

PD-ABS-403



WORLD ENVIRONMENT CENTER

TRIP REPORT

**AKMENES CEMENTAS
AKMENE, LITHUANIA**

**Environmental/Waste Minimization Assessment
January 16-25 1994**

**WORLD ENVIRONMENT CENTER
419 Park Avenue South, Suite 1800
New York, N.Y. 10016**

September, 1994

41'

Disclaimer

The opinions expressed herein are the professional opinions of the author and do not represent the official position of the Government of the United States or the World Environment Center. This report contains confidential information regarding an industrial enterprise and therefore is not for distribution.

CONFIDENTIAL - 2'

DISTRIBUTION

James D. Taft, Senior Environmental Specialist, Bureau for Europe and New Independent States, United States Agency for International Development

John Cloutier, USAID Representative, Vilnius, Lithuania

Patricia A. Swahn, Acquisitions Manager, Document Acquisitions, United States Agency for International Development

Antony G. Marcil, WEC

George Carter, WEC

Thomas J. McGrath, WEC

Romuald Michalek, WEC

Gretchen Mikeska, WEC

Jonas Kapturauskas, WEC Coordinator, Lithuania

Frank C. Stevens, Stevens Consulting Co.

Charles W. Fox, Fox Manufacturing, Inc.

(2) File

TABLE OF CONTENTS

- I. Introduction
- II. Executive Summary
- III. Appendix A - Frank C. Stevens - Report of Akmenes Cementas
- IV. Appendix B - Additional Technical Information

I. INTRODUCTION

Pursuant to the technical assistance program for Central and Eastern European countries funded by the United States Agency of International Development, the World Environment Center (WEC) team conducted on January 16-25, 1994 an environmental/waste minimization assessment of Akmenes Cementas (Akmenes) in Akmene, Lithuania. During that visit, waste minimization opportunities were identified for Akmenes and equipment and process modifications were recommended by the WEC team.

II. EXECUTIVE SUMMARY

On January 16-25, 1994, the WEC team consisting of Frank C. Stevens and Charles Fox visited Cementas Akmenes (Akmenes) located in Akmenes, Lithuania. The purpose of the visit was to assess Akmenes' operations and production of products (primarily cement) and generation of waste materials and emissions, in order to identify waste minimization opportunities. The WEC team visited and made preliminary assessments of Akmenes concrete products plants, steam generation plant (used for heating the Plant and the town of 15,000 people), the Akmenes Lime Plant, and the quarry for Akmenes Cement. They also visited lime and building materials plant of Venta Building Materials, located near the town of Akmenes.

Built in 1952, Akmenes Cement Plant (Akmenes) uses the wet process system for the manufacture of cement. This is a complex process, requiring a large capital investment and is labor intensive in production and maintenance of equipment. Under Russian standards, plant labor, fuel, and maintenance costs were considered average, however, Akmenes is not currently competitive when compared to Western European standards. Capital investments are required to update Akmenes, which has not been modernized since its opening.

The most significant problem for Akmenes is the lack of a cement market for its product since the former Soviet Union stopped buying the full output of the Plant. During 1990, the production and sale of cement was 3,350,000 tons annually which is the full output of the plant. In 1993, the output of the plant was reduced to 726,900 tons (22 per cent of full production), utilizing only 1.8 kilns out of a possible 8 kilns. In order to be competitive with other cement producers outside Lithuania, Akmenes must reduce operating cost by installing new equipment and introducing modern technology. The capital investment for a new low production cost cement plant will be at least \$100,000,000 U.S. and could range up to \$150,000,000 U.S., depending on inflation, equipment, and construction costs.

Akmenes also needs environmental monitoring equipment capable of measuring air flow in kilns and grinding systems, particulate emissions, and performing kiln exit gas analyses for oxygen, carbon monoxide, nitrogen oxides and sulfur oxides, such monitoring equipment would cost approximately \$350,000 U.S.

Other immediate capital requirements of Akmenes are for instruments and operating controls in the raw grinding cement kilns and cement grinding departments of the Plant, and for the equipment necessary for converting the fuel from oil to coal. (Russian oil currently costs \$70 U.S. per ton, where as coal from Poland and Russia cost approximately about \$30 U.S.) A capital investment summary follows:

- o Basic instruments and operating controls for grinding and kiln operations for two of eight kilns. Estimated cost is \$800,000 U.S. Payback period is less than two years
- o Updating and improving operation of 1 kiln and 1 cement grinding mill. Estimated cost is \$350,000 U.S. Payback period is less than 1.5 years.
- o Environmental testing equipment for emissions of gases and particulate. Estimated cost is \$350,000 U.S. Payback period is less than 1.5 years. Estimated cost is 3,000,000. Payback period is less than two years.
- o Coal, handling, pulverizing and kiln firing equipment and controls for two of the eight kilns. Estimated costs is \$8,500,000 U.S. payback periods - less than three years.

Payback periods for these capital investments are calculated based on improvement in production, better quality clinker and cement, improved environmental monitoring and control, and savings in fuel costs.

Another method for reducing fuel costs, while maintaining good production rates of clinker and cement, above standard quality of product, and improved and acceptable environmental emissions meeting the requirements of the Lithuanian Government, is the use of alternative waste fuels. Such alternative wastes include organic wastes from petroleum refineries, automobile and manufacturing plants; plants using coal, oil, and natural gas as the raw materials for their chemical products; and chemical plants using and producing organic materials. The cost of a system for handling organic wastes including, tires, agricultural products, and selected trash and garbage (organic) is estimated to be \$5,000,000 U.S. to \$6,000,000 U.S., with a payback period of less than 2 years. This capital investment will include kiln controls, environmental monitoring equipment, and will utilize the existing facilities of two large wet process cement kilns at Akmenes.

By comparison with other cement plants built in 1952, the WEC team found Akmenes to be clean and well-maintained, with good production rates, good quality cement, and acceptable environmental emissions, except in the case of particulate emissions which are more than twice the allowable level in Western Europe and the U.S. Akmenes has an excellent training programs for health and safety and welfare of the plant employees and their families that live in the town of Akmenes. Results will be further improved when the proposed capital improvements are implemented.

Following this initial assessment, Akmenes will be participating in WEC's Waste Minimization Impact Project.

7

III. APPENDIX A

Report of Frank C. Stevens, Stevens Consulting Co.

Environmental Waste Minimization Assessment For
Akmenes Cementas
Akmene, Lithuania

January 16-25, 1994

Table of Contents

Section 1 - Introduction

- 1.1 Background
- 1.2 Manufacturing Process

Section 2 - Observation and Recommendations

- 2.1 Plant Operations
- 2.2 Alternative Fuels
- 2.3 Environmental and Waste Minimization Action for Improvements
- 2.4 Health and Safety
- 2.5 Actions for Improvements

Section 3 - Conclusions & Recommendations

Appendix B - Additional Technical Information

Section I

INTRODUCTION

World Environment Center (WEC), under an Agreement of Cooperation with Akmenes Cementas (Akmenes), signed December 13, 1993, agreed to complete an environmental/waste minimization of plant operations. The primary goal of the assessment was to identify opportunities for low cost activities which could provide environmental and economic benefits for Akmenes, and to familiarize plant personnel with assessments techniques and procedures. The assessment was completed by the following team:

- o Ms. Gretchen Mikeska, Project Manager of WEC, New York, N.Y.
- o Mr. Charles W. Fox, President of Fox Industries, Cottonwood, Arizona, Senior Consultant Volunteer Expert for Cement and Process Industries.
- o Mr. Frank C. Stevens, President of Stevens Consulting, Yucaipa, California, Senior Consultant Volunteer Expert for Cement and Process Industries.
- o Mr. Simonas V. Anuzis and Mr. Algimantas Mituzas, Director and Technical Director, respectively, of Akmenes, Akmene, Lithuania.
- o Dr. Jonas Kapturauskas, WEC Country Coordinator, Vilnius, Lithuania.

WEC's assistance to Akmenes will continue through Akmenes participation in WEC's Waste Minimization Impact Project (WMIP) for Lithuania.

The WMIP commences with a waste minimization workshop (May 24-27, 1994), attendance by Akmenes personnel at the Institute of Electrical and Electronics Engineers (IEEE) 1994 Cement Industry Technical Conference, and visits to the U.S. cement plants (May 30 through June 4, 1994). Further study and the methods for financing will be continued through 1994 and early 1995.

1.1 Background

Akmenes Cement plant and facilities were built by the former Soviet Union in 1952; an expanded plant was completed in 1972. The plant was situated in Akmenes because of excellent raw materials, skilled work force, availability of USSR fuel and electricity, the need for cement in Lithuania, export access eastward to the former Soviet Union, and the excellent work ethic of the Lithuanians.

In addition to the annual production of up to 3,350,000 tons of cement, Akmenes has facilities for making numerous concrete products and generates steam for heating of the Plant and the town of Akmenes. The Cement Asbestos Products Plant, which currently produces asbestos sheeting and pipe, is changing from asbestos-based products to a mineral and cellular fiber based cement products. (Asbestos is no longer used because of health problems.) Akmenes maintenance shops manufacture metal products for other industries and businesses throughout Lithuania. The supply of fuel oil from the former Soviet Union and maintenance parts for repairs of Akmenes equipment have been very costly and only sporadically available, due to the increasing difficult political climate between Lithuania and Russia since the independence of Lithuania in 1991.

When the former Soviet Union took over Lithuania in 1940, almost one million Lithuanians were killed. The population today, is about 3,700,000 people. The citizens work very hard, primarily in agriculture, farming, and animal raising as their main source of income. Lithuania is slowly changing to an industrial services economy. The environmental outlook is very good, with compliance to Western standards a goal of Lithuanian government officials. Large enterprises, such as Akmenes, are generally in need of financial assistance in order to be competitive in world markets. Outside investments are required.

While the WEC team was at Akmenes in January 1994, the Plant exported 3000 tons of high grade cement to Sweden which was then shipped to Africa. Akmenes is also pursuing other export markets. The plant management is doing an outstanding job of maintaining jobs for employees who have no other source of income.

Akmenes is now 52 per cent privately owned, and is controlled by employees operating and managing the company and plant. The Lithuanian government and of the private investors have a 48% minority investment without control. With financial assistance, the Akmenes management, technical and engineering, supervision, and plant employees are competent with a good work ethic, and are capable of operating a clean, well-maintained, environmentally acceptable, and profitable plant that is needed in Lithuania for its development and economic strength in the free world.

1.2 Manufacturing Process

Akmenes uses the wet process for grinding and blending of raw materials (limestone and clay). These raw materials sent to long rotary kilns equipped with chains at the feed end to dry and preheat the raw materials, and a fuel oil burning system at the discharge end of the kiln to supply heat for clinkering the kiln feed into cement clinker at 1450°. The clinker, after cooling, is ground with 5 per cent gypsum into a fine powder called cement. Cement is reactive with water, sand, and crushed stone and forms concrete - the basic building material for all types of construction, homes, infrastructure, buildings, highways, concrete products, and factories. The process requires about 140 KWH of electricity per ton of cement and 1600 kcal per kg of clinker produced in the kiln. The equivalent fuel oil use is 160 kg per ton of clinker produced. For the 3,000,000 tons of annual production, approximately 1800 employees are required.

Raw material sources are generally located near the Plant and are owned by private Lithuanian companies. Since all of the equipment was engineered and manufactured by former Soviet companies which are no longer available to Akmenes, the Plant is salvaging parts from idle equipment, while developing other sources of supply, including fabricating equipment in their own shops.

Most of Akmenes plant kiln dust is collected and returned to the system. Sanitary waste water from the Plant is recycled for cooling purposes. Effluent from the town's water treatment plant is in compliance with government standards, and is recycled to Akmenes where it is used to make raw material water slurry. This slurry, containing up to 40 per cent water, is the raw feed for the cement kilns.

When economic conditions improve in Lithuania and a market develops, for cement exports to countries of Eastern Europe and Western Europe, Akmene's annual production is projected to be 2,500,000 tons per year.

Akmenes does not have any electronic equipment controls or instruments which are needed for production, maintenance, laboratory, equipment operation, and office functions. Environmental instrumentation are also urgently needed.

Akmenes product quality is superior, considering their lack of instrumentation and that the processing of materials (from quarry, crushing, blending, clinkering, cooling, cement grinding, to the cement storage and shipping) is very complex. The process of making cement and the equipment required are presented in Appendix.

Details of Akmenes, statistics, product composition, manpower, organization, environmental information, government standards, training, and health and safety programs, are presented in Appendix. A flow chart of the process is provide in Appendix B-2.

Section 2

OBSERVATIONS AND RECOMMENDATIONS

2.1 Plant Operations

Akmenes staff was very willing and eager to assist the WEC team in the assessment, answered all our questions, complied with our requests, and were willing to listen to our advice. Information supplied to the team and not presented in the body of this report, is presented in the Appendices.

Although Akmenes' equipment is old, dating back 20 to 45 years, it is well operated, maintained, and kept clean. Managers and department heads are aware of technical developments in the cement industry, but lacked funds to travel to seminars, make plant visits, and/or purchase technical literature. Through constrained by limited funds and lack of up-to-date technical information and equipment, Akmenes has optimized their production process within the limitations of their equipment. Plant personnel are proud of these improvements.

Plant water supply is adequate. The Plant receives fresh water from near-by wells and process water from the wastewater treatment plant, which is operated by the plant for the town of Akmene.

Electric power is obtained from a Soviet-built nuclear power plant, located near Lithuanian's border with Belarus. When possible, the plant uses off-peak power to save on electrical power costs and balance the power plant load.

Akmenes uses some iron ore mixed with the limestone and clay to optimize the chemical composition and burnability of the raw materials in the kiln to clinker. Gypsum is added to clinker at a rate of 5 percent to control the setting and hardening rate of the cement. Pozzolan is also used as a cement mixture, with additions of up to 30 per cent to the clinker and gypsum and ground to a fine powder for suitable pozzolan cement.

In Appendix B-4 is a copy of the brochure entitled "Akmenes Cement", written in Lithuanian, English, and German. This is filled with excellent history, operations, data, and interesting features of the Plant.

2.2 Alternative Fuels

As previously described, Akmenes uses the wet process for handling raw materials and feeding the kiln, which requires a higher fuel usage (1600 K cal per kg. of clinker versus modern kiln that uses 50 per cent less fuel). Akmenes can reduce its fuel costs by 50 per cent by using coal instead of the high price fuel oil from the former Soviet Union. With the addition of alternative waste fuels replacing up to 50 per cent of the fuel, whether it is oil or coal or both, fuel cost could be negligible, considering the income that the generators of waste fuel would pay Akmenes when this market develops.

At the present time, Akmenes is paying fines for excess emissions of carbon monoxide (CO), sulfur oxide (SO₂), and nitrogen oxides (NO_x). Using good kiln instrumentation and controls, emission monitors for kiln exit gases, and low NO_x burners, emissions of these gases would be reduced considerably. Such instrumentation and control would also make it feasible and safe for Akmenes to use alternative fuels (coal and waste organics). Not only would Akmenes benefit from less expensive fuel supplies, but existing waste stock piles generated from Lithuanian industry could be reduced.

Many wet process plants in the United States and other countries have been incinerating wastes safely, improving the environment, and lowering operating costs since 1975. The publication "All Fired Up" (see Appendix B-5) states that burning of organic wastes results in the following benefits.

- o energy recovery from combustible wastes,
- o conservation of fossil fuels such as coal and oil,
- o reduction in cement production costs, and
- o destruction of hazardous organic wastes.

This publication is considered by many cement industry experts to be the best and most authoritative text on the subject.

2.3 Environmental and Waste Minimization

The gaseous (CO_x, NO_x and SO₂) and particulate emissions from the kiln systems in Akmenes are considerable less than most of the cement plants in Eastern Europe, primarily because the Plant has well-maintained equipment.

The dust collection for raw materials, crushing and grinding, clinker production and handling, and cement grinding processes are adequate. However, particulate emissions from the cement kilns following electrostatic precipitation is more than twice the allowable level in Western Europe and United States.

Gaseous emissions from the kiln system are similar to those in other cement plants in Western Europe and United States, and contain constituents similar to a properly operated fuel-fired electric power steam generation plant. Emissions can be reduced to acceptable levels by installing instrumentation and process emission controls. The electrostatic precipitators, which collect dust from material handling systems, kilns, and grinding systems, can be made more efficient by enlarging electrode plates, adding modern electron emitting electrodes and better high voltage supplies and insulators, and by optimizing precipitator control. With outside financing, these improvements can be implemented, and will result in a cleaner environment, higher production rates, and lower operating costs.

As previously described, water for the wet process section of Akmenes is supplied by the effluent from the Plant and the town's water treatment plant. Electrical power usage could be reduced in the Plants grinding and handling systems, but only with a large capital expenditure. Currently, this is not a critical use of capital, as the cost of electricity from the nearby nuclear power plant is about two cents U.S./KWH, as compared with higher electric costs in other parts of Europe. However, electric power use is becoming critical, as poorly built Soviet nuclear power plants are shut down and the power costs continue to increase. The cost for reducing electric power costs and the payback will be estimated during Akmenes WMIP.

Man-hours required to produce a ton of cement are several times higher at Akmenes than in western Europe and United States where plants are more modern. The average labor cost is the equivalent of \$100 U.S. per month per employee, based on 4 litas per U.S. dollar. Man-hours could be reduced with a new modern plant, which would require a very large capital investment. Considering unemployment in Lithuania and other manpower intensive projects providing Akmenes with both economic and environmental benefits, these expenditures can not be justified at this time.

2.4 Health and Safety

Akmenes has a written and enforced environmental policy and health and safety policy. Each employee receives 30 hours of safety training. Each year, about 200 new employees are trained and about 350 workers improve their qualifications. Approximately 110 technologists and engineers improve their professional qualifications and safety engineering each year. Supervisory and management personnel receive training and specialized instruction when available and required.

The Department of Labor is in charge of the worker's medical examinations, safe labor working conditions, and environment measurements such as noise, vibration, dust, air and lighting conditions throughout the Plant.

2.5 **Actions for Improvements**

For employees and their families, there is a good health protection plan with doctors and nurses. The Plant also has six remote resort locations that operate from June through August for workers' rest, relaxation and rehabilitation. In the Plant, there is an excellent sports palace and large swimming pool. However, these health and welfare services that benefit all employees need updating, including new equipment, latest training procedures and manuals, updated medical and laboratory instruments and procedures.

Environmental testing equipment is needed for field and laboratory, as it is practically nonexistent at the Plant. Immediate needs will cost about \$350,000.

Kilns and grinding mills require new instruments and controls, plus updating the clinker coolers, kiln chain systems, precipitators and the electrical and electronic systems in the grinding mills and kilns. The minimum cost for updating one kiln and one cement grinding mill is estimated to be \$3,000,000.

We recommend that at least two and up to four of the larger kiln systems be converted to coal firing and waste fuel firing. The estimated cost is about \$8,500,000 U.S. for 2 kilns. The payback on this conversion to alternative fuels is less than two years.

Plant management has previously considered these improvements and is capable of implementing them, with western technical assistance and funding.

Section 3

CONCLUSIONS AND RECOMMENDATIONS

In summary, the assessment of Akmenes Cementas follows:

- o Akmenes is vital to the economy and welfare of Lithuania. Cement is the basic building material for homes, buildings, industries, and infrastructure. The plant and country need immediate money infusion. Capital for the improvements previously described are necessary for securing Akmenes position in the competitive western cement market.

Capital for the improvements previously described are necessary for securing Akmenes' position in the competitive western cement market.

- o Lithuanians are diligent hard working, intelligent, and are very capable and able to make the needed improvements.
- o The kiln system needs improvements that will result in a cleaner environment and lower costs, with higher production rates. Priority for the capital investments are as follows:

1.	Emission testing equipment	\$ 350,000 U.S.
2.	Basic instruments and controls for two kilns	\$ 850,000 U.S.
3.	Coal burning for two of eight kilns	\$8,000,000 U.S.
4.	Waste fuel system for four kilns	\$5,500,000 U.S.
5.	Updating and improving operation of 1 kiln and 1 cement grinding mill	\$3,000,000 U.S.

While money is being obtained for this list of 5 capital investments, the following no cost/low cost equipment should be purchased:

- o Provide technical literature, seminars, and direct training for upgrading Plant operations and management know-how.
- o Obtain at least five personal computers and programs for Plant use.
- o Initiate a program for completing studies and justifying capital investments.

- o Following a second Plant visit during Autumn 1994, present this report to the World Bank and USAID.

- o Continue work with WEC's WMIP which includes a Waste Minimization Workshop (May 24-27, 1994, in Palanga, Lithuania) and a cement industry tour in the United States, May 29 through June 5, 1994.

APPENDIX B

Additional Technical Information

- B-1 Charles W. Fox Report of Visit to Akmenes Cementas, January 16-25
- B-2 Business Cards of Contacts
- B-3 Technological Scheme of Akmenes Cementas
- B-4 Akmenes Cementas Organizational Chart
- B-5 Overview of Akmenes Cementas
- B-6 All Fired Up - Burning Hazardous Waste in Cement Kilns
- B-7 Cement Kilns for Hazardous Waste Disposal
- B-8 Hazardous Waste Incineration: The Cement Kiln Option
- B-9 EPA's Draft Strategy for Combustion of Hazardous Wastes

Appendix B-1

Charles W. Fox Report of Visit to Akmenes Cementas, January 16-25, 1994

Plant Name/Address:

Akmenes Cementas
Dalinreviciaus 2
5464 Naujoji, Akmene, Lithuania

Contacts: Dr. Algimantas Mituzas, Technical Director
Tel. 370-95-54150,58634
Fax: 370-95-53301

Stock Company: 52% private and 48% Lithuanian Government

Translators: Dr. A. Mituzes, Technical Director
Julius Mituzes, Chemical Laboratory Equipment Engineer
Dr. Jonas Kapturauskus, WEC Country Coordinator, Lithuania

Complex Facilities: Engineered and constructed by former Soviet Union

Consists of: Cement Plant

Cement Asbestos Plant manufacturing pipe and siding. Presently
Presently being converted to cement-cellulose.

Line Burning Plant - Due to depressed building economy, plant
may be shut down.

Limestone Quarry - Reserves in excess of 50 years, 60 feet of
uniform quality limestone.

Effluent Water Treatment Plant - Built 1914 by the former Soviet
Union: Serves the Cement Plant and City of Akmene, (5,000
homes), central heating plant (Complex and City of Akmene)

Cement Heating Plant - Serves the Cement Plant and City of
Akmene

Cement Plant No. 1 - Wet Process, kilns Nos. 1-4, commissioned in 1952; consists of:

- 400 T/H jaw crusher (1)
- 175 T/H hammermills (2)
- 52 T/H, 2.4m x 13m raw grinding mills (2)
- 100 T/H, 3.2m x 15m raw grinding mills (1)
- 16 T/H, 6m x 127m rotary kilns with satellite coolers, Nos. 1-3 (3)
- 32 T/H, rotary kiln with grate cooler, No. 4 (1)
- 17 T/H, 2.2m x 13m cement grinding mills (3)
(2 compartment, no separators)
- 17 T/H, 2.4m x 13m cement grinding mills (2)
(2 compartment, no separators)
- 43 T/H, 3.2m x 15m cement grinding mills (1)
(2 compartment, no separators)

In 1990, Plant No. 1 produced 800,000 tons of clinker.

