & Waste Management Association 87th Annual Meeting & Exhibition, Cincinnati, Ohio, 1994*.

NAS, 1994. *Science and Policy in Risk Assessment*, National Academy of Sciences, 1994.

NTP, 1994. *7th Annual Report on Carcinogens*, National Toxicology Program of the U.S. Public Health Service, 1994.

Schrama, H., Blumenthal, M., and Weatherhead, E. C., 1995. "A Survey of Tire Burning Technology for the Cement Industry," *Proceedings From the IEEE Cement Industry Technical Conference, San Juan, Puerto Rico, 1995*.

Schwartz, J. W., Jr. "Engineering for Success in the TDF Market", *Proceedings From the Recycling Search Institute Scrap Tire Processing and Recycling Seminar, West Palm Beach, FL, 1989*.

Williams, P. L. and Burson, J. L., 1985. *Industrial Toxicology, Safety and Health Applications in the Workplace*, Van Nostrand Reinhold