Cement Plant No. 2 -

- Wet Process, kilns Nos. 5-8, commissioned in 1972; consists of:

- 800 T/H jaw crushers (2)
- 800 KW hammermills (2)
- 140 T/H, 4m x 13.5m raw grinding mills (4)
- 72 T/H, 5m x 185m rotary kilns with grate coolers (4)
- 80 T/H, 4m x 13.5m cement grinding mills with separators (5)

Key:

T/H - tons/hour

(1) Number of units

KW - kilowatts

m - meters

Storage and Handling

Quarried limestone, clay and iron oxide, materials required for kiln feed are stored in covered open storage and are reclaimed by traveling bridge crane to bins feeding the raw mill where water is added for grinding kiln feed slurry.

Kiln product, clinker, is stored in silos. Plant No. 1 capacity - 25,000m³, Plant No. 2 capacity - 43,200m³.

Gypsum and puzzolin are stored in open covered storage and reclaimed by traveling bridge crane to bins for proportioning by feeders serving the cement grinding mills.

Preventative Maintenance Plant is clean and appears to be well maintained

Production

Operation costs:

	<u>% of total Operating Cost</u>
Raw materials	16
Energy	20
Wages	30
Repairs	12
Non production & other	16
Amortization	6
	<hr/> 100%

	<u>Clinker</u> (tons)	<u>Cement</u> (tons)
1990	3,057,510	3,359,000 (last year under former Soviet control)
1991	2,855,000	3,125,000
1992	1,366,495	1,484,804
1993	635,971	726,872 (300,000 exports)

Man Power

Production Employees	1,594
Nonproduction Employees	228
	<hr/> 1,822 (Total No. Employees Jan. 1994)

Staff Distribution:

Directors	7
Administration	102
Engineering and Technical	239
Workers	1355
Other	119

Energy Sources

Electrical power is received by 2,110KW transmission lines from Lithuanian Energy System. Power consumption is 140 KWH/ton of ton cement.

Fuel: heavy oil from refinery 55 kilometers from plant, or by rail car from Russia, is used to fire cement kilns, drier, lime kilns, and central heating plant. Cement kiln heat consumption is 1,500-1,600Kcal of clinker. Fuel oil costs range from \$52 to \$58 ton in summer to \$70/ton winter. Coal can be delivered for \$20/ton. Present plans are to convert No. 4 kiln to coal.

Cement Physical Properties

	<u>1 day</u>	<u>3 Day</u>	<u>7 Day</u>	<u>28 Day</u>
Tensile		4.9	6.6	9.2
Compression	18.3	26.5	46.3	58.7
Blaine	4663			
Init. Setting	185 mins.			
W/C	0.5			
H ₂ O	28.4			
SO ₃	2.0			
Expansion	0.0			
Liter Weight	1019			

Water Sources and Treatments:

During full cement plant production in 1991, water consumption was $2.6 \times 10^6 \text{m}^3$. In 1991, the City of Akmeine used $3.0 \times 10^6 \text{m}^3$ of water. Water is obtained from wells, the Agluome River, and a $2.0 \times 10^6 \text{m}^3$ capacity pond. Effluent water from Akmerie is mechanically and biologically treated at the $10.0 \times 10^6 \text{m}^3$ capacity treatment plant. The treated water is returned to the cement plant and consumed in producing the slurried kiln feed.

Treatment facilities are in compliance with government requirements. The 300 tons/yr. of sludge produced is deposited as landfill.

Environmental Data

The plant has 96 sources of emissions.

Five sources are tested every three months by the Lithuanian Government for particulate, CO, NO_x and SO₂ emissions. They are:

- Plant No. 1 - Kiln Nos. 1, 2 and 3
- Plant No. 1 - Kiln Nos. 4
- Plant No. 2 - Kiln Nos. 5 and 6
- Plant No. 2 - Kiln Nos. 7 and 8
- Plant No. 2 - Clay Drier

During the last test, the following emissions exceeded government standards:

Nos. 7 & 8 Kilns - particulate and CO

Nos. 1 & 3 Kilns - particulate and SO₂

91 sources are tested for particulate emission only. During the last test, the following exceeded government standards.

Nos. 7 & 8 Clinker Cooler

Nos. 3 & 4 Cement Mills

All particulates collected are returned to process. None are wasted. There are 22 electrostatic precipitator dust collectors and the balance are cloth filter collectors. Age of collectors in range age from 1946-1972 and appear to be well maintained.

For the kilns, there are no instruments that permit the kiln operator to monitor the CO, O₂ and SO₂ emissions. Monitoring of CO and O₂ optimizes the air/fuel ratio. Reduced kiln gas volume leaving the kiln reduces particulate carry-out and improves precipitator efficiency. Fine penalties range from \$30,000 to \$40,000/yr.

Health and Safety

The Plant has a written environmental policy and a written health and safety policy. Each employer receives 30 hours of safety training per year. Each year, the Plant trains about 200 new workers and about 350 workers improve their qualification. Approximately 110 engineers and technologists improve their qualifications in their professional sphere as well as in safety engineering.

The Department of Labor Protection is in charge of the workers' check up, medical service, safe labor conditions and their control. This department measures the noise, vibration, dust and lighting levels.

Akmenes has a health protection system available to all workers. A doctor and six nurses take care of the patients at the Plant. In the City of Akmene, the Plant has a sanitorium with three doctors and 34 medical workers to take care of patients.

The Plant also maintains a 983m² sports palace with a 24m x 18m pool. The Plant has six remote resort locations that operate from June through August for workers' rest and rehabilitation.

Typical Chemical Analyses of Akme s Raw Materials and Products (%)

Constituents	Lime-Stone	Clay	Iron Oxide	Fuzz Olan	Raw Mix (Kiln Fired)	Clinker	Kiln Dust	Gypsum	Cement
SiO ₂	3.0	47.70	13.21	40.66	13.6	21.0	13.8		20.6
Al ₂ O ₃	0.14	13.90	8.28	1.42	3.4	5.3	4.6		5.1
Fe ₂ O ₃	0.74	5.97	70.02	0.99	1.1	2.8	2.1		3.6
Ca ^o	51.13	10.66	2.47	26.16	42.4	64.3	45.6	35.02	64.1
MgO	1.37	3.86	1.03	1.15	1.7	3.14	1.9		3.1
SO ₃	0.16	0.13	2.71	0.85	0.7	0.82	4.8	35.44	2.75
	41.08	16.02							
Na ₂ O							0.45		
K ₂ O							4.3		0.18
Free CaO							4.6		
S/R						2.70			
A/F						1.9			
Ca/SiO ₂						3.13			
C ₃ S						64.0			
C ₂ S						11.0			
C ₃ A						8.0			
CAF						8.0			
						0.32			
Tons (1991)	4,321,700	1,315,800	70,300	404,519		2,855,000			3,125,500

22

CW Fox
 Home 602-634-5876
 '02-634-4164

WEC
 Sponsoring

Imonė "DIEVYTA"

24 Jan 1994 Prof Umisvitytis
 Vilnius

Vytautas DIENINIS

CHEM. M. K. DIREKTORIUS

Rinktinės 13-151
 Vilnius 2051
 tel. 35 93 74 (d.)
 57

tel. 46 29 12 (m.)

Most of
 People WFS
 & CWF met
 in Lithuania
 during January
 1994

STEVENS CONSULTING CO.

13688 OAK MOUNTAIN DR., SUITE II
 YUCAIPA, CA 92399
 PHONE: (909) 790-4033
 FAX: (909) 790-4031

FRANK C. STEVENS
 PRESIDENT

X "Venta" Thursday 20 January 1994
 LEONAITIS Pranas, Jono (47 years)
 Direktorius Venta Building (Akmenės raj.)
 Akmenės statybinių medžiagų kombinatas
 5458 Akmenės
 370-954
 Td.: tarnyb. 39 531
 39 545
 52 491
 39 550
 Uostų fioms namų 39 550
 390-95
 VIRGINIJA 39974 - home
 Fax 390-95-39 588

X  EDMUNDAS KACKUS
 REDA DAGUŠINSKIENĖ
 26 Jan 1994 PROJECT MANAGEMENT SPECIALIST
 OF THE UNITED STATES
 AGENCY FOR INTERNATIONAL
 DEVELOPMENT
 Ph. 370 2 63 05 65
 370 2 22 30 31
 Fax: 370 2 22 27 79
 370 2 63 05 65
 A.I.D.
 Ciurlionio 66
 Vilnius, Lithuania

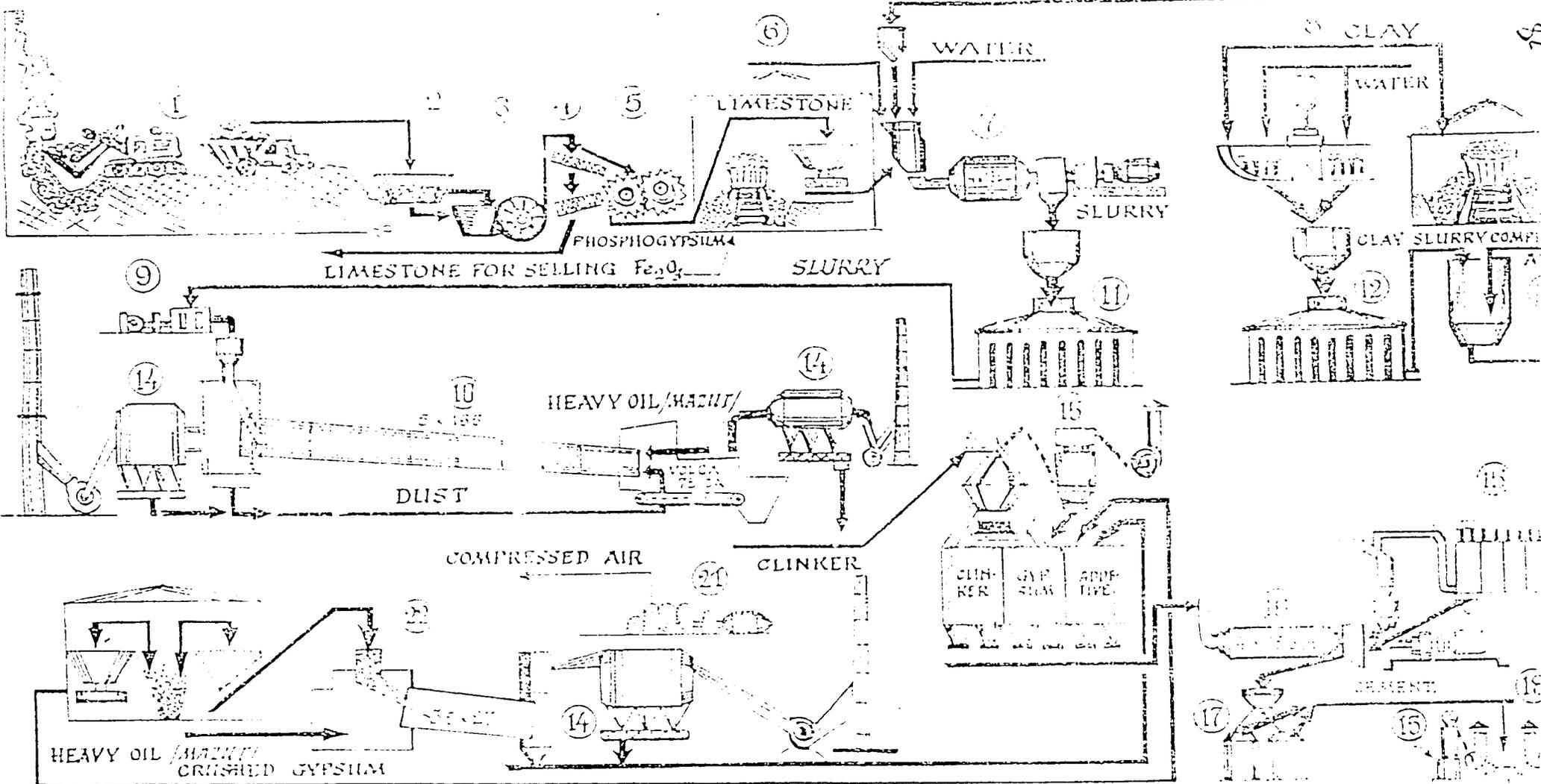
X  World Environment Center
 17 Jan '94 Regis J. J.
 DR. JONAS KAPTURAUSKAS
 COUNTRY COORDINATOR, LITHUANIA
 WORLD ENVIRONMENT CENTER
 410 PARK AVENUE SOUTH
 SUITE 1800
 NEW YORK, N.Y. 10016
 (212) 683-4700
 TEL 201 290-5500 EXT
 FAX (212) 683-5053
 SAULIŲ KĖDŪ
 2054 VILNUS LITHUANIA
 TEL 3702 470381
 PRIVATE
 ŽEMAIŠOS 5-9
 2022 VILNUS LITHUANIA
 TEL 3702 470381

X Frank C. Stevens 18 Jan 1994
 Lietuvos Respublika
 Государственное предприятие
 «АКМЕНЕС ЦЕМЕНТАС»
 СИМОНАС ВИТИС АНУЖИС
 Директор
 Домашний адрес:
 235464 г. И. Акмене
 Республикас 12-82
 телефон: 51 629
 Рабочая
 235464 г. И. Акмене
 телефон: 58 645
 54 140
 Факс (8 295) 5-2198
 SIMONAS VIKTIS ANUZIS

X Frank C. Stevens WEC
 18 Jan 1994
 ALGIMANTAS MITUZAS
 Valdybos narys
 Technikos direktorius
 AKCINE BENDROVE
 J. Dalinkevičiaus 2
 5464 Naujoji Akmenė
 tel. (8-295) 54150, 58634
 Faksas (8-295) 53301

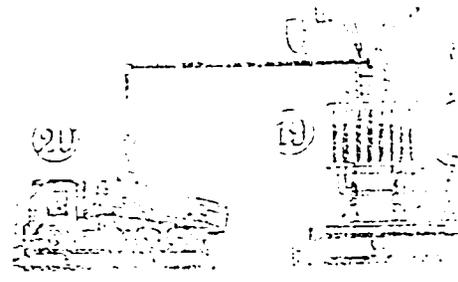
X  26 Jan 1994
 NORMAN K. WOLFE
 PROGRAM SPECIALIST
 USAID
 Ciurlionio g. 66
 2600 Vilnius
 tel.: (370-2) 660-566
 fax: (370-2) 222-779

X Environmental Protection Department
 of the Republic of Lithuania
 Judita Šukytė Board
 Head of Central Environmental Research
 Office:
 A. Juozapavičiaus 9,
 2600 Vilnius
 Lithuania
 Tel: (370-2) (01-22) 353 284
 Fax: (370-2) (01-22) 353 020
 (476-2) (01-22) 353 516
 Elex: 261 191 GAMTA SU
 Private
 Taikos 50-35,
 Vilnius
 Lithuania

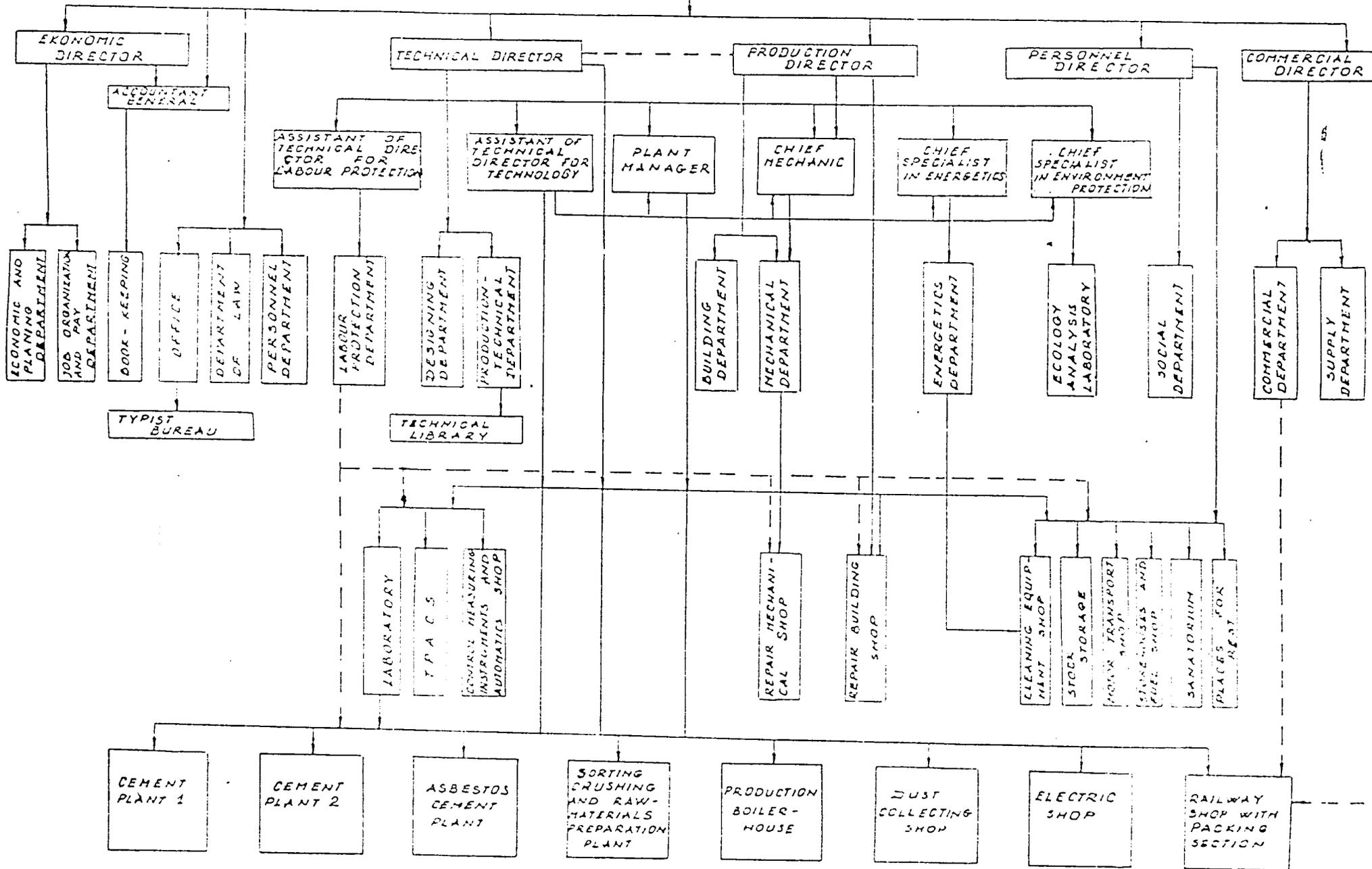


Technological SCHEME of cement production in state works Akmenis cementas

- | | | | |
|---------------------------|----------------------|---------------------------------|--------------------------------------|
| ① Quarry | ⑦ Raw mill | ⑬ Clay slurry dosing tank | ⑲ Cement dispatch by rail transport |
| ② Limestone receiving bin | ⑧ Clay washmill | ⑭ Electrical precipitation tank | ⑳ Cement dispatch by motor transport |
| ③ Jaw crusher | ⑨ slurry dosing tank | ⑮ Filter stocking | ㉑ Compressor |
| ④ Limestone sorting unit | ⑩ Rotary kiln | ⑯ Cement mill | ㉒ Additives dryer |
| ⑤ Hammer crusher | ⑪ Slurry basin | ⑰ Air pump | |
| ⑥ Limestone feeder | ⑫ Clay slurry basin | ⑱ Cement silo | |



DIRECTOR VYTIŠ ANUŽIS



AKMENĖS CEMENTAS

Lietuvos Respublikos valstybinė įmone

ŽMONĖS. METAI. DARBAS

17 December 1994 Frank C. STEVENS

AKMENĖ CEMENT

State Plant

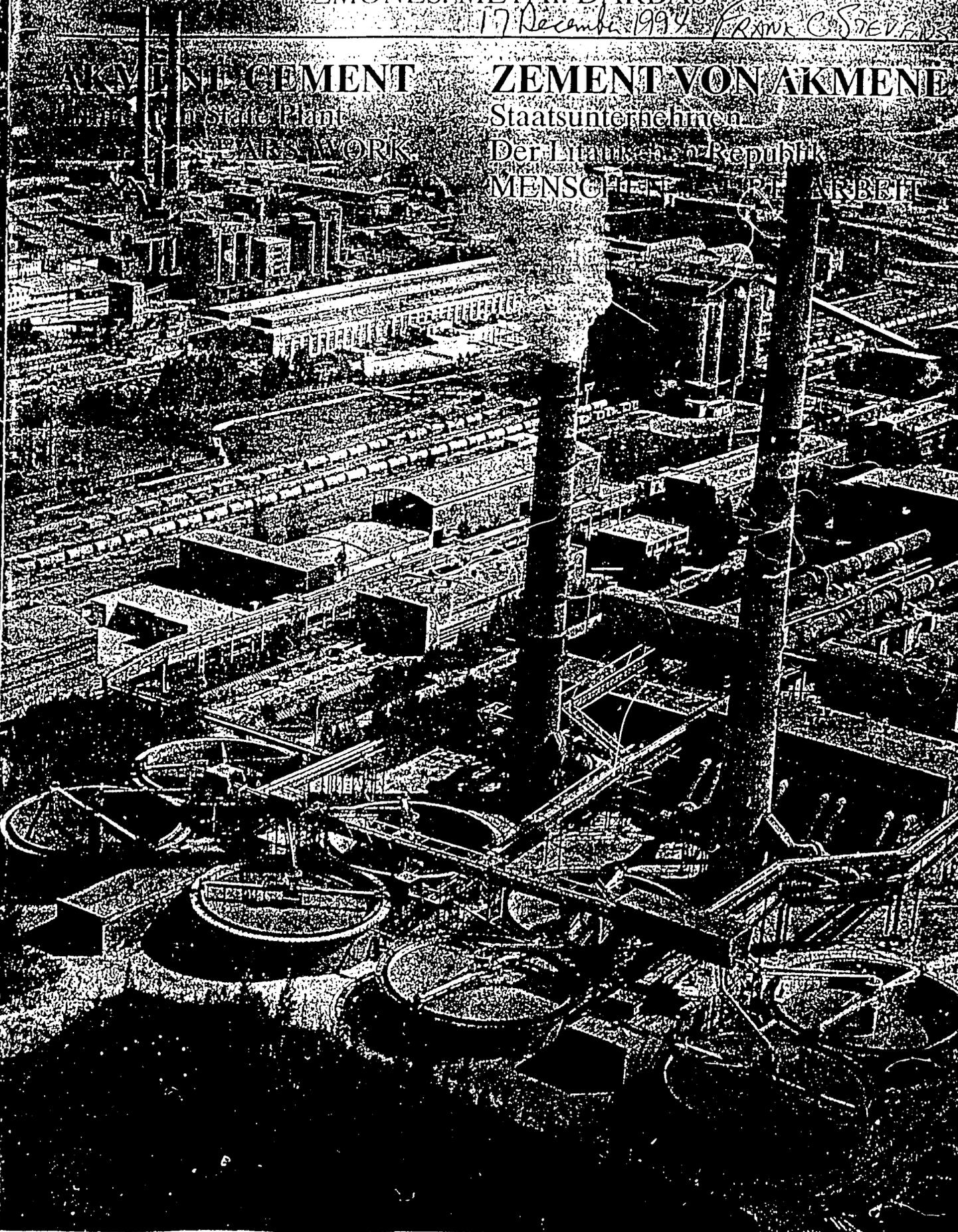
YEARS WORK

ZEMENT VON AKMENE

Staatsunternehmen

Der Litauischen Republik

MENSCHEN. ZEIT. ARBEIT



Lietuvos Respublika - sena, iš naujo atgimstanti valstybė, gražus kraštas rytinėje Baltijos jūros pakrantėje. Čia derlingi laukai, žydri ežerai ir upės, nedideli tvarkingi miestai. Gyvena čia darbštūs ir nuoširdūs žmonės, svetingi savo šalies šeiminkai.

Tokia Lietuva po penkių inkorporavimo į buvusią TSRS deimtmečių grįžta į pasaulio tautų šeimą. Ji nori ir siekia pažinti pasaulį ir jame pritapti, siekia, kad ir pasaulis ją pažintų.

Šis iliustruotas pasakojimas - apie vieną iš stambiausių ir stabiliausiai dirbančių Lietuvos statybinių medžiagų gamyklų - Akmenės valstybinę įmonę „Akmenės cementas“, esančią pačioje Lietuvos šiaurėje.

Įmonės produkcija padėjo atstatyti po II Pasaulinio Karo sugriautą Lietuvos ūkį, įmonės žmonių darbas įamžintas ne tik Lietuvos, bet ir kitų kraštų miestų pastatuose, kaimų sodybose.

Lithuanian Republic is an old and beautiful state near the Baltic sea going through the period of rebirth. One can see fertile soil, blue lakes and rivers, small neat towns here. There live diligent and sincere people in Lithuania who are well known for their hospitality.

Lithuania is coming back to Europe and to the family of the world nations after fifty years of Soviet incorporation. It is eager to know the world and to find its place there. At the same time Lithuania wants the world to know it.

Here is a story about one of the largest Lithuanian plants of building materials - „Akmenė Cement“. It is one of the most stable working plants, situated in Akmenė, in the north of Lithuania.

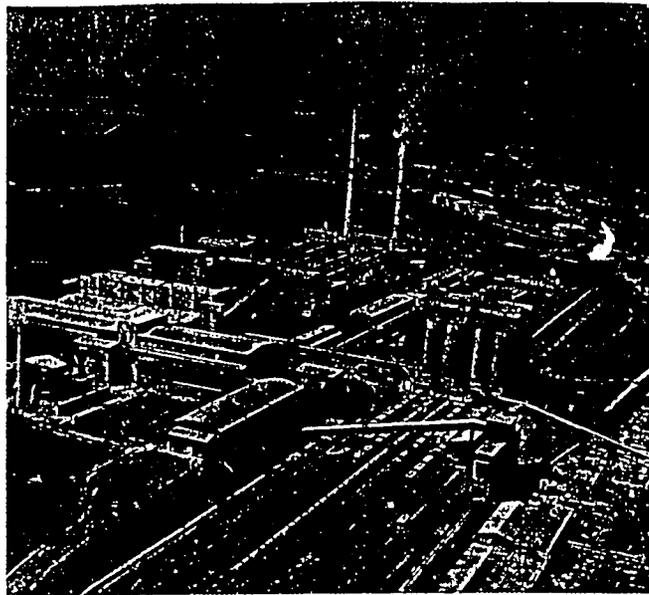
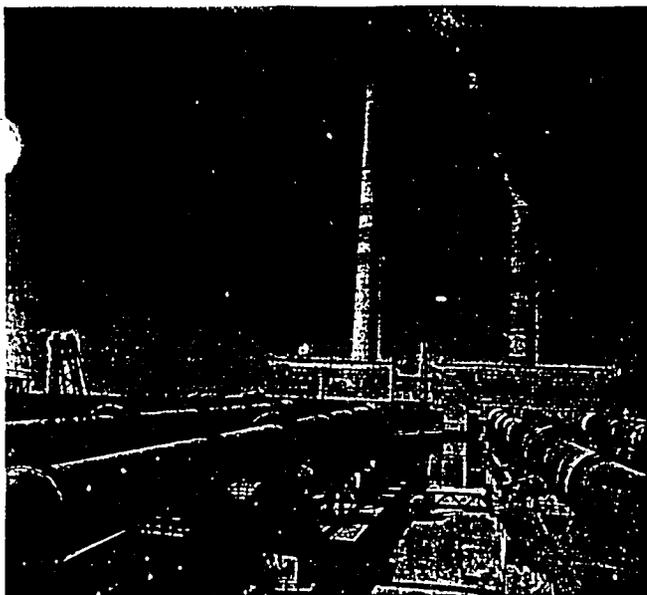
The plant's production helped too restore Lithuania after the 2nd World War. Its production can be seen not only in Lithuania but in other countries as well.

Litauische Republik ist ein alter neuerstehender Staat, ein schönes Land auf der östlichen Ostseesüde. Fruchtbare Felder, himmelblaue Seen und Flüsse, kleine, ordentliche Städte. Hier leben fleissige und herzlich Menschen, tüchtige Gastgeber.

Nach fünf Inkorporationsjahren kehrt also das Litauen in die Familie der Weltvölker zurück. Es strebt nach Welterkenntnis, wünscht sich in sie einzuschalten, strebt nach Weltanerkennung.

Diese illustrierte Erzählung stellt einen der grössten und stabilsten Baumaterialienbetriebe Litauens vor - Akmenėer Staatsunternehmen „Zement von Akmenė“, das sich im Norden Litauens befindet.

Betriebsproduktion trug zum Aufbau der zerstörten Volkswirtschaft Litauens nach dem 2. Weltkrieg bei. Tätigkeit der Fabrikarbeiter wurde nicht nur in Litauen, sondern auch in Stadtgebäuden und Bauernhöfen anderer Regionen verewigt.



CEMENTAS PASAULYJE

Nė vienas kraštas negali išsiversti be statybų. Kuo statybos sudėtingesnės, tuo patikimesnių reikia rišamųjų medžiagų. ypač aštriai šią problemą iškėlė spartėjanti civilizacijos raida, poreikis statyti didelius tvirtus tiltus, pastatus ir įrengimus vandenyje.

XVIII a. Anglijoje iš molingų klinčių (mergelio) imta degti hidraulines kalkes. 1796 m. anglų technikas Parkeris atrado būdą iš mergelio gaminti cementą. 1824 m. tas pats išradėjas, aukštoje temperatūroje degdamas klinčių ir molio mišinį, pagamino naują rišamąją medžiagą, spalva primenančią Portlando provincijos uolienas, ir pavadino ją portlandcementu. Jo gamyba greitai plėto Anglijoje ir Prancūzijoje, o nuo 1856 m. - ir kitose Vakarų Europos valstybėse, Rusijoje, JAV.

Nuo XX a. pradžios cementas - svarbiausia ir plačiausiai nau-

CEMENT IN THE WORLD

No land can exist without constructions. The more complicated the construction, the more reliable materials it demands. The development of civilization showed how acute this problem was in building bridges, houses and construction in the water.

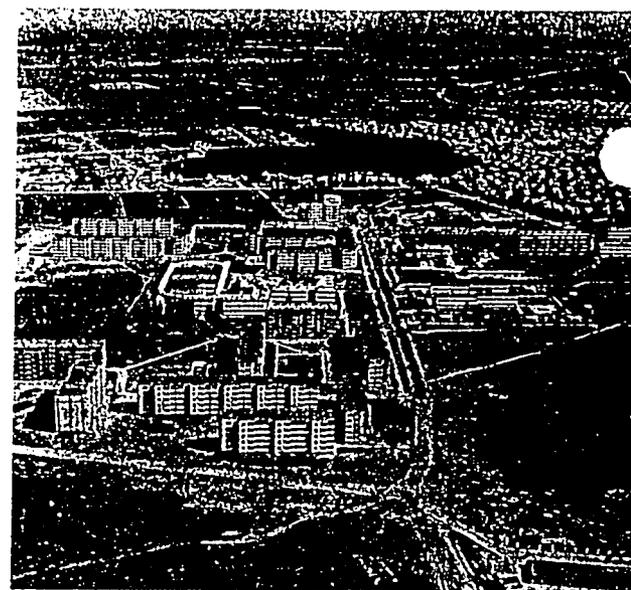
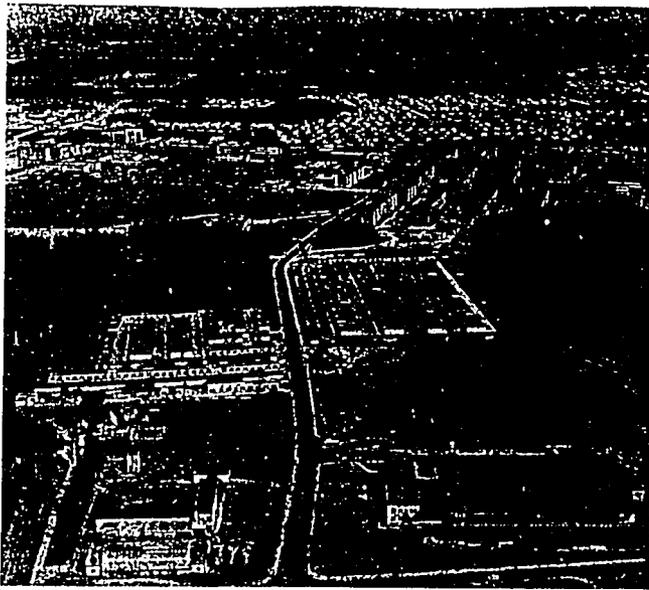
In 18 c. in England hydraulic lime was made from marl. In 1796 the English technician Parker discovered how to make cement from marl. In 1824 the same inventor made a new binding material, burning clay and limestone at very high temperature. The new material was called portlandcement because its colour reminded of the rocks in the province of Portland. Its production was rapidly spreading in England and France. Since 1856 it has been produced in Western

ZEMENT IN DER WELT

Kein Land kann ohne Bau auskommen. Je komplizierter der Bau, desto zuverlässigere Bindemittel werden gebraucht. Mit der intensiven Zivilisationsentwicklung, dem Bedürfniss nach Bau von grossen und festen Brücken, Gebäuden und Einrichtungen im Wasser tauchte dieses Problem besonders scharf auf.

Im 18. Jahrhundert begann man in England aus kalkhaltigen Tonen (Mergel) hydraulische Kalke zu brennen. 1796 hat der englische Techniker Parker Zementherstellungsmethode aus Mergel gefunden. 1824 erzeugte derselbe Erfinder durch Brennen der Mischung von Kalkstein und Ton ein neues Bindemittel, das den Gesteinen der Provinz Portland ähnelt, und nannte es Portlandzement. Seine Herstellung verbreitete sich rasch in England und Frankreich, vom Jahre 1856 auch in anderen Ländern Westeuropas, Russland, USA.

32



dojama rišamoji statybų medžiaga. 1929 m. pasaulyje jo pagaminta 68 mln. t.

Cemento gamyba didžiausiose pasaulio valstybėse 1990 m. (mln.t)

Kinija	203,0
TSRS	137,3
JAV	75,5
Japonija	84,45
Italija	41,69
VFR	39,26
Prancūzija	26,98
Didžioji-Britanija	14,0

CEMENTAS LIETUVOJE

Grupė Lietuvos verslininkų 1912 m. įkūrė „Lietuvos portlandcemento bendrovę“. Jos įgaliotas inžinierius ir mokslininkas P.Jodelė suprojektavo ir savo žemėje, tarp Varėnos ir Valkininkų, pastatė fabriką, kuris 1914 m. iš čia kasamų kreidos ir molio pradėjo gaminti cementą. Pirmojo pasaulinio karo metais

European countries and in Russia as well as in the USA.

Since the beginning of the 20 c. cement has been one of the main and most used binding materials. In 1929 the world produced 68 milion tons of cement.

The production of cement in the largest countries of the world in 1990 (mln. t.)

China	203,0
USSR	137,3
USA	75,5
Japan	84,45
Italy	41,69
GFR	30,26
France	26,98
Great Britain	14,0

CEMENT IN LITHUANIA

In 1912 a group of Lithuania businessmen founded the company „Lithuanian portlandcement“. It supported P. Jodelė, an engineer and

Vom Anfang des 20. Janhrhunderts ist Zement das Wichtigste und gebräuchlichste Bindemittel im Bau. 1929 wurden 68 Mill. Zement in der Welt hergestellt. Zementherstellung in den größten Staaten der Welt i.J. 1990 (mill. t)

SU	137,3
USA	75,5
Japan	84,45
Italien	41,69
BRD	30,26
Frankreich	26,98
China	203,0
Grossbritannien	14,0

ZEMENT IN LITAUEN

Eine Gruppe von litauische Unternehmern gründete 1912 „Gesellschaft des Portlandzements Litauens“. Ihre Vertrauensperson Ingenieur und Wissenschaftler P. Jodelė projektierte und baute in seinem Heimatland, zwischen Varėna und Druskininkai, eine Fabrik, in:

įmonė buvo sugriauta, įrengimai sunaikinti.

Nepriklausoma Lietuvos Respublika 1918-1940 m. cementą importuodavo iš Didžiosios Britanijos, Belgijos, Danijos, Latvijos, Norvegijos, TSRS bei Vokietijos.

Cemento įvežimas Lietuvos Respublikoje (tūkst. t.)

1926 m.	31
1928 m.	47
1938 m.	124

Cemento gamyklos statybos klausimas ne kartą keltas 1930 - 1940 metais, bet Lietuvos Respublika stokojo tam lėšų, o užsienio firmos, bręstant II Pasauliniam Karui, nesiryžo investuoti Lietuvoje kapitalo. Vis dėlto 1940 m. pradėtas statyti cemento fabrikas ties Skirsnemune, bet prasidėjęs karas statybą nutraukė. Diskutuota ir galimybė statyti cemento gamyklą Akmenės apylinkėse, kur jau buvo išžvalgyti dideli klinčių klotai.

Nusiritus į Vakarus II Pasaulinio Karo bangai, iškilo reikalas kuo greičiau atstatyti sugriautą ūkį. Griuvėsiais buvo paversti daugelis miestų ir miestelių, gamyklų ir fabriku. Lietuvą vėl okupavusios TSRS partinė ir valstybinė valdžia ieškojo galimybių Pabaltijo ir Baltarusijos ir Kaliningrado srities atstatymui cementą gaminti čia pat, panaudojant gausius darbo jėgos išteklius.

Vykdydama centrinės valdžios direktyvas, tuometinė Lietuvos

scientist, who on his own piece of land between the towns of Varėna and Valkininkai, built a factory which produced cement from local chalk and clay. During the 1st World War this factory was destroyed.

Independent Lithuanian Republic imported cement from Great Britain, Belgium, Denmark, Latvia, Norway, USSR and Germany in the period of 1918 - 1940.

Import of cement to Lithuania (thousand tons)

In 1926 31

In 1928 47

In 1938 124

The question of building a cement plant was discussed several times in 1930 - 1940, but Lithuanian Republic was poor and couldn't afford it, and foreign firms didn't risk to invest their money on the verge of the 2th World War. In 1940 the construction of a cement plant near Skirsnemunė began, but the war stopped it. There began a discussion about building a cement plant in Akmenė district, because huge resources of limestone had been explored there.

The wave of the war moving to the West, there arose a great demand to restore the devastated economy. A number of towns, factories and plants became ruins. The occupant power of the USSR in Lithuania wanted to produce cement using cheap

man 1914 aus den hiesigen Ton und Kreide die Zementherstellung begann. In den Jahren des I. Weltkriegs wurde der Betrieb zerstört, die Einrichtungen vernichtet.

1918-1940 importierte die unabhängige Litauische Republik Zement aus Grossbritannien, Belgien, Danemark, Lettland, Norwegen, SU und Deutschland.

Zementeinfuhr in der Litauischen Republik (tausend t)

i. J. 1926 31

i. J. 1928 47

i. J. 1938 124

Die Frage eines Zementbetriebsbaus wurde mehrmals in den Jahren 1930-1940 aufgeworfen, Litauische Republik aber empfand Bedürfniss nach den Geldmitteln und ausländische Firmen konnten sich nicht entschliessen, ihr Kapital in Litauen anzulegen, indem der 2. Weltkrieg heranreifte. 1940 wurde immerhin der Bau eines Zementbetriebs bei Skirsnemunė begonnen, der Krieg aber hatte den Bau unterbrochen. Besprochen wurde auch die Möglichkeit einen Betrieb in der Umgebung Akmenė zu bauen, wo grosse Kalksteinschichten gefunden wurden.

Nach dem 2. Weltkrieg entstand das Bedürfniss so schnell wie möglich die zerstörte Wirtschaft wiederherzustellen. Der Krieg hinterliess die meisten Städte und Stadtchen, Betriebe und Fabriken in Ruinen. Besatzungsbehörden der USSR suchten nach Möglichkeiten,

TSR liaudies komisarių taryba 1945 m. liepos 27 d. priėmė nutarimą statyti Lietuvoje cemento gamyklą. Statybai šį kartą pasirinktas Akmenės regionas, kuriame jau buvo ištirti gausūs cemento gamybai tinkamų klinčių ir molio klodai. Pirmąjį projektą rengė Leningrado institutas „Giprocement“. 1947 m. pradėti statybos darbai. Pirmoji cemento gamybos technologinė linija paleista 1952 m. rugsėjo 20 d.

**LIETUVOS RESPUBLIKOS
VALSTYBINĖ ĮMONĖ
„AKMENĖS CEMENTAS“**

Iš įmonės vizitinės kortelės

Sprendimas pradėti statybą:
1945 m. liepos 27 d.

Projektavimo pradžia: 1946 m.
rugsėjo 11 d.

Statybos darbų pradžia: 1947 m.
Ižkurta pirmoji sukamoji krosnis:
1952 m. rugsėjo 20 d.

ĮMONĖS DIREKTORIAI

Ustinas JURAGA (1947 - 1949)

Pavlas PURMALIS (1949 -
1951)

Leonidas ZASEDATELIS
(1951 - 1954)

Aleksandras ANDROSOVAS
(1954 - 1956)

Viktoras MARKEVIČIUS
(1956 - 1959)

Aleksandras SPUDULIS (1959
- 1962)

Leopoldas PIETRAVIČIUS
(1962 - 1990)

Simonas Vytis ANUŽIS (nuo
1990)

labour force, which was very necessary not only for rebuilding Lithuanian towns, but other republics as well.

Under the directions of central power, the Commissars' Soviet of Lithuanian SSR issued an order to build a cement plant. It was decided to choose Akmenė district, as it was rich in limestone and clay that was good for making cement. The first project was made by institution „Giprocement“ in Leningrad. In 1947 the construction of plant was started. The first technological line of cement production began to operate on September 20, 1952.

**LITHUANIAN STATE PLANT
„AKMENĖ CEMENT“**

Important data:

The decision to build the plant:
July 27, 1945

The beginning of the project:
September 11, 1946

The beginning of construction:
1947

The first rotating kiln started to work:
September 20, 1952

MANAGERS OF THE PLANT

Justinas JURAGA (1947-1949)
Pavlas PURMALIS
(1949-1951)

Leonidas ZASEDATELIS
(1951-1954)

Aleksandras ANDROSOVAS
(1954-1956)

Viktoras MARKEVIČIUS
(1956-1959)

Aleksandras SPUDULIS
(1959-1962)

Baltikum, Belorussland und Gebiet Kaliningrad mit Hilfe der Zementherstellung an Ort und Stelle Verwendung der ergiebigen Arbeitskräfte aufzubauen.

Der damalige Rat der Volkskommissare der Litauischen SSR hielt sich an die Richtlinien der Zentralregierung und fasste den Beschluss, einen Zementherstellungsbetrieb in Litauen zu bauen. Für den Bau wurde Gebiet Akmenė gewählt, wo grosse für Zementherstellung nötige Kalkstein- und Tonschichten gefunden wurden. Den ersten Bauentwurf machte das Institut „Giprocement“ von Leningrad. 1947 begannen die Bauarbeiten. Die erste technologische Linie der Zementherstellung wurde am 20. September 1952 in Betrieb gesetzt.

**STAATSUNTERNEHMEN
DER LITAUISCHEN
REPUBLIK**

„ZEMENT VON AKMENĖ“

Aus der Visitenkarte des Unternehmens:

Beschluss zum Baubeginn: der
27. Juli 1945

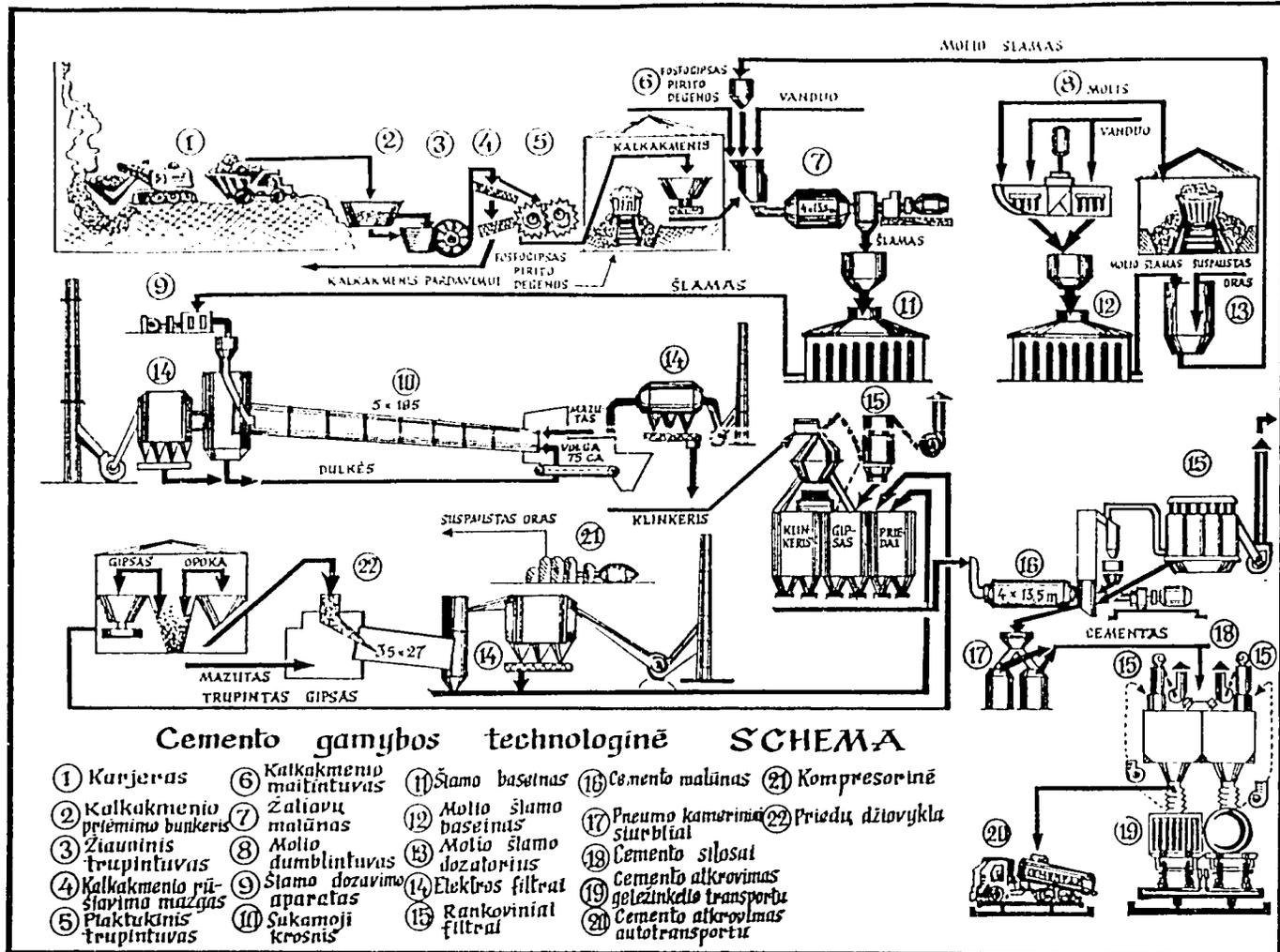
Projektierungsanfang: der 11.
September 1946

Anfang der Bauarbeiten: 1947
Der 1. Drehrohrofen in Betrieb
gesetzt: am 20. September 1952

**DIREKTOREN DES
UNTERNEHMENS**

Ustinas JURAGA (1947-1949)
Pavlas PURMALIS (1949-
1951)

Leonidas ZASEDATELIS
(1951-1954)



STEBĖTOJŲ TARYBA

Išrinkta 1990 m. gruodžio 27 d.
 Stebėtojų tarybos pirmininkas
 Valerijus ZAVJALOVAS
 sekretorius Klemas RIMUTIS
 nariai Dalia BINKULIENĖ
 Vytautas Jonas BORUSEVIČIUS
 Edmundas DIMITREVIČIUS
 Edmundas KRIPAS
 Julius UŠPARAS

DIREKTORIŲ VALDYBA

Patvirtinta 1991 m. sausio 29 d.
 Simonas Vytis ANUŽIS - direktorius, valdybos pirmininkas
 Vincas MONTVILA - direktorius pavaduotojas, valdybos narys

Leopoldas PETRAVIČIUS (1962-1990)
 Simonas Vytis ANUŽIS (since 1990)

SUPERVISORS COUNCIL

Elected on December 27, 1990.
 The head of the council
 Valerijus Zavjalovas
 Secretary Klemas Rimutis
 Members Dalia Binkulienė
 Jonas Borusevičius
 Eimundas Dimitreivičius
 Julius Užparas

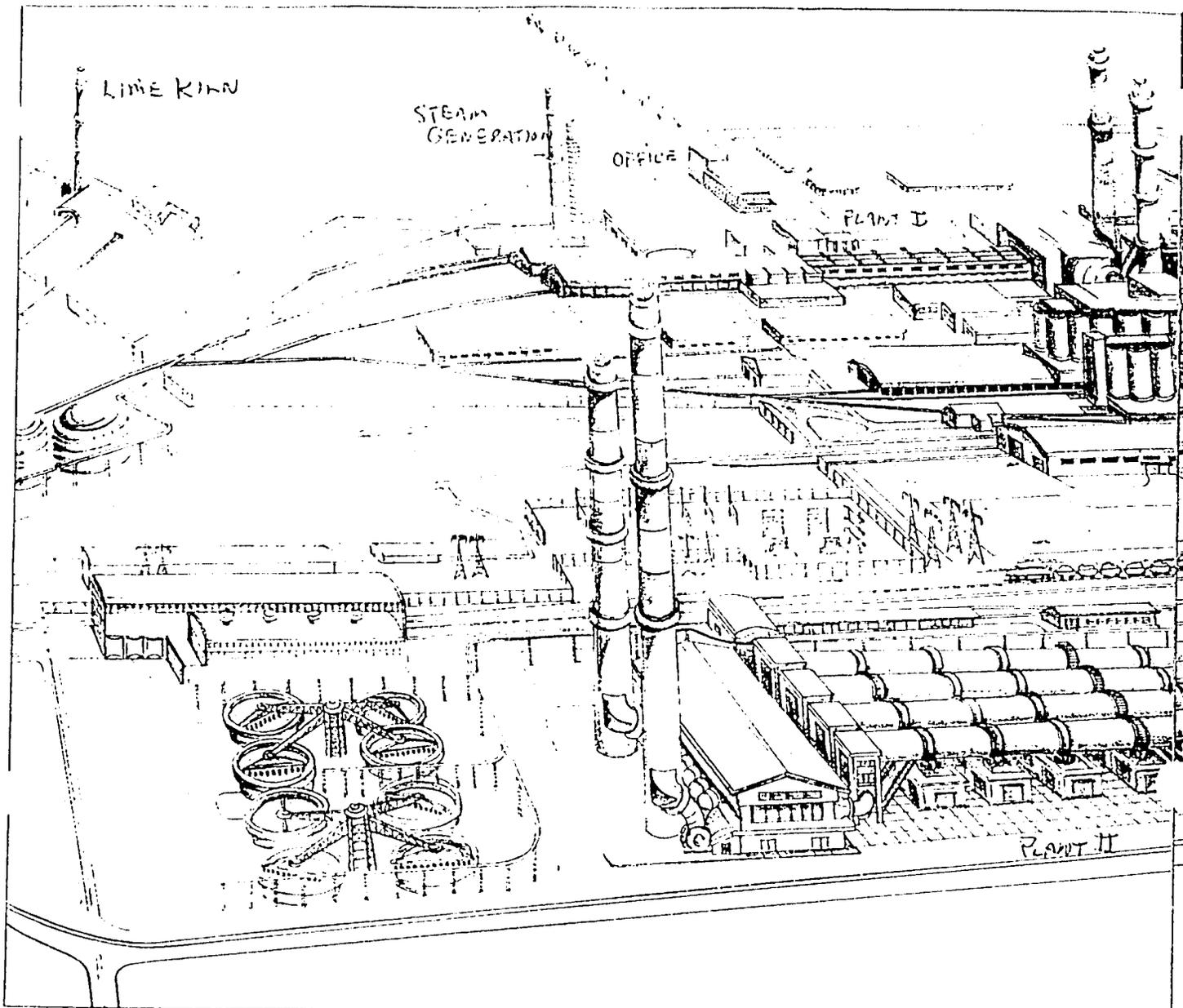
THE COUNCIL OF MANAGERS

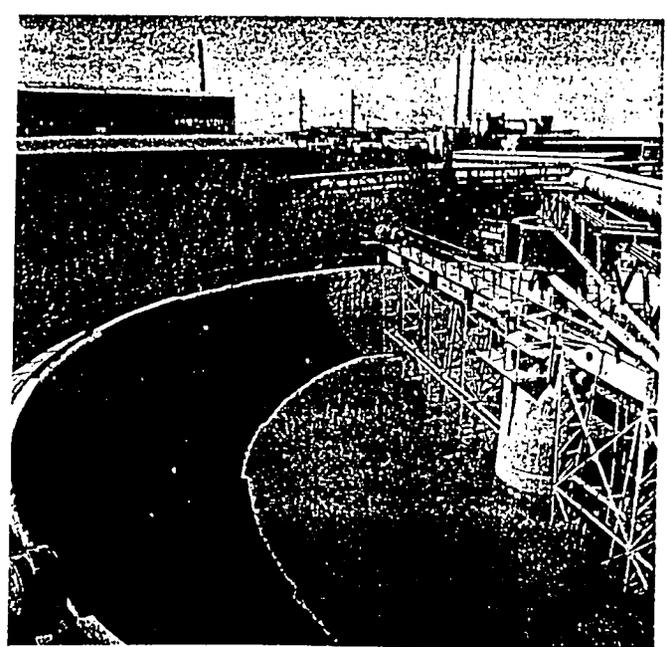
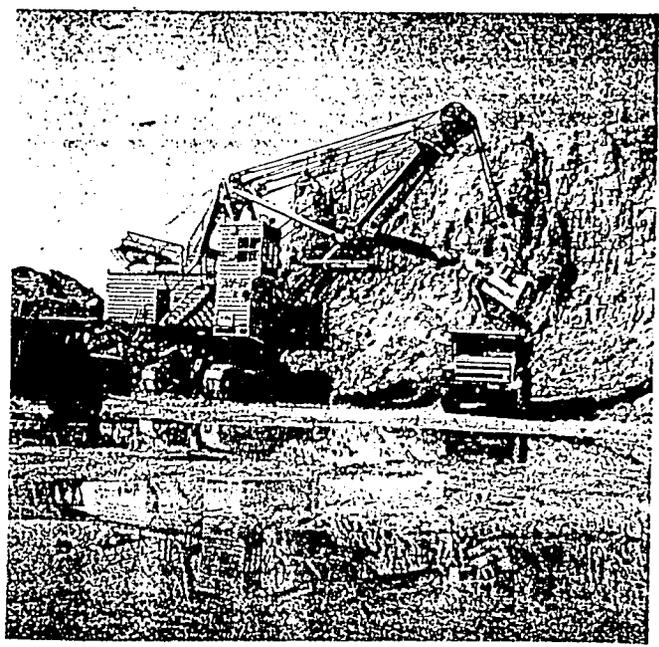
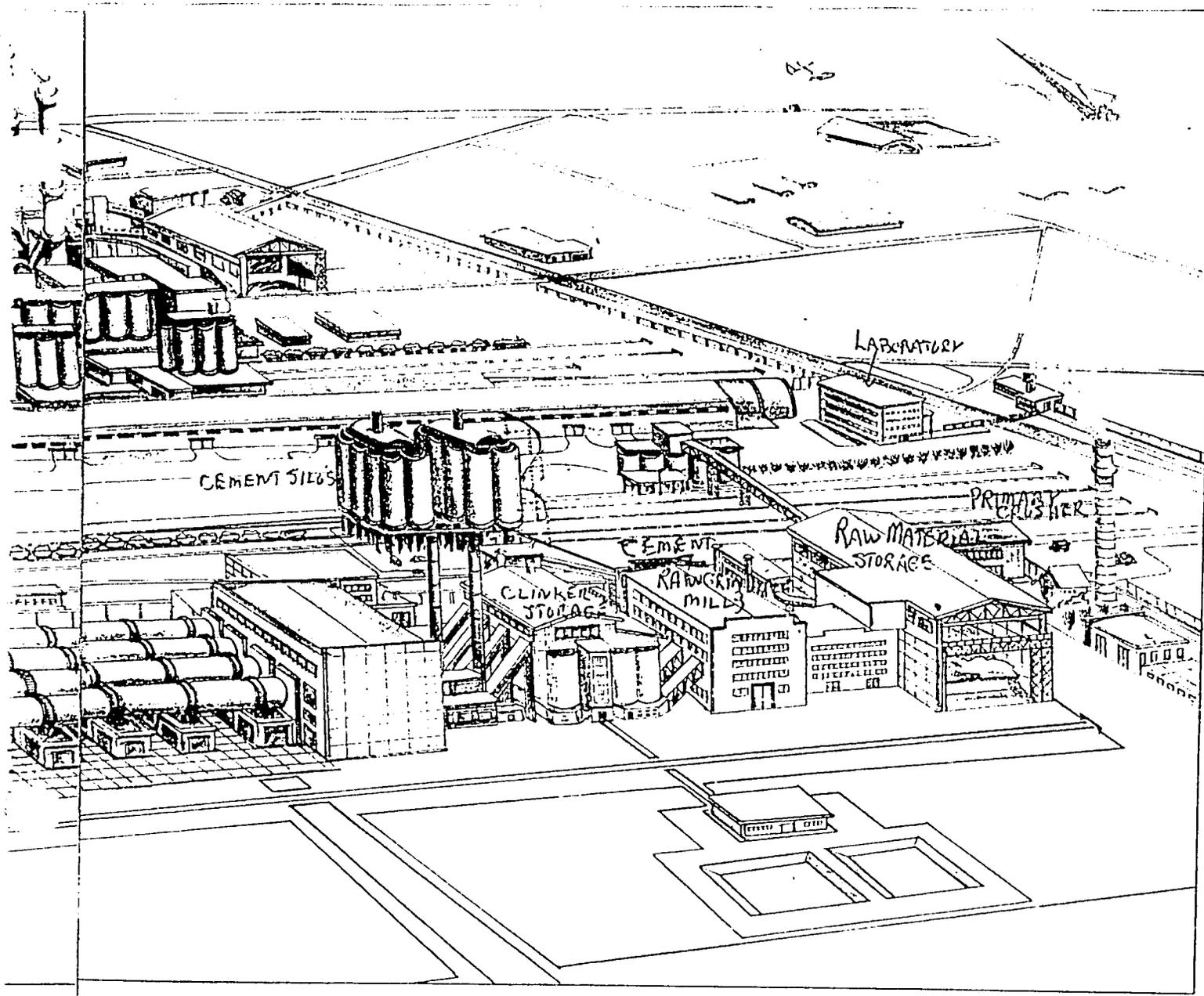
Approved on January 29, 1991
 Simonas Vytis Anužis - manager, the head of the council

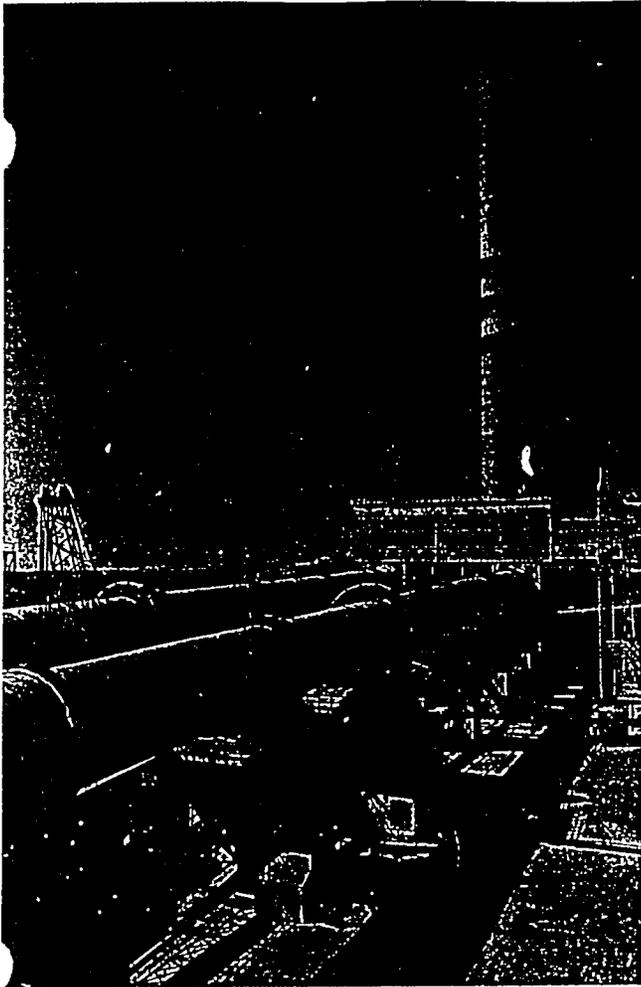
Aleksandras ANDROSOVAS (1954-1956)
 Viktoras MARKEVIČIUS (1956-1959)
 Aleksandras SPUDULIS (1959-1962)
 Leopoldas PETRAVIČIUS (1962-1990)
 Simonas Vytis ANUŽIS /ANUSHIS/ (vom 1990 an)

AUFSICHTSRAT

Am 27. Dezember 1990 gewählt.
 Vorsitzende des Aufsichtsrates
 Valerijus ZAVJALOVAS
 Sekretär Klemas RIMUTIS
 Mitglieder Dalia BINKULIENĖ
 Vytautas Jonas BORUSEVIČIUS
 Edmundas DIMITREVIČIUS







*Albinas KLIMAS - direktorius
pavaduotojas, valdybos narys
Olius DANYLA - direktoriaus
pavaduotojas, valdybos narys
Romualdas NORKUS - direkto-
riaus pavaduotojas, valdybos
narys
Algimantas MITUZAS - vyriaus-
siasis inžinierius, valdybos narys*

*Valstybinėje įmonėje
„Akmenės cementas”*

*pagaminta 1991 m.
cemento - 3125,5 tūkst. tonų,
banguoto šiferio (asbestcemen-
čio) - 69501 tūkst. sutartinių
lakštų,
asbestcementinių vamzdžių (su-
tartinio diametro) - 1885,2 km.*

*Vincas Montvila - assistant
manager, council member
Albinas Klimas - assistant
manager, council member
Olius Danyla - assistant
manager, council member
Romualdas Norkus - assistant
manager, council member
Algimantas Mituzas - chief
engineer, council member
The state plant „Akmenė
Cement” produced in 1991:
cement - 3125,5 thousand tons
ruffled slate (asbestos cement) -
69501 thousand leaves
pipes made of asbestos cement
(set diameter) - 1885,2 km*

*Edmundas KRIPAS
Julius UŠPARAS*

DIREKTORIUM

*Am 29. Januar 1991 bestätigt.
Simonas Vytis ANUŽIS - der Di-
rektor, Vorsitzende des Direkto-
riums
Vincas MONTVILA - der stel-
lvertreter/de Direktor, Mitglied
des Direktoriums
Albinas KLIMAS - der stellvert-
retende Direktor, Mitglied des
Direktoriums
Olius DANYLA - der stellvertre-
tende Direktor, Mitglied des Di-
rektoriums*

**PAGRINDINIAI GAMYBOS
PADALINIAI**

1-OJI CEMENTO GAMYKLA:
4 sukamosios krosnys. Gamykloje yra trupinimo ir rūšiavimo bei pakavimo skyriai, žaliavų, degimo, malimo, dulkių surinkimo, mechaninis, elektros, remonto ir statybos, laboratorijos cechai.

Gamykloje dirba 778 žmonės, iš jų 700 darbininkų, 78 specialistai, meistrai vadovai.

1991 m. pagaminta:

portlandcemenčio M400 - 149000 t,

greit kietėjančio portlandcemenčio M400 - 430000 t,

smėlinio portlandcemenčio - 143000 t,

cemento kelių dangai - 39000 t.

2-OJI CEMENTO GAMYKLA:

4 didžiosios (185 m. ilgio, 5 m. diametro) sukamosios krosnys. Gamykloje 3 barai - degimo, malimo, energetikos. Dirba 405 žmonės, iš jų 373 darbininkai, 32 vadovai, specialistai, meistrai.

1991 m. pagaminta:

portlandcemenčio M400 - 125000 t,

greit kietėjančio portlandcemenčio M400 - 1634000 t,

M500 - 605000 t.

ASBESTCEMENČIO GAMYKLA: dirba 293 žmonės, iš jų 271 darbininkas, 22 specialistai, meistrai ir vadovai.

Gamina: banguotus asbestcemenčio (šiferio) lakštus (1750x1130x5,8 mm), įvairaus diametro asbestcementinius vamzdžius ir movas slėginiams ir beslėginams vamzdžiams.

**THE MAIN PRODUCING
SECTION**

CEMENT PLANT 1: 4 rotatory kilns. In the plant there are crushing, sorting and packing divisions, raw materials, burning, milling, dust collecting, mechanical, electric, repair building, laboratory departments.

There work 778 people at the plant, 700 are workers, the rest 78 are specialists, masters and chiefs.

In 1991 it produced:

portlandcement M400 - 149000 t

fast hardening portlandcement

M400 - 430000 t

sand portlandcement - 143000 t

cement for road cover - 39000 t.

CEMENT PLANT 2: 4 big (185

m. long, 5 m. diameter) rotatory

kiln. There are 3 sections -

burning, grinding, energetics.

There work 405 people - 373

workers, 32 chiefs, specialists,

masters.

ASBESTOS CEMENT

PLANT: there work 293 people

271 workers, 22 specialists,

masters and chiefs.

It produces:

ruffled asbestos cement (slate)

leaves (1750x130x5,8 mm)

pipes and clutches of various

diameter made of asbestos

cement for using under pressure

and without pressure.

**RAW MATERIALS AND
THEIR PROVIDERS**

Data of 1991

Limestone (local pit Karpėnai) -

4321,7 th. t

Romualdas NORKUS - der stellvertretende Direktor, Mitglied des Direktoriums

Algimantas MITUZAS - der Chefingenieur, Mitglied des Direktoriums

Produktion des Staatsunternehmens „Zement von Akmenė“ i. J. 1991

Zement - 3125,5 tausend t,

Wellschiefer (Asbestzement) -

69501 tausend Vertragsplatten,

Asbestzementröhren (im vert-

raglichen Durchmesser) - 1885,2

km.

HAUPTUNTERABTEILUNGEN

Der 1. Zementbetrieb: 4 Dreh-

rohröfen. Im Betrieb sind:

Zerkümmelung-, Sortier- und

Verpackungsabteilungen, Roh-

stoff-, Brenn-, Mühl-, Staub-

sammlung-, Maschinen-,

Elektro-, Reparatur- und Bau-,

Laborabteilungen.

Beschäftigtenzahl: 778 (700 sind

Arbeiter, 78 sind Fachleute,

Werkmeister, Leiter)

Herstellungsprogramm i. J.

1991:

Portlandzement M400 - 149000 t,

schnell verhärtender Portlandze-

ment M 400 - 430000 t,

Sandportlandzement - 143000 t,

Zement für Strassenbelag -

39000 t.

Der 2. Zementbetrieb: 4 Rie-

sendrehrohröfen (185 m lang, 5

m Diameter). Im Betrieb gibt es

Brenn-, Mühl- und Energiepro-

duktionsbereiche. 405 Leute

sind beschäftigt, 373 unter ihnen

sind Arbeiter, 32 Leiter, Fach-

leute, Werkmeister.

40

ŽALIAVOS IR JŲ TIEKĖJAI

1991 m. duomenys

Klintys (vietinis Karpėnų karjeras) - 4321,7 tūkst. t;

Molis (Šaltiškių molio karjeras) - 1315,8 tūkst. t;

Gipsas (Sauriešo kasykla Latvijoje) - 5 tūkst. t;

Pirito degenos (Kingisepo gamybinis susivienijimas „Fosforit“) - 70,3 tūkst. t;

Opoka (Stoniškių karjeras) - 46,6 tūkst. t;

Fosfogipsas (Kėdainių chemijos gamykla) - 52,1 tūkst. t;

Fosfogipsas (Gomelio chemijos kombinatas Baltarusijoje) - 23,8 tūkst. t.

KURO IR ENERGIJOS ŠALTINIAI

1991 m. duomenys

Mazutas (pagrindinė tiekėja - 1ažeikių naftos perdirbimo įmonė) - 469,2 tūkst. t,

Gamtinės dujos (gamybinei katilinei) - 54776 tūkst. kub. m,

Elektros energija (gaunama 2 maitinimo 110 kv linijomis iš Lietuvos energtinės sistemos) - 397257 mln kWh,

Mazuto ūkį aptarnauja 28 Darbuotojai.

AUTOTRANSPORTO ŪKIS

Įmonė turi 146 įvairių markių ir paskirties automašinas, iš jų 76 savivartės, 14 autobusų.

1991 m. pervežta 5353 tūkst. krovininių. Autotransporto ūkį aptarnauja 105 darbuotojai.

GELEŽINKELIO ŪKIS

Geležinkeliu 1991 m. išsiųsta:

Clay (Šaltiškiai clay pit) - 1315,8 th. t

Gyps (Siauries pit in Latvia) - 5 th. t

Pyrite (Kingisep plant „Phosphorite“) - 70,3 th. t

Opoka (Staniškiai pit) - 46,6 th. t

Phosphogyps (Kėdainiai chemical plant) - 52, 1 th. t

Phosphogyps (Gomel chemical plant in Bielorusia) - 23,8 th. t

SOURCES OF FUEL AND ENERGY

Data of 1991

Oil (the main provider is Mažeikiai oil plant) - 469,2 th. t

Natural gas (for boilers) - 54776 th. cubic m.

Electric energy (it comes in 2 lines 110 kV from Lithuanian energetic system) - 397257 mln. kwh

28 workers are in charge of oil.

MOTOR TRANSPORT SERVICE

The plant possesses 146 vehicles of all kinds, among them - 76 trucks, 14 buses.

1991 they carried 5353, 1 th. t of load. 105 workers are in charge of transport service.

RAILWAY

In 1991 there were sent by railway: 44732 carriages of cement (among them 1645 carriages were exported), 972 carriages with slate, 1258 carriages with asbestos cement pipes. The plant has 11 steam engines. 287 workers are in charge of railway.

Herstellungsprogramm i.J. 1991:

Portlandzement M 400 - 125000 t,

scheil verhartender Portlandzement M 400 - 1634000 t, M 500 - 605000 t.

Asbestzementbetrieb: Beschäftigtenzahl 293 (271 Arbeiter, 22 Fachleute, Werkmeister, Leiter)

Produktion:

Wellschieferplatten (Asbestzement) (1750x1130x5,8 mm)

Asbestzementröhren und-muffen mit unterschiedlichem Durchmesser für Druck- und drucklose Leitung.

ROHSTOFFE UND LIEFERANTEN

Angaben fürs Jahr 1991

Kalkstein (hiesige Kalksteingrube von Karpenai) - 4321,7 tausend t,

Ton (Tongrube von Šaltiškiai) - 1315,8 tausend t,

Piritushorst (Produktionsvereinigung „Fosforit“ von Kingisep) - 70,3 tausend t,

Kieselkalkton (Grube von Stoniškiai) - 46,6 tausend t,

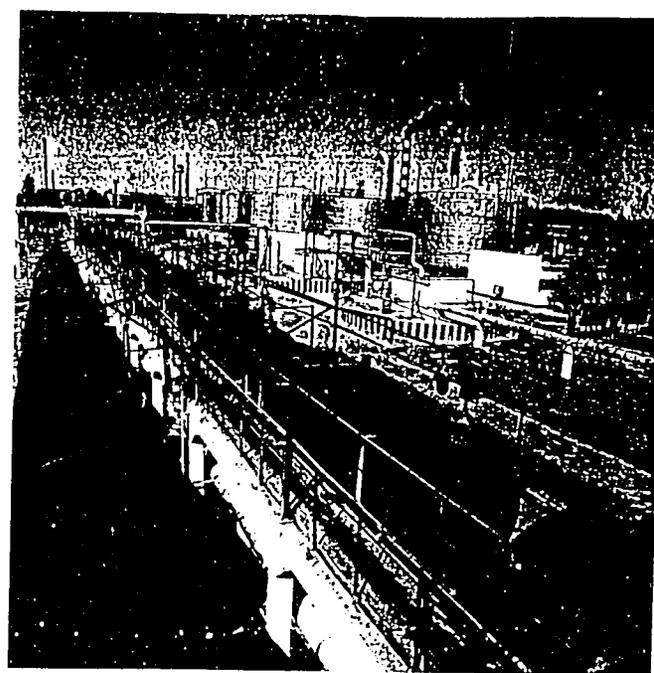
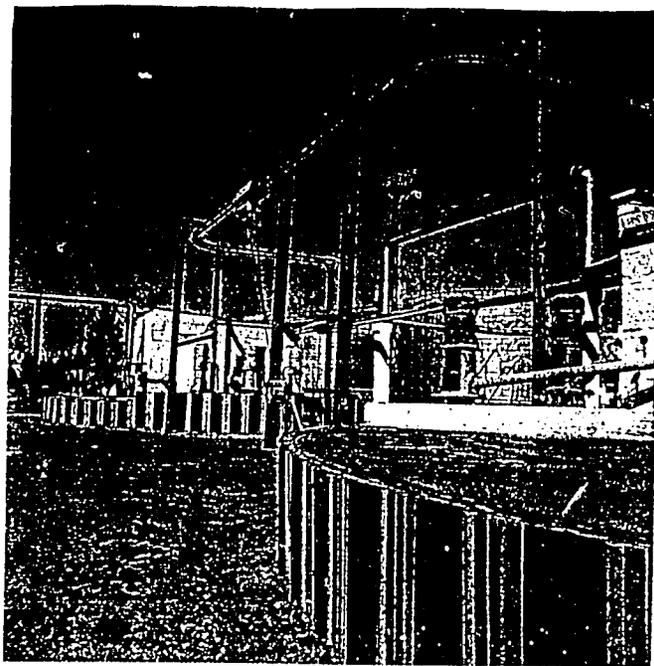
Fosfogips (Chemiewerk von Kėdainiai) - 52,1 tausend t,

Fosfogips (Chemiewerk von Gomel in Belorussland) - 23,8 tausend t.

BRENNSTOFF-UND ENERGIEQUELLEN

Angaben fürs 1991

Masut (Hauptanlieferer-Erdölraffinerie von Mažeikiai) - 469,2 tausend t,



44732 vagonai cemento (tame tarpe 1645 vagonai - eksportui), 972 vagonai šiferio, 1258 vagonai asbestcementinių vamzdžių. Įmonė turi 11 šilumvežių. Geležinkelio ūkį aptarnauja 287 darbuotojai.

ŠILUMOS ŪKIS

Per metus įmonė pagamina 419 tūkst. gigakalorijų šilumos.

Asbestcemenčio gamyklai ir valstybinei gelžbetonio įmonei „Karpėnai“ 1991 m. patiekta 66,9 tūkst. Gcal garo.

Karšto vandens 16000 Gcal sunaudota įmonėje. Naujosios Akmenės-miestui patiekta 66,4 Gcal šilumos (šildymas ir karštas vanduo).

VANDENS ŪKIS

Technologinėms reikmėms 1991 m. sunaudota 2622 tūkst. kubinių metrų vandens iš Agluonos upės ir 1333 tūkst. kubinių metrų - iš Sablauskio tvenkinio.

THERMAL SERVICE

Every year the plant produces 419 thousand Gcal of heat. In 1991 the plant of asbestos cement and the state concentrate plant „Karpėnai“ received 66,9 Gcal of steam.

The plant consumed 16000 Gcal of hot water. It supplies the town of Naujoji Akmenė with 66,4 Gcal of heat (heating and hot water).

WATER SUPPLY

In 1991 technological processes demanded 2622 th cubic metres of water that came from the river Agluona and from the Sablauskiai pond.

The area of Sablauskiai pond is 123,8 ha, its size is 2 mln cubic metres.

Drinking water supplies reach 3044 th cubic metres per year. In 1991 the town of Naujoji Akmenė got 3021 th cubic metres of drinking water.

Erdgas (für den Betriebskesselraum) - 54776 tausend Kubikmeter,

Elektroenergie (Versorgung durch zwei 110-kv-Leitungen vom Verbundsystem Litauens) - 397257 kwh.

Masutwirtschaft wird von 28 Werktätigen bedient.

TRANSPORTWESEN

Das Unternehmen verfüng über 146 verschiedenartige Kraftfahrzeuge, darunter 76 Kippautos 14 Autobusse.

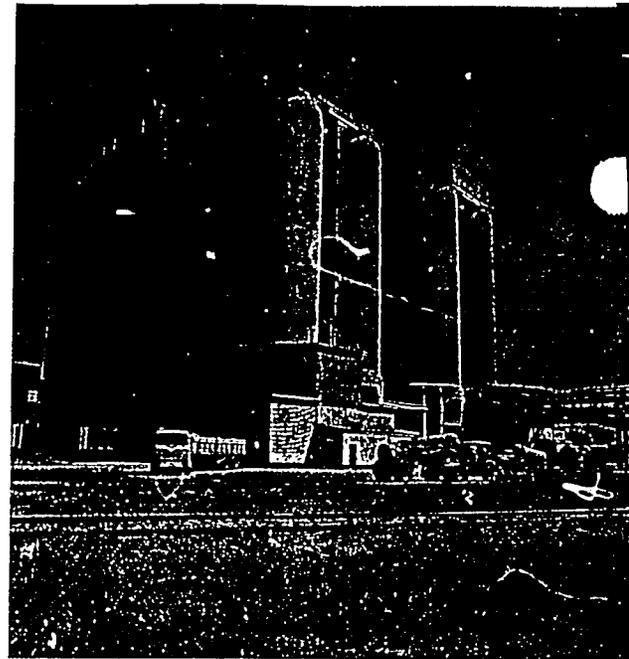
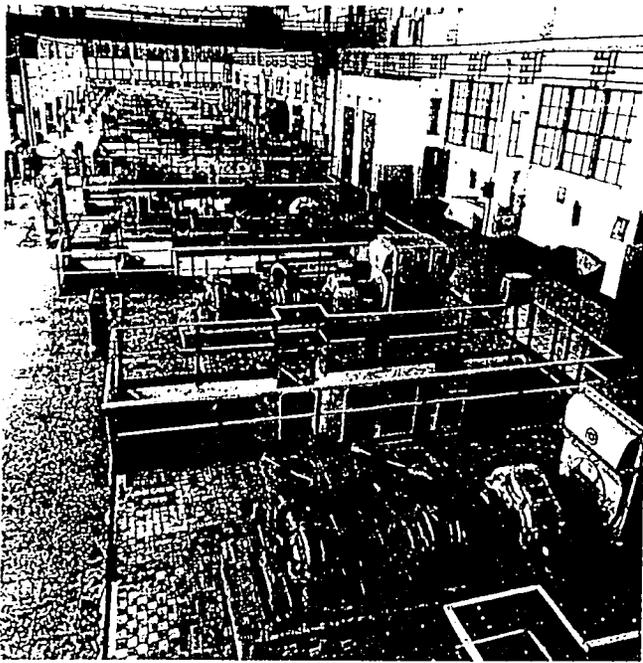
Gütertransport fürs Jahr 1991: 5353,1 tausend t.

Beschäftigtenzahl 105.

EISENBAHNWESEN

Bahntransport im Jahre 1991: 44732 Güterwagen mit Zement (darunter 1645 Wagen zur Ausfuhr), 972 Güterwagen mit Schiefer, 1258 Güterwagen mit Asbestzementröhren. Das Unternehmen verfügt über 11 Die-

42



Sablauskių tvenkinio plotas 123,8 ha, tūris - 2 mln kubinių metrų.

Geriamo vandens verslovės pajėgumas 3044 tūkst. kubinių metrų per metus. 1991 m. Naujosios Akmenės miestui patiekta 3021 tūkst. kubinių metrų geriamo vandens.

EKOLOGINIS ŪKIS

Įmonės eksploatuojamų vandens valymo įrengimų pajėgumas 10 tūkst. kubinių metrų vandens per parą. Per metus išvaloma 2,5 mln kubinių metrų vandens.

Per metus sugaudoma 1125 tūkst. t klinkerio dulkių. Įrengti 22 elektros filtrai. Prie cemento malūnų, cemento ir klinkerio silosų bei pakavimo mašinų įrengti per 40 rankovinių filtrų. Sugaudytos dulkės gražinamos į sukamąsias krosnis

EKOLOGICAL SERVICE

The cleaning equipment used by the plant has industrial capacity of 2,5 mln cubic metres of water per year.

Every year 1125 t of clinker dust is caught. There are 22 electric filters. There are over 40 sleeve-like filters near the cement mills, cement and clinker silo, packing machines. The caught dust is turned back to the rotatory kilns.

TRAINING OF SPECIALISTS

Every year the state plant „Akmenė Cement“ trains 200 new workers on average, 350 workers improve their qualifications, 2000 workers are tested anew. Every year about 100-120 engineers and technologists improve their qualifications in their professional sphere as well in safety engineering.

sellokomotiven, Beschäftigtenzahl 287.

WÄRMEWIRTSCHAFT

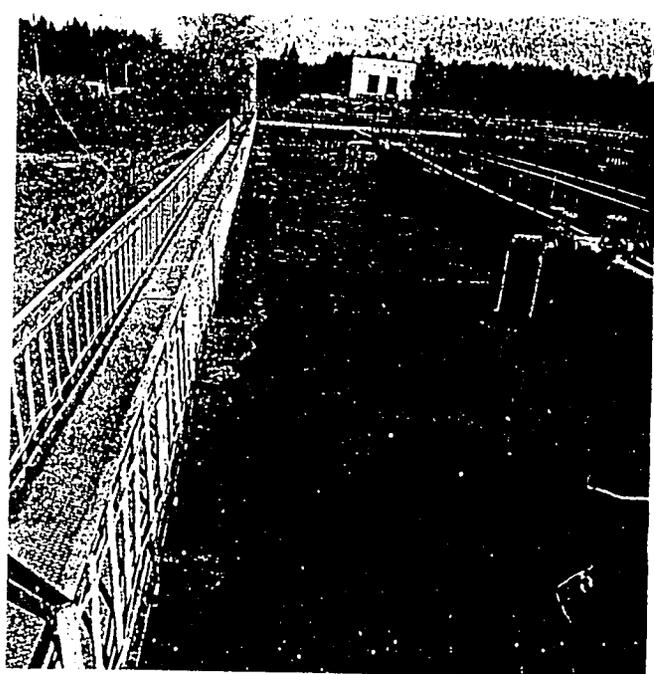
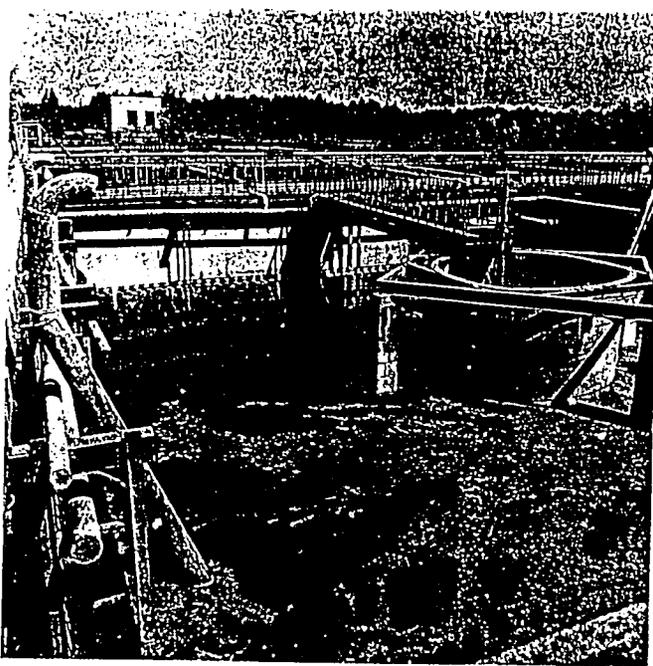
Jährliche Wärmeerzeugung: 419 Gcal.

Dampfanlieferung dem Asbestzementbetrieb und dem Strichsbetrieb „Karpėnai“ i.J. 19... 66,9 tausend Gcal.

Heisswassergebrauch: 16000 Gcal. Wärmeanlieferung für die Stadt Naujoji Akmenė: 66,4 Gcal Wärme (Heizung und Heisswasser).

WASSERWIRTSCHAFT

1991 hat man 2622 tausend m³ Wasser aus dem Fluss Agluona und 1333 tausend m³ Wasser aus dem Teich Sablauskiai für technologische Ziele gebraucht. Der Teich Sablauskiai mit einer Fläche von 123,8 ha, Fassungsvermögen von 2 Mill.m³. Kapazität der Wasserwirtschaft: 3044 tausend m³ pro Jahr. Anlieferung der Stadt Naujoji Ak-



DARBUOTOJŲ RENGIMAS IR MOKYMAS

Per metus valstybinėje įmonėje „Akmenės cementas“ parengiama vidutiniškai po 200 naujų darbuotojų, kvalifikaciją pakelia 350 darbuotojų, peratestuojama 2000 darbuotojų. Kasmet 100-120 inžinerijos technikos darbuotojų pakelia profesinę kvalifikaciją, atnaujiną ir pagilina saugumo technikos, darbo apsaugos žinias.

DARBO APSAUGOS SISTEMA

Kolektyvinė sutartis ir kiti susitarimai įmonės administraciją įpareigoja užtikrinti sveikas ir saugias darbo sąlygas. Sveikatai kenksmingiausi faktoriai yra vibracija, įrengimų triukšmas, dulketumas, aukšta temperatūra gamybos patalpose. Darbo saugos profilaktika, priežiūra, kontrolė, darbuotojų konsultavimu ir medicininio aptarnavimo rūpinasi įmonės darbo apsaugos ir saugumo technikos skyrius.

THE SYSTEM OF LABOUR PROTECTION

Collective and other agreements oblige the administration of the plant to guarantee safe working conditions. The factors harmful for health are the following: vibration, noise, dust, high temperature in working places.

The department of labour protection is in charge of the workers medical check up, medical service, safe labour conditions and their control.

The workers of this department measure the noise, vibration, dust, lighting, instruction workers on safe methods of work, check up the equipments in working places.

The rate of the worker's illnesses and professional diseases is stable. During the year every worker is ill for 10 days.

HEALTH PROTECTION

The plant „Akmenė Cement“ has created a reasonable health

menė i.J. 1991: 3021 tausend m3 Trinkwasser.

ÖKOLOGIEWIRTSCHAFT

Kapazität der Wassereinrichtungen für Reinigung: 10 tausend m3 Wasser pro Tag und Nacht. Jährlich wird 2,5 Mill.m3 Wasser gereinigt.

Jährlich wird 1125 tausend t Klinkerstaub aufgefangen. Es sind 22 Elektrofilter eingerichtet. An den Zementmühlen, Zement- und Klinkersilos, Verpackungsmaschinen sind mehr als 40 Ärmelfilter eingerichtet. Aufgefangener Staub wird in die Drehrohröfen zurückgegeben.

BESCHÄFTIGTENSCHULUNG

Jährlich werden durchschnittlich 200 neue Arbeitstätige im staatlichen Unternehmen „Akmenės cementas“ angelernt, 350 Beschäftigte weiterausgebildet, 2000 Werkstätige umgeschult. Jährlich bekommen 100-120 Ingenieure und Techniker Weite-

Skyriaus darbuotojai tikrina triukšmo, vibracijos, dulkelumo, apšvietimo parametrus darbo vietoje, rengia instruktažus ir saugių darbo metodų mokymo užsiėmimus, kelimo ir šildymo įrenginių eksploatavimo patikrinimus bei kitas kontrolės priemones.

Įmonėje stabilus bendrasis bei profesinis darbuotojų sergamumas. Per metus vienas įmonės darbuotojas serga vidutiniškai 10 dienų.

SVEIKATOS APSAUGA

Įmonėje „Akmenės cementas“ sukurta patogi ir visiems darbuotojams prieinama sveikatos apsaugos sistema.

Pačioje įmonėje veikia sveikatos punktas. Jame pacientus aptarnauja gydytojas ir 6 medicinos personalo darbuotojai. Atliekamos visos fizinės procedūros, injekcijos, veikia stomatologinis kabinetas.

Naujosios Akmenės mieste veikia įmonės sanatorija profilaktoriumas. Čia ligonius aptarnauja 34 darbuotojai, iš jų 3 gydytojai. Veikia fizinės, purvo, vandens procedūrų skyriai, gydomosios fizikultūros, inhaliacijų, stomatologinis ir procedūrų kabinetai, yra poilsio patalpos. 1991 m. sanatorija profilaktoriumas aptarnavo 1470 žmonių iš „Akmenės cemento“ bei kitų miesto žmonių ir žinybų.

protection system, which is accessible to all the workers.

Health service operates at the very plant. A doctor and 6 nurses take care of the patients. All kinds of physiotherapeutic treatment, injections, stomatological service are available here.

The plant has a prophylactic sanatorium in the town of Naujoji Akmenė. 34 medical workers take care of patients here, among them there are 3 doctors. There one can find all sorts of procedures: physiotherapeutic, mud, water, gymnastics, inhalations. The prophylactic sanatorium in 1991 treated 1480 people from „Akmenė Cement“ and from other enterprises.

CONDITIONS FOR WORKERS' REST AND REHABILITATION

For the worker's summer rest the plant „Akmenė Cement“ has its own residence near the Baltic sea and in the health resort Druskininkai. There is a beautiful place for weekends near the river Virvytė, 30 km from town of Naujoji Akmenė.

The plant has the places for rest in the following health resorts near the Baltic Sea:

In Palanga - 80 places

In Pervalka (Neringa) - 20 places

In ruca (Latvia) - 40 places

In health resort Druskininkai 16 places

rausbildung, erneuern und vertiefen ihre Arbeitsschutzkenntnisse.

ARBEITSSCHUTZSYSTEM

Vertrag der Belegschaft und andere Verabredungen verpflichten die Administration des Unternehmens gesunde und sichere Arbeitsbedingungen zu garantieren. Gesundheitsschädlichste Faktoren sind Vibration, Einrichtungsgeräusche, Staubigkeit, hohe Temperatur in Betriebsräumen. Die Arbeitsschutzabteilung des Unternehmens sorgt für Sicherheitstechnikprophylaxe, -aufsicht und -kontrolle, Beschäftigtenberatung und medizinische Betreuung.

Die Mitarbeiter der Abteilung prüfen Lärm-, Vibration-, Staubigkeits-, Beleuchtungsparameter an Arbeitsstellen, veranstalten Belehrungen, unterrichten in Betriebssicherheitsmethoden, kontrollieren den Hebe- und Heizeinrichtungenbetrieb u.a.

Stabile Allgemein- und Berufsmorbidität der Beschäftigten. Jährlich ist ein Arbeiter im Durchschnitt 10 Tage krank.

GESUNDHEITSSCHUTZ

Das Gesundheitsschutzsystem des Unternehmens „Zement von Akmenė“ ist bequem und für alle Arbeiter zugänglich.

Es funktioniert eine Sanitätsstelle. Da bedient die Patienten ein Arzt, ihm helfen 6 Mitarbeiter des Gesundheitswesens. Es werden alle Physiotherapieverfahren durchgeführt,

DARBUOTOJŲ POILSIO IR REABILITACIJOS SALYGOS

Darbuotojų vasaros poilsiuvi mėnė „Akmenės cementas“ turi nuosavas bazes Baltijos pajūryje ir Druskininkų kurorte ir trumpam savaitgalio poilsiuvi - prie Virvytės upės, už 30 km nuo Naujosios Akmenės miesto.

Baltijos pajūryje veikia šios poilsio bazės:

Palangoje - 80 vietų,

Pervalkoje (Neringa) - 20 vietų,

Rucavoje (Latvija) - 40 vietų.

Poilsio bazė Druskininkų kurorte turi 16 vietų.

Trumpalaikio poilsio bazė „Virvytė“ - 160 vietų.

Poilsio bazės veikia pamainomis nuo birželio 1 iki rugsėjo 1 d.

Aktyviai sportuojantiems įmonės darbuotojams bei jų šeimoms skirti „Akmenės cemento“ sporto rūmai. Juose yra 983 kv. m ploto sporto žaidimų salė, 25x14 m plaukymo baseinas. Įmonė turi šaudymo sporto bazę. Ji remia aviacijos technikos sporto klubą, rengiantį sklandymo ir parašiutinio sporto entuziastus. Lietuvos ir Akmenės rajono pirmenybėse dalyvauja įmonės krepšinio, futbolo, tinklinio, šaudymo, šachmatininkų komandos.

EKONOMIKA IR FINANSAI

Įstatinio kapitalo struktūra

Įmonės bendras įstatinis kapitalas 100 proc.

tame tarpe: valstybinis kapitalas 90 proc.

akcinis kapitalas 10 proc.

For short rest in „Virvytė“ - 160 places.

The places for rest operate in 9 shifts from June till September.

„Akmenės Cement“ has a sports palace for its workers and their families. There is a big hall (983 sq. m.) for games, a swimming pool (25x14 m). It has a place for shooting. It supports the aviation club training glider pilots and parachute jumpers. There are good basketball, football and volleyball teams, many chessplayers at the plant.

ECONOMICS AND FINANCE

General regulations capital of the plant 100 %

including: state capital 90 %

capital of shares 10 %

PROFITABLENESS

1991 indexes

The profitableness of plant according to production costs 37 %

The profitableness of the plant's regulations capital 33 %

INCOME STRUCTURE AND RESOURCES

1991

Income resources	Income in thousand roubles	Income structure %
General income	274448,8	100
for cement	212161,3	77,3
for slate	18623,1	6,79
for asbestos cement pipes	16951,4	6,18
for other production	26713,0	9,73

EXPENSES STRUCTURE

1991 (%)

Expense	%
The whole costs	100
raw and basic materials	8
additional materials	5

Injektionen gemacht, zur Verfügung steht ein Stomatologe.

In der Stadt Naujoji Akmenė gibt es das Betriebssanatorium. Die Kranken werden hier von 34 Mitarbeitern des Gesundheitswesens (3Ärzten) bedient. Es funktionieren Physiotherapiezimmer, Moorbäder, Wasserheilverfahrenabteilung, Kabinette für kurative Körperkultur, Stomatologie, Heilverfahren, Entspannungsräume. 1991 hat das Betriebssanatorium 1480 Menschen aus „Zement von Akmenė“ und anderen Betrieben der Stadt behandelt.

ERHOLUNGS-UND REHABILITATIONSBEDINGUNGEN DER WERKTÄTIGEN

Zur Erholung im Sommer hat das Unternehmen eigene Erholungsheime an der Ostsee und im Kurort Druskininkai, zur Erholung am Wochenende - am Fluss Virvytė, 30 km von Naujoji Akmenė entfernt.

Am Ostseestrand funktionieren folgende Erholungsstationen:

in Palanga - 80 Plätze,

in Pervalka (Neringa) - 20 Plätze,

in Rucava (Lettland) - 40 Plätze.

Im Kurort Druskininkai gibt es 16 Plätze, in „Virvytė“ 160 Plätze. Erholungsstationen sind vom 1. Juni bis zum 1. September in 9 Schichten in Betrieb.

Für aktive Sportler steht der Sportpalast zur Verfügung. Da gibt es eine 983 m³ grosse Turnhalle, ein 25x14 m grosses Hal-

Rentabilumas

1991 m. rodikliai

Įmonės rentabilumas pagal produkcijos savikainą 37 proc.

Įmonės įstatinio kapitalo rentabilumas 33 proc.

PAJAMŲ STRUKTŪRA IR ŠALTINIAI 1991 m.

Pajamų šaltiniai	Pajamų kiekis tūkst. rb	Pajamų struktūra proc.,
Bendrosios pajamos iš jų:	274448,8	100,
už cementų	212161,3	77,3
už šiferį	18623,1	6,79
už asbestcementinius vamzdžius	16951,4	6,18,
už kitų produkcijų	26713,0	9,73

IŠLAIDŲ STRUKTŪRA 1991 m. (proc.)

Išlaidų pobūdis	Proc.
Visa įmonės savikaina tame tarpe	100
žaliavos ir pagrindinės medžiagos	8
pagalbinės medžiagos	5
energetiniai resursai	60
darbo apmokėjimo lėšos	15
amortizacija	3
remonto ir kitos piniginės lėšos	6
negamybinės išlaidos	3

PELNAS IR JO PASKIRSTYMAS 1991 m.

Iš viso gauta pelno 1991 metais 73766 tūkst. rublių

Pelno panaudojimo tikslas	Proc.
Visi valstybiniai mokesčiai į biudžetą	40
pelno mokesčiai	30
palikanos už valstybinio kapitalo naudojimą	12
Įmonei likęs pelnas priskaičiuoti	58
dividentai akcininkams	2
panaudotos labdarai, naujos technikos diegimui, projektavimo darbai	2
išmokeita premijų, santiejų darbuotojams	10

sources of energy	60
wages	15
amortization	3
repair & other expenses nonproduction	6
expenses	3

PROFIT AND ITS DISTRIBUTION 1991

The whole profit in 1991 was 73766 thousand roubles

use of profit	%
All state tax for budget including:	42
profit tax	
interest for using state capital	12
The profit remaining at the plant	58
including: dividends for shareholders	2
charity, new technical devices/projects	2
premiums and bounties for workers	10
for social and cultural programs	8
reserve fund	14
reserve fund of share capital	22

TRADE UNIONS OF WORKERS

There is the trade union of construction workers at the state plant „Akmenė Cement“. It consist of 1700 members. There are 29 organizations at different departments.

The highest organ of the union is conference, taking place every 3 years.

Committees of primary organizations make reports on their work and are elected every 2 years.

The committee of trade union of the plant consists of 27 members, delegated by primary trade union organizations of other departments.

The chairman of the committee of plant's trade union Drąsutis

lenschwimmbad, einen Schiessplatz. Das Unternehmen unterstützt den Lufttechnikklub der Segelflieger und Fallschirmspringer ausbildet. Meisterschaften Litauens u. des Bezirks Akmenė nehmen Fussball-, Basketball-, Volleyball-, Schiess-, Schachspielmannschaften teil.

ÖKONOMIK UND FINANZEN

Struktur des Grundkapitals

Grundkapital des Unternehmens 100%

darunter:

Staatskapital 90%

Aktienkapital 10%

Eintrüglichkeit 1991

Eintrüglichkeit des Unternehmens

nach Produktionsselbstkosten 37%

Eintrüglichkeit des Grundkapitals 33%

STRUKTUR UND QUELLEN DER EINKÜNFEN 1991

Quellen der Einnahmen	Einnahmengen tausend Rbl.	Struktur der Einnahmen %
Allgemeine Einnahmen	274448,8	100
darunter: für Zement	212161,3	77,3
für Schiefer	18623,3	6,79
für Asbestzementröhren	16951,4	6,18
für andere Produktionsarten	26713,0	9,73

AUSGABENSTRUKTUR 1991 (%)

Ausgabeneigenschaften	%
Selbstkostenpreis des Unternehmens	100
darunter: Rohstoffe u. Hauptmaterialien	8
Hilfsmaterialien	5

panaudota įmonės socialinėms ir kultūrinėms programoms realizuoti išsargos pelno rezervo fondas	8
akcinio kapitalo rezervo fondas	14
	22

DARBUOTOJŲ PROFESINĖ SAJUNGA

Valstybinėje įmonėje „Akmenės cementas“ veikia Statybos ir statybinių medžiagų pramonės darbuotojų profsajungos organizacija. Joje 1700 profesinės sąjungos narių. Įkurtos 29 pirminės (cechų, barių) organizacijos.

Aukščiausias profesinės sąjungos organizacijos organas - konferencija, šaukiama kas 3 metai. Pirminių organizacijų komitetai atsiskaito ir renkami kas 2 metai. Įmonės profesinės sąjungos komitete 27 nariai, deleguoti pirminių (cechų, barių) profsajungos organizacijų.

Įmonės profsajungos komiteto pirmininkas Drąsuis LAKAVIČIUS, išrinktas 1991 m. kovo 12 d.

ĮMONĖ IR MIESTAS

Darbininkų gyvenvietė 3 km nuo cemento gamyklos per 4 dešimtmečius išaugo į Naujosios Akmenės miestą, kuriame dabar gyvena 14 tūkstančių žmonių. Įmonės ir miesto ūkis glaudžiai susiję. Per daugelį metų įmonė pastatė 3180 butų ir individualių namų. Įmonė miestui tiekia šilumą ir karštą vandenį, eksploatuoja geriamo vandens verslovę. Daugelį metų „Akmenės cementas“ atlieka arba finan-

LAKAVIČIUS was elected on March 12, 1991.

THE PLANT AND THE TOWN

The workers' settlement, 3 km from cement plant, grew into the town of Naujoji Akmenė during 4 decades. the population is 14 thousand at present. The economics of the plant and the town are tied together. In the period of years the plant has built 3180 flats and individual houses. The plant supplies the town with heat and hot water, operates drinking water enterprise.

In 1958 the plant built a palace of culture which became the center of the town's cultural life. All kinds of banks, folk music groups, choirs, performers, children's art studio find place for work, rehearsals and shows under its roof.

The plant „Akmenė Cement“ operates a number of engineering networks, supports 3 secondary schools and the central hospital. The people of the town are allowed to make use of the plant's resting places. The town and people living in the vicinity can watch TV programs broadcasted via the transmitter set up by the plant. The activity of the „Akmenė Cement“ keeps in line with the directions of activity of other plants in the town. The state plant of construction materials in Naujoji Akmenė supplies the cement production with lime and clay, operates the pits and

Energiequellen	60
Mittel des Leistungslohnes	15
Amortisierung	3
Reparatur und andere Gebührenden	6
nichtbetriebliche Ausgaben	3

DER ERTRAG UND VERTEILUNG 1991

Ertrag fürs Jahr 1991: 73766 tausend Rbl.

Ziel der Ertragsverwendung	%
Alle Staatssteuern des Budgets	42
darunter: Gewinnsteuer	30
Lombard-Zins für Gebrauch des Staatskapitals	12
Dem Unternehmen gebührender Gewinn	58
darunter: Dividenden für Aktionäre	2
Wohltätigkeit, Automatisierung u. Mechanisierung, Projektierarbeiten u. Gratzuzugaben den Mitarbeitern	10
Sozial- und Kulturprogramm	8
Gewinnreservefonds	14
Reservefonds des Aktienkapitals	22

GEWERKSCHAFT DER WERKTÄTIGEN

Im Unternehmen wirkt Gewerkschaft der Bau- und Bauproduktionsindustrie. Sie umfasst 1700 Mitglieder. Es sind 29 Grundorganisationen gegründet.

Höchstes Organ der Gewerkschaft ist Konferenz (alle 3 Jahre).

Komitees der Grundorganisationen werden alle 2 Jahre gewählt. Im Komitee der Unternehmensgewerkschaft sind 27 Mitglieder aus Grundorganisationen.

suoja miesto valymo, gatvių asfaltavimo darbus, apšvietimą. 1958 metais įmonės pastatyti kultūros rūmai yra miesto kultūrinio gyvenimo centras, juose repetuoja ir koncertuoja choras, liaudies kapela, vokaliniai ansambliai, spektaklius ir koncertus rengia atvykstantys profesionalūs meniniai kolektyvai, veikia liaudies teatras, vaikų dailės studija.

„Akmenės cemento“ įmonė nutiesė ir eksploatuoja daug miesto inžinerinių tinklų, teikia paramą mieste esančioms 3 vidurinėms mokykloms, rajono centrinei ligoninei. Miesto gyventojai turi galimybių naudotis cementininkų sanatorijos prifilaktoriūmo paslaugomis, miesto ir jo apylinkių gyventojams iš cementininkų įrengto retransliatoriaus transliuojamos televizijos programos.

„Akmenės cemento“ gamybinė veikla susijusi su kitų miesto įmonių veiklos profiliu. Naujosios Akmenės valstybinė statybinių medžiagų įmonė tiekia gamybai klintis ir molį, eksploatuoja karjerus ir atlieka daug įrengimų remonto darbų. Valstybinė autotransporto įmonė specialiomis mašinomis cementą pristato Lietuvos teritorijoje esantiems klientams.

Keletas įmonės darbuotojų išrinkti Akmenės rajono Tarybos deputatais.

ĮMONĖ IR LIETUVA

„Akmenės cementas“ jau daug metų yra viena iš didžiausių ir viena iš stabiliausiai dirbančių

provides repair of the equipments. The state transportation plant provides social trucks for carrying cement to different places all over Lithuania.

THE PLANT AND LITHUANIA

For many years „Akmenė Cement“ has been one of the biggest stable working plants in Lithuania, having a big importance to the economics of the whole state. The production of the plant can be met in different corners of Lithuania. Everything built or restored in Lithuania during the past 40 years couldn't do without Akmenė cement. One can mention Kaunas and Elektrėnai power stations, restoration of old towns, churches, theatres, health resorts, Klaipėda's port etc.

„Akmenė Cement“ was one of the first plants in Lithuania that freed itself from the direct the Moscow rule. The plant gave financial help to Lithuanian SAJUDIS and donated 20 thousand dollars to Lithuanian TV, destroyed by the Soviet army which occupied the TV tower on January 13, 1991.

THE PLANT AND THE WORLD

Since the very beginning up to 1990 „Akmenė Cement“ was integrated into the industry of building materials of former USSR and was one of the most progressive plants according to the Soviet standards. That's why

Der Vorsitzende des Gewerkschaftskomitees ist Drąsutis LAKAVIČIUS - LAKAVITSCHIJS, am 12.März 1991 gewählt.

DAS UNTERNEHMEN UND DIE STADT

Arbeitersiedlung in 3 km vom Zementherstellungsunternehmen ist in 4 Jahrzehnten zur Stadt Naujoji Akmenė geworden, die heutzutage 14 tausend Menschen zählt. Die Wirtschaft der Stadt und des Unternehmens sind eng verbunden. In den vielen Jahren hat das Unternehmen 3180 Wohnungen und Einfamilienhäuser gebaut. Es liefert Heizung und Heißwasser der Stadt. Seit vielen Jahren führt es durch und finanziert die Arbeiten der Stadtreinigung, Strassenasphaltierung und -beleuchtung.

Der 1958 vom Unternehmen gebaute Kulturpalast ist zum Zentrum des Kulturlebens der Stadt geworden. Dort arbeiten: Chor, Volkskapelle, Vokalensembles, Volkstheater, Kinderkunstschule. Ihre Vorstellungen und Konzerte veranstalten zur Gastrolle kommende Schauspielerkollektive, Kulturgruppen.

Das Unternehmen hat das Ingenieurnetz der Stadt gebaut und betreibt es, leistet den 3 Mittelschulen, dem Zentralkrankenhaus des Bezirks Beihilfe. Die Stadteinwohner dürfen das Betriebs-sanatorium besuchen, Fernsehsendungen beobachten, die vom Unternehmen eingerichteter Fernsehzubringer überträgt.

Lietuvos gamyklų, reikšminga visos valstybės ekonomikai. Akmenės cementininkų darbo pėdsakus šiandien aptiksi visuose Lietuvos kampeliuose. Kauno hidroelektrinė ir Elektrėnų šiluminė elektrinė, restauruoti senų miestų kvartalai ir bažnyčios, teatrai ir kurortai, Klaipėdos uostas - visa, kas per pastaruosius 40 metų Lietuvoje pastatyta ar restauruota, daryta naudojant Akmenės cementą.

„Akmenės cementas“ buvo viena iš pirmųjų tiesiogiai Maskvai pavaldžių Lietuvos įmonių, išsivadavusių iš TSRS diktato ir perėjusių į Lietuvos reguliavimo sferą. Įmonė materialiai parėmė Lietuvos Sąjūdį jo kūrimosi metais, skyrė 20 tūkst. dolerių okupacinės TSRS kariuomenės nuniokotai po 1991 m. sausio 13 - osios Lietuvos televizijai.

ĮMONĖ IR PASAULIS

Nuo pat pradžios iki 1990 metų „Akmenės cementas“ buvo tvirtai integruotas į buvusios TSRS statybinių medžiagų pramonę kaip viena stambiausių ir pagal TSRS lygi viena pažangiausių cemento gamyklų. Suprantama, kad įmonėje dirba TSRS pagaminti įrengimai, iš ten iki šiol gaunama žaliavų, remonto medžiagų. Savo ruožtu ilgą laiką daugiau kaip pusė Akmenėje pagaminto cemento buvo tiekiamą kitoms buvusioms TSRS respublikoms ir sritims. Atkūrus nepriklausomą Lietuvos valstybę, su buvusios TSRS įmonėmis for-

there work equipments made in the USSR and some raw materials or the materials used for repair are brought from there. For a long time more than a half of the cement produced in Akmenė had been sent to other republics of the former USSR. After the restoration of the independent Lithuanian State useful trade and exchange are encouraged on both sides.

A number of workers from cement plants of Cuba, Vietnam, Iraq and other states used to work probation or improve their skills at „Akmenė Cement“. At the same time 37 workers from the plant worked in cement production in Egypt, Cuba, Iraq, Bulgaria, Poland, Mali, Yemen, Mongolia.

Small quantities of „Akmenė Cement“ production has been exported to Poland and Yugoslavia for a long time. Since 1988 its cement has been exported to Finland, later - to Sweden. There are connections with German cement plants and firms, Export of cement from Akmenė has all the possibilities to expand.

THE MOST IMPORTANT MOMENTS FROM THE HISTORY OF „AKMENĖ CEMENT“

27. 12 1945 - decision to build a cement plant in Lithuania

11. 09. 1946 - the beginning of the project

1947 - beginning of construction in the village of Karpėnai, building of the railway

Die Betriebstätigkeit ist eng mit den anderen Stadtbetrieben verbunden. „Zement von Akmenė“ bekommt Kalkstein und Ton vom Baumaterialienbetrieb, der auch Einrichtungenreparatur durchführt, Gruben betreibt. Staatliches Transportunternehmen liefert den Kunden Litauens Zement.

Einige Werk tätige sind Deputierte des Bezirksowjets von Akmenė.

AS UNTERNEHMEN UND LITAUEN

„Zement von Akmenė“ zählt seit vielen Jahren zu den grössten und stabilsten Unternehmen Litauens, das auch für die Staatswirtschaft bedeutend ist. Die Arbeitsspuren der Mitarbeiter kann man überall in Litauen finden. Pumpspeicherwerk von Kaunas, Wärmekraftwerk von Elektrėnai, restaurierte Kirchen, Theater, Wohnviertel der alten Städte und Kurorte, Hafen von Klaipėda - das ist alles, was mit Zement von Akmenė in 40 Jahren geleistet wurde.

„Zement von Akmenė“ war eines der ersten Unternehmen, das sich von der Zustandigkeit Moskaus befreit hat. Es hat der nationalen Befreiungsbewegung Litauens „Sąjūdis“ in ihren Gründungsjahren materiell geholfen, 20 tausend Dollar dem am 13. Januar 1991 von der Sowjetarmee verwüsteten Fernsehen ausgezahlt.

DAS UNTERNEHMEN UND DIE WELT

Vom Bauanfang an bis zum Jahre 1990 war „Zement von

muojasi abipusiškai naudingi prekybos ir mainų santykiai.

Akmenėje yra stažavęsi ir kėlę kvalifikaciją Irako, Kubos, Vietnamo ir kitų valstybių cemento gamyklų darbininkai bei specialistai. Savo ruožtu 37 „Akmenės cemento“ darbininkai ir specialistai yra dirbę įsisavinant cemento gamybos pajėgumus Egipto, Mali, Kubos, Irako, Mongolijos, Jemeno, Bulgarijos, Lenkijos gamyklose.

Jau seniau „Akmenės cemento“ produkcija nedideliais kiekiais buvo eksportuojama į Jugoslaviją, Lenkiją. Nuo 1988 metų Akmenėje pagamintas cementas eksportuojamas į Suomiją, vėliau - į Švediją. Dalykiniai ryšiai užmegzti su Vokietijos cemento gamyklomis ir firmomis. Cemento eksportas iš Akmenės turi galimybių plėstis.

SVARBESNI „AKMENĖS CEMENTO“ ISTORIJS PUSLAPIAI

1945. VII. 27 - priimtas nutarimas statyti cemento gamyklą Lietuvoje.

1946. IX. 11 - įmonės darbų pradžia.

1947 m. - pradėti statybos darbai Karpėnų kaime, tiesiamas geležinkelis.

1950 m. - pradėti Karpėnų klinčių karjero atidengimo darbai.

1952. IX. 20 - paleista pirmoji sukamoji krosnis.

1953. XI - paleista antroji sukamoji krosnis.

1956 m. - atlikta abiejų technologinių linijų rekonstrukcija, na-

1950 - beginning to operate Karpėnai limestone pit

20. 09. 1952 - the first rotatory furnace starts working

1956 - reconstruction of both technological lines, increase of efficiency 40 %, the plant starts stable operation

09. 1959 - the construction of the 3rd cement production line is finished

15. 07. 1961 - the 4th rotatory furnace started working

1963 - the plant of asbestos cement is built, producing ruffled slate

1964 - beginning to produce asbestos cement tubes. Oil is used for fuel instead of shale

02. 1967 - the beginning of the construction of 5th and 6th cement technological lines

10. 1969 - the construction of 5th technological line is finished

06. 1970 - 6th rotatory furnace begins to work

08. 1974 - 7th rotatory furnace begins to work

11. 1974 - 8th rotatory kiln begins to work, construction of 2nd cement plant is over

1975 - the plant reaches the efficiency of 3 mln. tons a year

1988 - Akmenė starts cement export to Finland

1990 - the plant gets into Lithuanian jurisdiction

Akmenė“ fest die Baumaterialienwirtschaft der SU integriert, als eines der grössten und besten in der damalige UdSSR. Selbstverständlich werden hier die in der SU hergestellte Einrichtungen und Anlagen betrieben, Rohstoffe benutzt. Lange Zeit ging die Hälfte der Zementlieferungen an ehemalige Sowjetrepubliken. Beim Wiederaufbau des unabhängigen Litauens bilden sich eiträgliche Handels- und Umtauschbeziehungen heraus.

In Akmenė haben Arbeiter der Zementherstellungsunternehmen und Fachleute aus Irak, Kuba, Vietnam u.a. Staaten Weiterbildung bekommen. 37 Mitarbeiter aus dem litauischen Betrieb haben in Ägypten, Mali, Kuba, Mongolei, Jemen, Bulgarien, Polen gearbeitet.

Schon früher hat man die Produktion von „Zement von Akmenė“ in kleinen Mengen an Jugoslawien, Polen, vom Jahr 1988 an Finnland, später an Schweden geliefert.

Das Unternehmen hat Fachbeziehungen mit Zementherstellungsunternehmen und Firmen Deutschlands aufgenommen. Zementausfuhr hat gute Möglichkeiten.

WICHTIGERE SEITEN DER GESCHICHTE „ZEMENT VON AKMENĖ“

1945.07.27 - Beschluss zum Bau des Zementherstellungsunternehmens in Litauen.

1946.09.11 - Anfang der Projektierungsarbeiten.

šumas padidėja 40 proc., įmonė pradeda dirbti stabiliai.

1959. IX - baigta 3-iosios technologinės cemento gamybos linijos statyba.

1961. VII. 15 - paleista 4-oji sukamoji krosnis.

1963 m. - pastatyta asbestcemenčio gamykla, pradėta banguoto šiferio gamyba.

1964 m. - pradėti gaminti asbestcemenčio vamzdžiai. Kuriai vietoj skalūnų imtas naudoti mazutas.

1967. II - pradėta 5-osios ir 6-osios cemento technologinių linijų statyba.

1969. X - baigta 5-osios technologinės linijos statyba.

1970, VI - paleista 6-oji sukamoji krosnis.

1974. VIII - baigta montuoti ir paleista 7-oji sukamoji krosnis.

1974. XI - paleista 8-oji sukamoji krosnis, baigta 2-osios cemento gamyklos statyba.

1975 m. - įmonė pasiekia 3 mln. tonų cemento per metus našumą.

1988 m. - Akmenės cementas pradamas eksportuoti į Suomiją.

1990 m. - įmonė tampa pavaldi Lietuvos Respublikai.



1947 - Beginn der Bauarbeiten im Dorf Karpėnai, Eisenbahnlegung.

1950 - Eröffnung der Kalksteingrube von Karpėnai.

1952.09.20 - Anlassen des ersten Drehrohrofens.

1953.11 - Anlassen des zweiten Drehrohrofens.

1956 - Rekonstruktion der beiden Technologielinien. Hebung der Arbeitsproduktivität zu 40%.

1959.09 - Ende der bauarbeiten der 3. technologischen Linie.

1961.07.15 - Anlassen des 3. Drehrohrofens.

1963 - Bauende des Asbestzementbetriebs, Anfang der Wellenschieferherstellung

1964 - Beginn der Herstellung von Asbestzementröhren. Masut gebrauch man als Brennstoff.

1967.02 - Baubeginn der 5. und 6. Zementherstellungslinien.

1969.10 - Anlassen der 5. technologischen Linie.

1970.06 - Anlassen des 6. Drehrohrofens.

1974.08 - Anlassen des 7. Drehrohrofens.

1974.11 - Anlassen des 8. Drehrohrofens, des 2. Zementbetriebs.

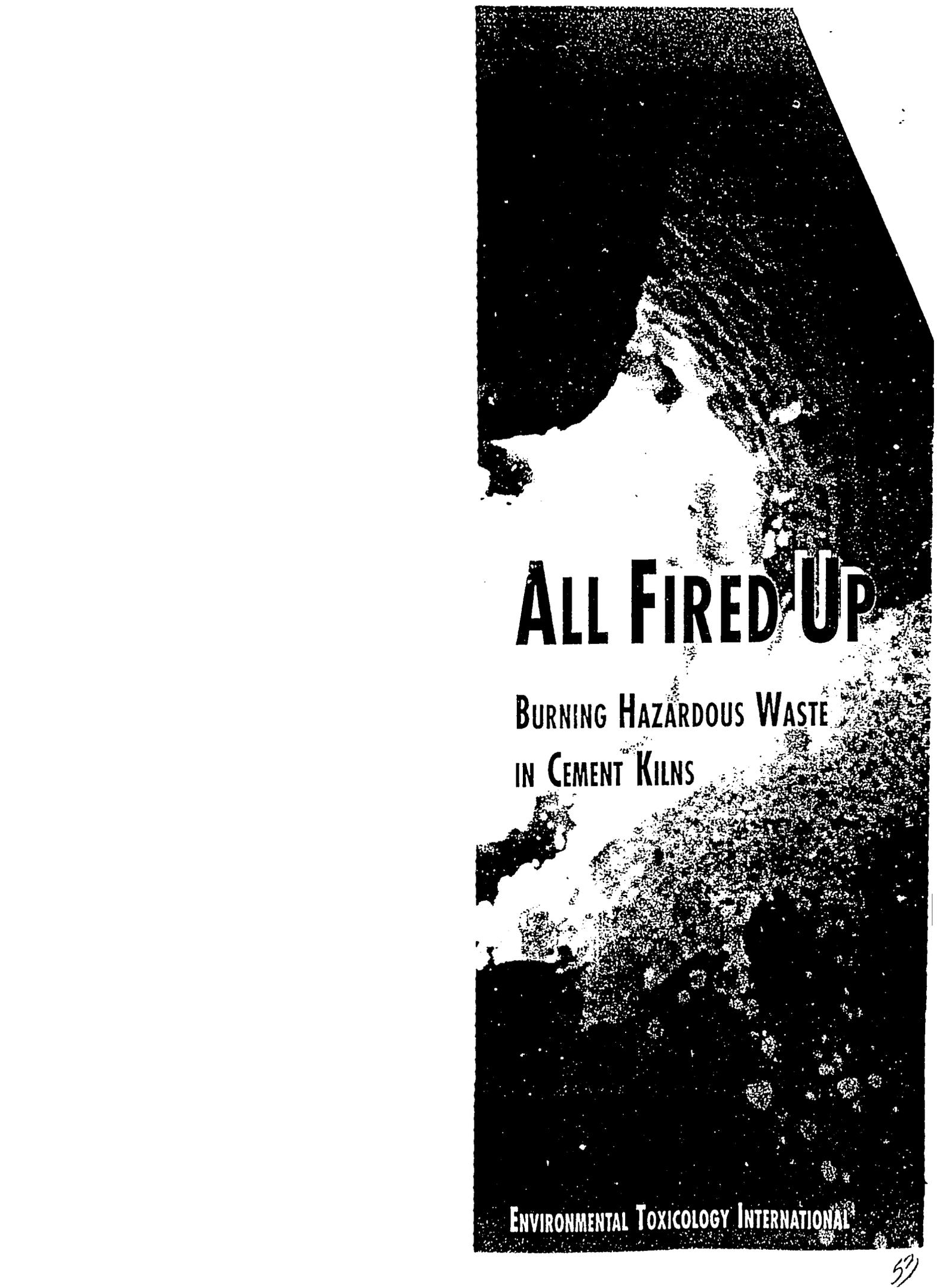
1975 - Hebung der Arbeitsproduktivität bis 3 Mill. t Zement pro Jahr.

1988 - Zementausfuhrbeginn nach Finnland.

1990 - Zuständigkeit des Unternehmens der Lit. Republik.

"AKMENĖS CEMENTAS", Naujoji Akmenė, 5464, Lithuania Tel. (8 - 295) 54140, 54995, 54097, Fax (8 - 295) 52198

92



ALL FIRED UP

BURNING HAZARDOUS WASTE
IN CEMENT KILNS

ENVIRONMENTAL TOXICOLOGY INTERNATIONAL

Published by Environmental Toxicology International (ETI), Inc.
&
The Combustion Research Institute, a Division of ETI
Copyright © 1992 by Environmental Toxicology International, Inc.
All Rights Reserved

ISBN 0-9631944-1-0

Ellen K. Mantus, Ph.D., Primary Author and Editor
Cover Design: The Rockey Company, Seattle, Washington
Cover Photo: Courtesy of Texas Industries, Inc.
Cement Kiln, Midlothian, Texas
Photo commissioned by
H.E.A.T., Inc., Dallas, Texas



This publication is printed on material
containing a minimum of 50% recycled waste paper.
The cover is printed on recycled stock.

For information on how to obtain copies
of this publication, contact:
Environmental Toxicology International, Inc.
600 Stewart Street, Suite 700
Seattle, Washington 98101 U.S.A.
Phone: (206) 441-6142 Fax: (206) 443-1812

This document may be photocopied with permission
of the publisher, ETI.

ETI is an environmental consulting firm dedicated
to the use of good science in the prevention, assessment, and communication
of environmental hazards throughout the world.

EXECUTIVE SUMMARY

Innovative ideas and new technologies are continually needed to manage hazardous waste. At present, one of the more controversial options in waste management is the burning of hazardous waste in cement kilns. This practice can result in the following benefits:

- energy recovery from combustible wastes with a high energy, low chlorine, and low metals content
- conservation of fossil fuels, such as coal and oil
- reduction in cement production costs
- destruction of hazardous organic waste.

The issues associated with burning hazardous waste in cement kilns are not generally reported in publicly accessible literature. This document has been written as a resource to help answer many of the questions that arise when evaluating this technology.

In presenting a comprehensive overview of the technical and regulatory issues surrounding the use of hazardous waste as a supplemental fuel in cement kilns, this document addresses the following topics:

- the cement production process
- restrictions on the wastes that can be used by the cement industry
- characteristics of a cement kiln that make it a suitable combustion device for the treatment of hazardous waste
- federal regulations that govern cement production facilities burning hazardous waste
- the fate of the constituents in the hazardous waste fuel
- the potential for adverse human health effects.

This analysis concludes that the organic and metal emissions of a well-designed and properly operated cement kiln burning hazardous waste are not substantially different from the emissions of a cement kiln burning only conventional fuel. In addition, the byproduct of the production process (i.e., cement kiln dust) and the final product (i.e., cement) do not appear to differ substantially as a result of burning hazardous waste as a supplemental fuel.

Because no substantial increases in organic and metal components have been observed in emissions, in cement kiln dust, or in cement when hazardous waste is burned as a supplemental fuel, no increases in adverse health effects due to the use of hazardous waste are expected. Assessments of health risks from emissions and cement kiln dust from kilns in the U.S. have supported this conclusion. Thus, properly operated cement production facilities under current (1991) regulations do not pose a greater risk to public health when a portion of the conventional fuel is replaced by hazardous waste.

TABLE OF CONTENTS

SECTION	PAGE
EXECUTIVE SUMMARY	iii
LIST OF TABLES.....	vii
LIST OF FIGURES	viii
ACRONYMS	ix
SOME QUESTIONS AND ANSWERS ABOUT BURNING HAZARDOUS WASTE IN CEMENT KILNS.....	x
1.0 OVERVIEW	1
2.0 CEMENT PRODUCTION.....	3
2.1 Raw Materials	3
2.2 The Production of Cement	5
2.3 Types of Processes for the Production of Cement	6
2.4 Cement Kiln Dust.....	8
3.0 HAZARDOUS WASTE AS A SUPPLEMENTAL FUEL.....	11
3.1 Definition of a Hazardous Waste	11
3.2 Types of Hazardous Waste Used by the Cement Industry.....	13
3.3 Fossil Fuel Versus Hazardous Waste Fuel	14
4.0 CHARACTERISTICS OF A CEMENT KILN	16
4.1 High Temperature and Long Residence Time.....	16
4.2 Natural Alkaline Environment.....	18
4.3 Minimization of Waste Generated	18
4.4 Thermal Stability	18
5.0 BENEFITS OF BURNING HAZARDOUS WASTE IN CEMENT KILNS.....	19
5.1 Recovery of Energy Value from Hazardous Waste	19
5.2 Conservation of Nonrenewable Fossil Fuels.....	19
5.3 Reduction in Production Costs.....	20
5.4 Use of Existing Technology to Treat Large Volumes of Hazardous Waste	20

TABLE OF CONTENTS (Continued)

SECTION	PAGE
6.0	FEDERAL REGULATIONS GOVERNING CEMENT KILNS THAT BURN HAZARDOUS WASTE.....21
6.1	The Boilers and Industrial Furnaces Rule.....21
6.1.1	Toxic Organic Emissions.....21
6.1.2	Toxic Metal Emissions.....23
6.1.3	Hydrogen Chloride/Chlorine Emissions.....25
6.1.4	Particulate Emissions.....25
6.1.5	Interim Status.....25
6.1.6	The BIF Rule and the Bevill Amendment.....26
6.1.7	Comparison of BIF Regulations to Hazardous Waste Incinerator Regulations.....26
6.1.8	Outcome of the BIF Rule.....27
6.2	Air Pollution Control Regulations.....27
6.3	Transportation Regulations.....28
6.4	Storage Requirements.....29
6.5	Worker Safety Requirements.....29
7.0	FATE OF THE CONSTITUENTS IN THE HAZARDOUS WASTE FUEL.....30
7.1	Organic Constituents.....30
7.1.1	DREs for Selected POHCs.....30
7.1.1.1	Problems with the Determination of the DRE.....30
7.1.1.2	Results from Trial Burns Conducted in the 1970s.....31
7.1.1.3	Results from Trial Burns Conducted in the 1980s.....32
7.1.1.4	Results from Trial Burns Conducted in the 1990s.....33
7.1.1.5	Results from Trial Burns that Focused on PCBs.....33
7.1.2	Products of Incomplete Combustion.....35
7.1.2.1	Comprehensive Studies.....35
7.1.2.2	Studies Focused on the Emission of PCDDs and PCDFs.....36
7.2	Metals.....39
7.2.1	General Behavior of Metals in the Cement Kiln.....39
7.2.2	Emissions.....41
7.2.3	Cement Kiln Dust.....43
7.2.3.1	Metal Concentrations in CKD.....43
7.2.3.2	Metal Concentrations in TCLP Extracts from CKD.....47
7.2.4	Cement.....49
7.2.4.1	Metal Concentrations in Cement.....49
7.2.4.2	Metal Concentrations in TCLP Extracts from Cement.....51

TABLE OF CONTENTS (Continued)

SECTION	PAGE
7.3 Acid Gas Emissions	53
7.3.1 HCl Emissions	53
7.3.2 SO ₂ Emissions	54
7.4 Particulate Emissions	55
8.0 POTENTIAL EFFECTS TO HUMAN HEALTH	56
8.1 Background	56
8.2 Cement Plant Emissions	58
8.2.1 Stack Emissions	58
8.2.2 Fugitive Emissions	60
8.2.3 Regulated Risks to Human Health	60
8.2.4 Health Assessments of Burning Hazardous Waste and Conventional Fuel	61
8.2.5 "Acceptable" Risk	63
8.3 Cement Kiln Dust	63
8.3.1 Dust	63
8.3.1.1 Occupational Studies	64
8.3.1.2 Public Health Impacts	65
8.3.2 Leachate	66
8.4 Cement	67
8.4.1 Dust	67
8.4.1.1 Occupational Studies	67
8.4.1.2 Public Health Impacts	68
8.4.2 Leachate	68
8.5 Risks of Transporting Hazardous Waste	69
8.6 Summary of Potential Health Effects	70
9.0 CONCLUDING REMARKS	71
10.0 GLOSSARY	72
11.0 REFERENCES	75
APPENDIX A: SAMPLE CALCULATION	A-1
APPENDIX B: LETTERS FROM LABOR UNIONS	B-1
ABOUT THE AUTHORS	

LIST OF TABLES

TABLE	PAGE
2.1 Concentrations (ppm) of Metals and Halogens Present in the Cement Raw Materials and in the Earth's Crust.....	4
2.2 Zones and Temperature Ranges of the Material in a Cement Kiln.....	5
2.3 Clinker Composition for Portland Cement.....	6
3.1 Concentrations (ppm) of Metals and Halogens in Coal and Used Oil.....	15
4.1 Combustion Criteria.....	16
7.1 Average DREs for a Wet and a Dry Process Cement Kiln.....	32
7.2 DREs for PCBs.....	34
7.3 Summary of PCDD/PCDF Stack Emissions by Source Category.....	38
7.4 Comparison of Metal Emissions (mg/sec) from Cement Kilns (CKs).....	41
7.5 Metal Emissions Comparisons.....	43
7.6 Metal Concentrations (ppm) in CKD: 1991 Investigation.....	44
7.7 Metal Concentrations (ppm) in CKD: 1982 Investigation.....	45
7.8 Comparison of Metal Concentrations (ppm) in CKD.....	46
7.9 Metal Concentration Limits for the TCLP Extract.....	47
7.10 Metal Concentrations (ppm) in TCLP Extracts from CKD.....	48
7.11 Metal Concentrations (ppm) in Cement.....	50
7.12 Comparison of Metal Concentrations (ppm) in Clinker.....	51
7.13 Metal Concentrations (ppm) in TCLP Extracts from Cement.....	52
8.1 Occupational Illness Rates, 1989.....	57
8.2 Occupational Illness Rates for the Concrete, Gypsum, and Plaster Products Industry.....	64
8.3 Comparison of Proposed "Acceptable" Metal Concentrations with Average Metal Concentrations in Portland Cement.....	69

LIST OF FIGURES

FIGURE	PAGE
1.1 Locations of Active Portland Cement Production Facilities in the U.S.	2
2.1 Typical Wet Process Cement Kiln.....	7
2.2 Typical Preheater Cement Kiln.....	9
4.1 Cumulative Gas Residence Time Versus Temperature for a Cement Kiln.....	17
7.1 General Chemical Structure for PCBs.....	34
7.2 General Chemical Structures for PCDDs and PCDFs.....	37
8.1 Modes of Dispersion and Deposition for Facility Stack Emissions.....	59

SOME QUESTIONS AND ANSWERS ABOUT BURNING HAZARDOUS WASTE IN CEMENT KILNS

The following questions are commonly asked about cement kilns and hazardous waste. The answers below are brief and thus greatly simplified. Comprehensive answers may be found in the sections of the document noted in parentheses.

Why does the cement industry burn hazardous waste?

*Bit/ oil Ton of fuel
3.95² 1 Ton Coal*

Cement production is an energy-intensive process. Hazardous waste replaces some of the nonrenewable fossil fuels (e.g., coal) required to make cement. If the U.S. cement industry replaced 25% of its energy requirement with hazardous waste, 3.8 million tons of domestic coal or 14.4 million barrels of domestic crude oil could be saved each year. (Sections 5.1, 5.2, and 5.3)

What types of waste are burned in a kiln?

The cement industry burns wastes that are now restricted from landfills, such as spent organic solvents and used oil. Energy values of these wastes are typically comparable with those of the fossil fuels that they are replacing. (Section 3.2)

Do any restrictions exist on the types of waste that can be used by the cement industry?

For the waste to serve as fuel, it must be combustible and have a significant energy content, low chlorine content, and low metals content. (Section 3.2)

Are toxic wastes burned in cement kilns?

Yes, but only if they are combustible and meet the criteria mentioned above. In addition, the organic components that make these wastes toxic are destroyed at the high temperatures that exist in the kilns. (Sections 3.2 and 4.1)

Is this practice a recent development?

No. Cement production facilities have been using hazardous waste as a supplemental fuel since the 1970s. Approximately 1.8 billion pounds of hazardous waste are burned in cement kilns each year. (Chapters 1.0 and 3.0)

Is the hazardous waste destroyed when it is burned as a supplemental fuel in cement kilns?

Hazardous waste consists of a variety of metal and organic constituents. The conditions (i.e., high temperature, turbulence, long residence time, and sufficient oxygen) that exist in cement kilns ensure destruction of the organic components in the hazardous waste. Metals are not destroyed by any combustion device; however, the vast majority of the metal components in the hazardous waste fuel are ultimately incorporated into the cement or the cement kiln dust. (Section 4.1 and Chapter 7.0)

ACRONYMS

APCD	Air pollution control device
ASTM	American Society for Testing and Materials
BIF	Boilers and Industrial Furnaces rule
Btu	British thermal unit
CAA	Clean Air Act
CFR	Code of Federal Regulations
CKD	Cement kiln dust
CRI	Combustion Research Institute
DRE	Destruction and removal efficiency
ESP	Electrostatic precipitator
MEI	Maximum exposed individual
NAAQS	National Ambient Air Quality Standards
NESHAP	National Emission Standards for Hazardous Air Pollutants
NSPS	New Source Performance Standards
PCA	Portland Cement Association
PCBs	Polychlorinated biphenyls
PCDDs	Polychlorinated dibenzo- <i>p</i> -dioxins
PCDFs	Polychlorinated dibenzofurans
PICs	Products of incomplete combustion
POHCs	Principal organic hazardous constituents
ppm	Parts per million
ppmv	Parts per million by volume
RCRA	Resource Conservation and Recovery Act
TCLP	Toxicity Characteristic Leaching Procedure
TSCA	Toxic Substances Control Act
U.S. EPA	United States Environmental Protection Agency

Do the emissions of a well-operated cement kiln burning hazardous waste fuel differ from the emissions of a cement kiln burning only conventional fuel?

The organic and metal emissions of a well-designed and properly operated cement kiln burning hazardous waste as a supplemental fuel are not substantially different from the emissions of a cement kiln burning only conventional fuel. In addition, recent data indicate that the byproduct of the production process (i.e., cement kiln dust) and the final product (i.e., cement) do not differ substantially as a result of burning hazardous waste. (Chapter 7.0)

Why are these wastes called hazardous?

These materials are labeled as hazardous waste for two reasons: (1) they no longer have commercial value and require disposal (this characteristic makes them a waste), and (2) they are either specifically listed by the U.S. Environmental Protection Agency (U.S. EPA) or meet one of the four U.S. EPA hazardous waste characteristics (ignitability, corrosivity, reactivity, or toxicity). Although the fuels (e.g., coal and oil) that have been burned in cement kilns for decades have commercial value and do not require disposal, they would meet at least one of the U.S. EPA hazardous waste characteristics. Thus, in a sense, the difference between the types of fuel (i.e., conventional versus hazardous) is primarily one of regulatory labels and definitions rather than any inherent hazardous characteristics. (Sections 3.1 and 3.3)

Are cement production facilities burning hazardous waste regulated?

Cement production facilities using hazardous waste as a supplemental fuel are required to meet a host of federal and state regulations that govern air emissions, waste transportation, waste storage, and worker safety. In February 1991, the U.S. EPA finalized the Boilers and Industrial Furnaces (BIF) rule. This rule, which is now in effect, includes emission standards for organic compounds, metals, hydrogen chloride, chlorine gas, and particulates. In addition, cement production facilities that burn hazardous waste must comply with any rules and regulations applicable to other hazardous waste treatment, storage, and disposal facilities. (Chapter 6.0)

What if an "upset" in the production process occurs?

The BIF rule requires that an automatic shutoff be installed in the waste fuel line so that the flow of waste to the kiln would cease in the case of an upset. Due to the large heat capacity of the kiln itself and the material inside the kiln, a significant change in temperature in a brief period of time is not possible. Therefore, the organic waste present in the kiln at the time of upset will be destroyed at the high temperature inside the kiln. (Sections 4.1, 4.4, and 6.1.1)

Where can I get further information about this process?

The attached document provides an overview of the technology and the currently available information on the effects of burning hazardous waste in cement kilns. The references provide additional sources of information.

1.0 OVERVIEW

Cement production is an extremely energy-intensive process. The average energy requirement to produce 1 ton of cement is approximately 4.4 million Btu (Ullman, 1991). This amount of energy is roughly equivalent to 400 pounds of coal. In 1990, the U.S. cement industry manufactured 79.7 million tons of cement (Huhta, 1991). The equivalent of 16 million tons of coal was required to produce this quantity of cement.

Because of the enormous energy requirements, the cement industry is continually investigating more economical production technologies and fuel options. In the 1970s, the U.S. cement industry recognized that hazardous waste with a high energy and low chlorine content could be used as a fuel in cement kilns. The viability of hazardous waste as a fuel in cement kilns has been demonstrated not only by the U.S., but by other countries such as Norway, Sweden, Switzerland, Germany, France, and Canada.

Currently (1991), 25 to 30 of the 105 active Portland cement production facilities in the U.S. (see Figure 1.1) burn hazardous waste (Costner and Thornton, 1990). Approximately 20 additional facilities are proposing to burn hazardous waste. Several benefits result from this practice. The most significant benefits are recovery of the energy value from the hazardous waste, conservation of nonrenewable fossil fuels (e.g., coal and oil), and reduction in a facility's fuel costs.

Regardless of these benefits, several issues must be considered. Most important among them is whether the cement industry can burn hazardous waste safely. In other words, can the use of hazardous waste as a fuel in the cement production process adversely affect human health? This question has recently become the topic of debate in many public forums.

This document addresses the issue of human health effects by first reviewing and discussing the best available data on the following topics:

- How is cement made?
- What is hazardous waste?
- What types of hazardous waste are used by the cement industry?
- What are the characteristics of a cement kiln that make it a suitable combustion device for the treatment of hazardous waste?
- Why does the cement industry want to burn hazardous waste?
- How are the cement production facilities that burn hazardous waste regulated?
- What happens to the organic and metal constituents in the hazardous waste?

Potential human health effects from the use of hazardous waste as a supplemental fuel in cement kilns are then evaluated.

The best available data were used in the generation of this document. As new data become available, a reevaluation of the conclusions noted in this document will be conducted and any changes in the conclusions will be reported in a second edition.

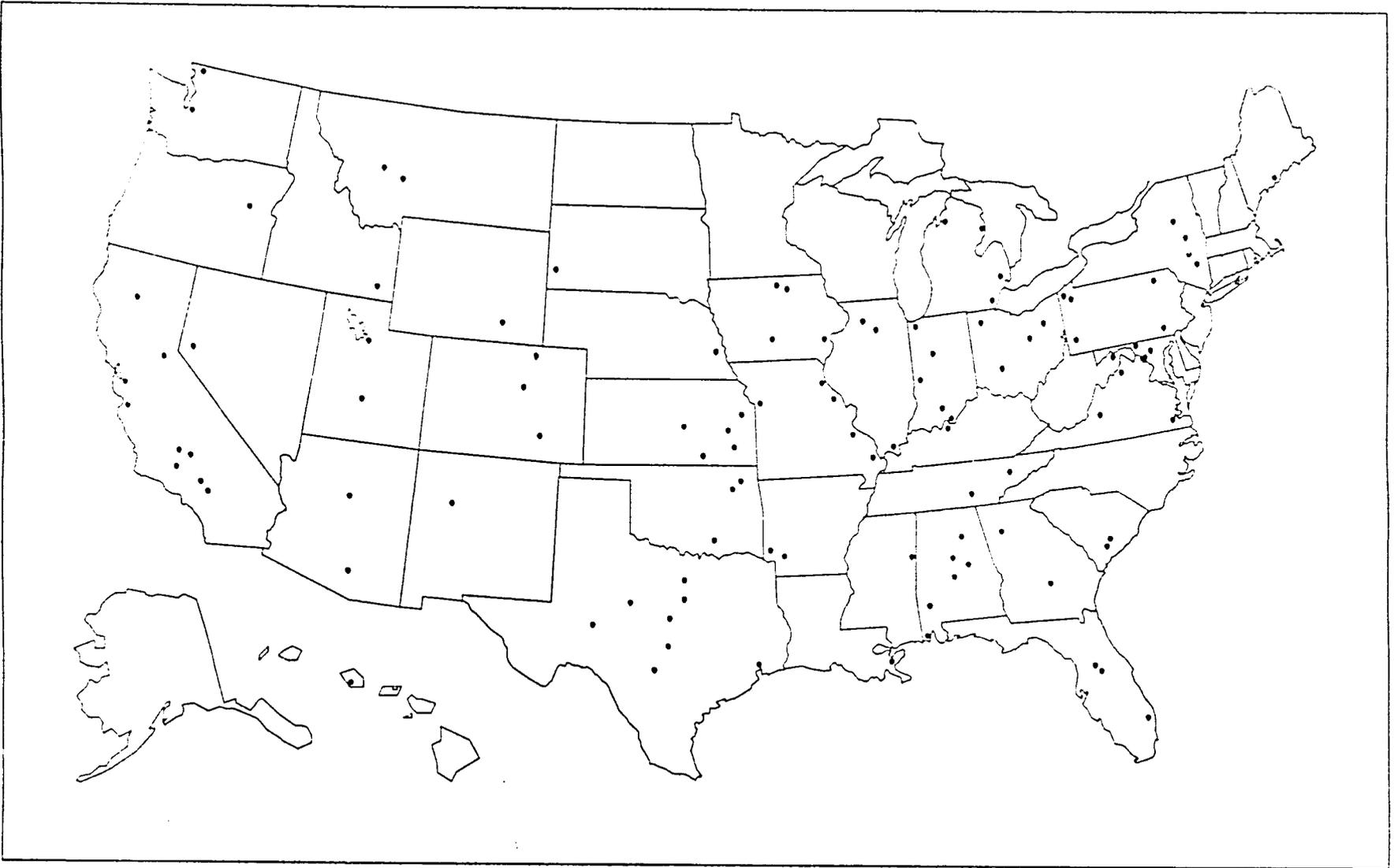


FIGURE 1.1 Locations of Active Portland Cement Production Facilities in the U.S.
(Map courtesy of *Rock Products Magazine*, 1990)

9

2.0 CEMENT PRODUCTION

Cement production involves heating raw materials, typically limestone and clay, to approximately 2,700°F to form clinker, which is cooled and then ground with a small amount of gypsum to give cement. The heating process occurs in a cement kiln [i.e., a cylinder lined with heat-resistant bricks, inclined 3 to 4% from the horizontal, and rotated one to four revolutions per minute (Taylor, 1990)]. The size of the cement kiln varies depending on the manufacturing process. A cement kiln can reach 750 feet in length and 25 feet in diameter (Engineering Digest, 1989). Details on the cement production process are presented below.

2.1 RAW MATERIALS

The production of cement requires the following components: calcium carbonate (CaCO_3), silica (SiO_2), alumina (Al_2O_3), and iron oxide (Fe_2O_3). Limestone typically provides the calcium carbonate. Clay or shale provides the remaining components. If necessary, the silica, alumina, or iron oxide content of the raw materials can be supplemented by sand, bauxite, or an iron ore respectively (Taylor, 1990).

The proportions of the raw materials used depend on the type of cement that is being produced. Portland cement, which requires a limestone to clay ratio of about 3 to 1, is the most common variety of cement manufactured (Sprung, 1985).

The raw materials used in the cement production process naturally contain metals and halogens (i.e., the group of elements in column VIIa of the periodic table). Thus, antimony, arsenic, barium, beryllium, cadmium, chromium, lead, mercury, nickel, selenium, silver, thallium, vanadium, zinc, bromine, chlorine, fluorine, and iodine are typically present in the raw materials. The amounts of these components depend on the geological formations from which the raw materials are mined.

Average concentrations of these constituents are listed in Table 2.1. Ranges of concentrations are presented when these data were available. For comparative purposes, the average concentrations of these components found in the earth's crust are also listed. Actual concentrations of each component in a given raw material might be higher or lower, depending on the source of the raw material.

In addition to the metals and halogens present, the raw materials can contain organic compounds. The U.S. Environmental Protection Agency (U.S. EPA) (Garg, 1990b) investigated the total quantity of organic compounds in the raw feed at a cement production facility. The greatest quantity of organic compounds was found in the shale. Although some aromatics were detected, the majority of the organic constituents were alkanes with 9 to 16 carbons.

TABLE 2.1
CONCENTRATIONS (ppm) OF METALS AND HALOGENS PRESENT IN THE
CEMENT RAW MATERIALS AND IN THE EARTH'S CRUST

CONSTITUENT	LIMESTONE	CLAY/SHALE	EARTH'S CRUST ^a
METALS			
Antimony	NDA ^b	NDA	1 ^c
Arsenic	0.2-12	13-23	5
Barium	NDA	NDA	250
Beryllium	0.5 ^{c,d}	3 ^d	6
Cadmium	0.035-0.1	0.016-0.3	0.15
Chromium	1.2-16	90-109	200
Lead	0.4-13	13-22	16
Mercury	0.03 ^d	0.45 ^d	0.5
Nickel	1.5-7.5	67-71	80
Selenium	0.19 ^d	0.5 ^d	0.09
Silver	NDA	0.07 ^d	0.1
Thallium	0.05-0.5	0.7-1.6	0.6
Vanadium	10-80	98-170	150
Zinc	22-24	59-115	132
HALOGENS			
Bromine	5.9	1-58	1.6
Chlorine	50-240	15-450	314
Fluorine	100-940	300-990	300
Iodine	0.25-0.75	0.2-2.2	0.3

^a CRC (1982).

^b NDA = no data available.

^c Estimated concentration.

^d Wedepohl (1991).

Source: Sprung (1985), unless otherwise noted.

The presence of metals, halogens, and organic compounds in the raw materials can complicate interpretation of emissions testing conducted at cement kilns. The complications arise because many of the components in the raw materials are identical to the components in the hazardous waste used as fuel. Once the raw materials and the hazardous waste are fed into the cement kiln, it becomes impossible to distinguish the source of identical components. For example, if cadmium were present in both the raw materials and the hazardous waste and were detected in the emissions, the origin of this metal could not be established by simply monitoring the emissions. In fact, the U.S. EPA study (Garg, 1990b) discussed above was undertaken to determine if the organic compounds in the raw feed could be responsible for the organic

compounds detected in the emissions. The U.S. EPA report concluded that the amount of organic constituents in the shale could account for the total amount of hydrocarbons detected in the emissions of the cement production facility under study.

2.2 THE PRODUCTION OF CEMENT

After being blended and ground, the mixed raw materials are fed into the inclined end of the kiln. Five thermal zones are present in the kiln (Peray, 1986). The zones and the corresponding temperature ranges of the material in the kiln are listed in Table 2.2. Temperatures of the gases within these zones are even higher than the temperatures of the material. For example, the gas temperature in the sintering zone is typically greater than 3,500°F (1,927°C), compared to the material temperature of approximately 2,700°F (1,482°C). The location and length of these zones depend on the manufacturing process (see Section 2.3).

TABLE 2.2
ZONES AND TEMPERATURE RANGES OF THE MATERIAL IN A CEMENT KILN

ZONES	TEMPERATURE RANGES OF MATERIAL	
	°F	°C
Drying and preheating	60-1,480	15-805
Calcining	1,480-2,192	805-1,200
Upper-transition	2,192-2,552	1,200-1,400
Sintering	2,552-2,750	1,400-1,510
Cooling (lower transition)	2,750-2,350	1,510-1,290

Source: Peray (1986).

In the drying and preheating zone, the free and chemically bound water is evaporated and the temperature of the feed material is raised to 1,480°F (805°C) (Peray, 1986). In the calcining zone, where the material reaches temperatures as high as 2,192°F (1,200°C), carbon dioxide is dissociated from the calcium carbonate to give calcium oxide, commonly referred to as lime. In addition, the small amounts of magnesium carbonate typically present in the raw feed is converted to magnesium oxide with the liberation of carbon dioxide. This liberation of carbon dioxide from these carbonate species is known as calcination.

The last three thermal zones of the kiln are collectively referred to as the burning zone, where the material is heated to approximately 2,700°F (1,482°C) (Peray, 1986). In the upper transition zone and, to some extent, in the calcining zone, di-calcium silicate and intermediate aluminates and ferrite compounds are formed. In the sintering zone, tricalcium silicate, tricalcium aluminate, and tetracalcium aluminoferrite are formed. In addition, the semiliquid material

condenses to form clinker, nodules approximately 0.1 to 0.75 inches (3 to 20 mm) in diameter (Taylor, 1990). The clinker solidifies and begins to cool in the last 10 to 20 feet of the cement kiln, which is designated as the cooling or lower transition zone (Peray, 1986). The final cooling of the clinker takes place outside of the cement kiln in the clinker cooler.

The composition of the clinker, as well as the names and formulas of the clinker components, are listed in Table 2.3. Traditionally, the composition of clinker is given as oxides of the elemental components. This convention originated in the early nineteenth century when the chemical structure could not be determined precisely (Pike *et al.*, 1988). Consequently, since calcium, silicon, aluminum, and iron are the major elements in clinker, its composition is typically listed in the following way: 67% calcium oxide (CaO), 22% silicon dioxide (SiO₂), 5% aluminum oxide (Al₂O₃), 3% iron oxide (Fe₂O₃) and 3% miscellaneous components (Taylor, 1990).

TABLE 2.3
CLINKER COMPOSITION FOR PORTLAND CEMENT

CHEMICAL NAME (COMMON NAME)	CHEMICAL FORMULA (COMMON NOTATION)	COMPOSITION IN PORTLAND CLINKER
Tricalcium silicate (alite)	Ca ₃ SiO ₅ (C ₃ S)	50-70%
Dicalcium silicate (belite)	Ca ₂ SiO ₄ (C ₂ S)	15-30%
Tricalcium aluminate	Ca ₃ Al ₂ O ₆ (C ₃ A)	5-10%
Tetracalcium aluminoferrite	Ca ₄ Al ₂ Fe ₂ O ₁₀ (C ₄ AF)	5-15%

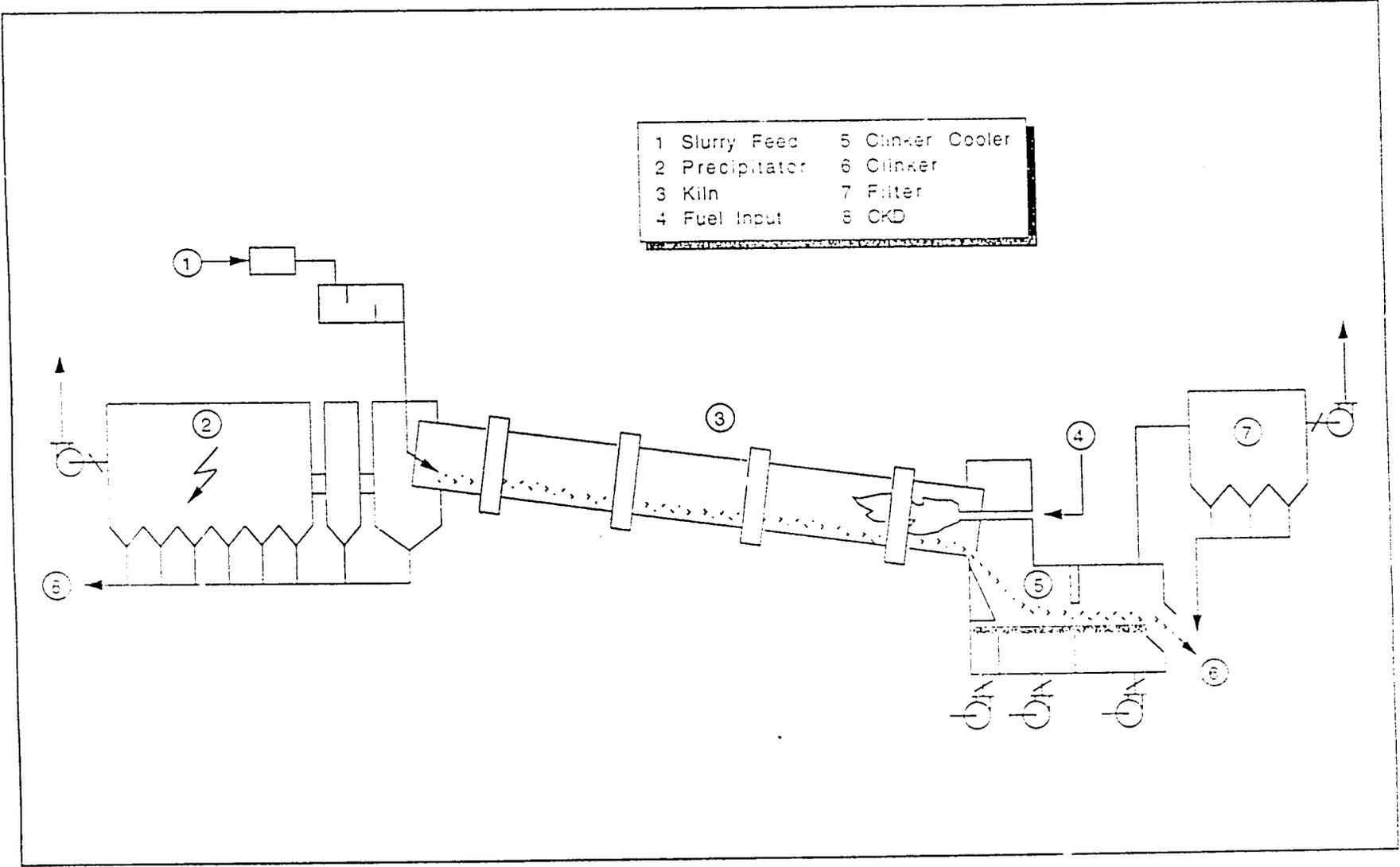
Source: Taylor (1990).

To complete the production of Portland cement, the cooled clinker is ground with a small amount of gypsum (CaSO₄•2H₂O). Gypsum is added in an amount sufficient to result in a total sulfate composition of 2 to 3% in the cement (Kerton and Murray, 1983). Without the addition of gypsum, the cement would set too quickly.

2.3 TYPES OF PROCESSES FOR THE PRODUCTION OF CEMENT

Cement may be produced by one of three processes: the wet, semi-dry, or dry process (Peray, 1986). In the wet process, the kiln feed is blended with water to promote homogenization of the mixture. The resulting slurry, which is typically 30 to 40% water, is fed directly into the inclined end of the kiln. Evaporation of water from the kiln feed requires both a cement kiln with a long drying and preheating zone and a substantial energy investment. A typical wet process cement kiln is illustrated in Figure 2.1. Although a more homogeneous mixture of the raw materials is obtained in the wet process, this process requires more energy than the other two.

7



- | | |
|----------------|------------------|
| 1 Slurry Feed | 5 Clinker Cooler |
| 2 Precipitator | 6 Clinker |
| 3 Kiln | 7 Filter |
| 4 Fuel Input | 8 CKD |

FIGURE 2.1 Typical Wet Process Cement Kiln
 (Source: Adapted from Hazelwood, *et al.*, 1982)

10

The semidry process is also referred to as the grate or Lepol process. In this process, water, typically 10 to 15%, is added to the ground dry feed material. The pellets that result are loaded onto a traveling grate through which the cement kiln's hot exit gases are drawn. By the time the feed material reaches the kiln entrance, the water has evaporated and calcination has begun. Since the hot exit gases of the kiln are used to dry, preheat, and initiate calcination of the feed material, the semidry process is extremely energy efficient.

In the dry process, the feed material enters the kiln in a dry powdered form. This process is characterized by three types of cement kilns: the dry kiln, the preheater kiln, and the precalciner kiln. The oldest type resembles the wet process kiln and is known simply as the dry kiln.

The preheater kiln, which is illustrated in Figure 2.2, became popular after World War II. This type of kiln is equipped with a tower of heat-exchanging cyclones (i.e., a preheater) in which the dry feed is preheated and partially calcined by the kiln's hot exit gases prior to entering the actual kiln. Because of the buildup of volatile components such as alkali salts in the lower stages of the tower and kiln entrance, the preheater kiln is often equipped with a bypass to divert a portion of the kiln's hot exit gases from the tower to air pollution control devices (APCDs).

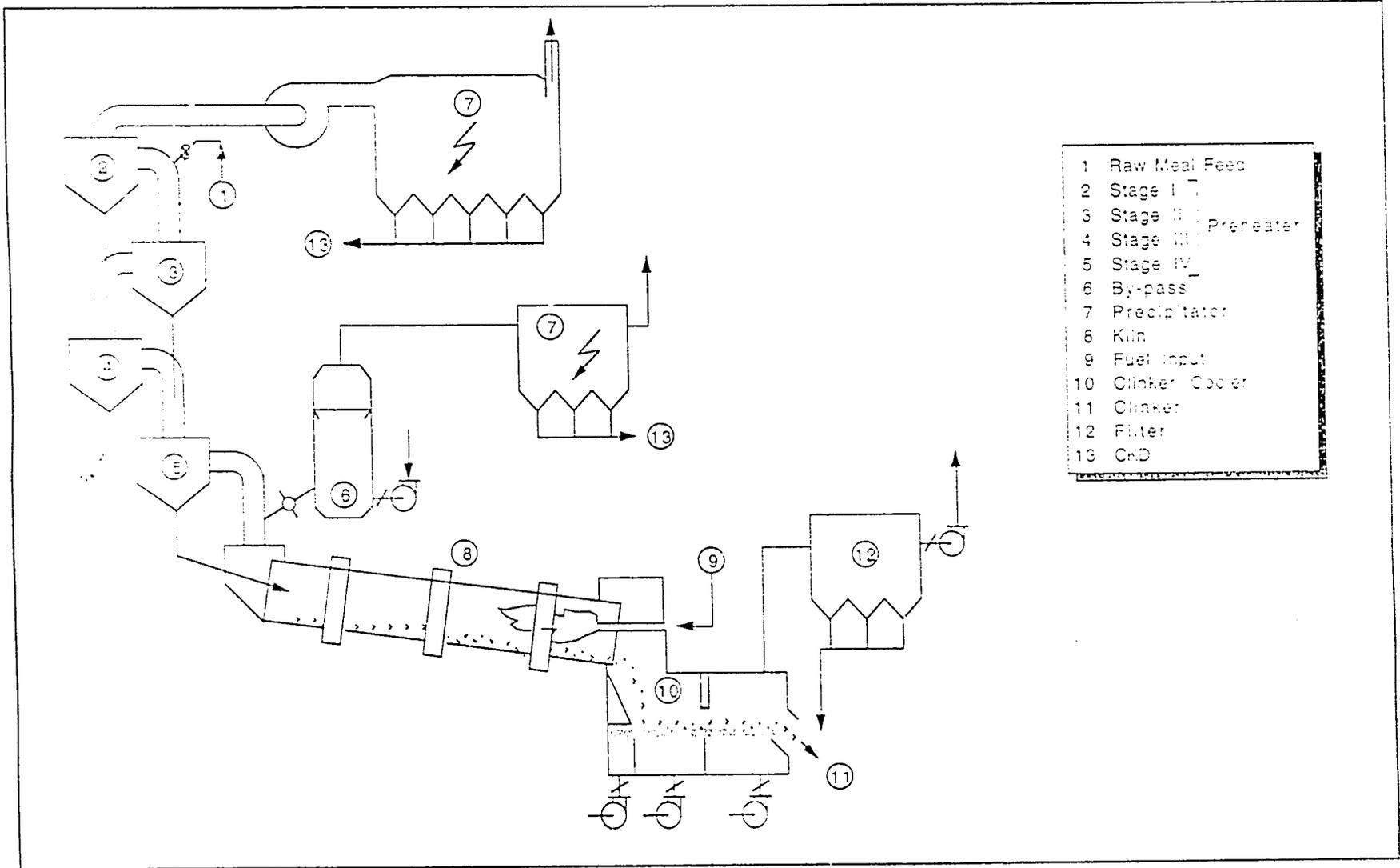
The precalciner kiln represents the most recent technological advancements. The precalciner kiln is identical to the preheater kiln except that a secondary firing device (i.e., precalciner) is added to the lower stage of the preheater in which further calcination of the material occurs. Consequently, the majority of the material that enters the kiln is completely calcined.

2.4 CEMENT KILN DUST

In a cement kiln, the hot kiln gases from combustion flow countercurrent to the raw feed. As the raw materials are fed into the entrance of the kiln system, hot kiln gases are exiting. Particulates are carried by these gases to APCDs, which remove the vast majority of the particulates from the gases. This collection of particulates is referred to as cement kiln dust (CKD).

CKD is typically returned to the kiln with the raw feed. As a result, some cement production facilities do not generate waste CKD. However, because of the buildup of alkali salts, which can disrupt operating conditions, a certain portion of the CKD is occasionally removed. CKD is used by other industries to neutralize acidic effluents and to stabilize and solidify wastes. In addition, the agricultural and construction industries use CKD as a lime substitute (Haynes and Kramer, 1982). The portion of the CKD not used as a resource is typically landfilled. Restrictions on the disposal of CKD are discussed in Section 6.1.6.

In response to the growing concerns regarding the potential environmental effects of the disposal of large volumes of CKD, the U.S. Bureau of Mines conducted an investigation to



- 1 Raw Meal Feed
- 2 Stage I
- 3 Stage II
- 4 Stage III
- 5 Stage IV
- 6 By-pass
- 7 Precipitator
- 8 Kiln
- 9 Fuel Input
- 10 Clinker Cooler
- 11 Clinker
- 12 Filter
- 13 C&D

FIGURE 2.2 Typical Preheater Cement Kiln
 (Source: Adapted from Hazelwood, *et al.*, 1982)

12

characterize the constituents in CKD and to determine whether CKD should be classified as a hazardous waste (Haynes and Kramer, 1982). For this study, 113 samples from 102 U.S. cement production facilities were collected and analyzed. The major constituents were found to be calcium carbonate (calcite), calcium oxide (lime), and calcium sulfate (anhydrite), with various amounts of silicon dioxide (quartz or sand) and calcium magnesium carbonate (dolomite). The presence of alkali salts was also noted. The report concluded that CKD is "a potential resource as a substitute for lime. Any environmental considerations are minor" (Haynes and Kramer, 1982). The same conclusion was reached in a recent report by the Portland Cement Association (PCA) (PCA, 1991). (See Section 7.2.3 for a discussion of the recent study.)

3.0 HAZARDOUS WASTE AS A SUPPLEMENTAL FUEL

Typically, a cement kiln is fired with coal, petroleum coke, oil, or natural gas. However, since the 1970s, some cement production facilities have used hazardous waste as well as used oil and tires to replace a portion of their conventional fuel. Approximately 1.8 billion pounds of hazardous waste are incinerated in cement kilns each year in place of fossil fuels (Costner and Thornton, 1990).

Although the term "hazardous waste" is frequently used, it is rarely defined. This Chapter addresses the following questions:

- What is a hazardous waste?
- What types of hazardous waste are burned in cement kilns?
- How do the constituents in fossil fuel compare with the constituents in the hazardous waste fuel?

3.1 DEFINITION OF A HAZARDOUS WASTE

A hazardous waste is a material that no longer has commercial value and requires disposal, and that is either specifically listed by the U.S. EPA or meets one of the four characteristics defined by the U.S. EPA. The characteristics (ignitability, corrosivity, reactivity, and toxicity) are defined by an extensive list of criteria [Title 40 of the U.S. Code of Federal Regulations, Part 261 (40 CFR 261)]. Typically, if a waste meets one of these criteria, it is labeled as a hazardous waste. The criteria for each of the four characteristics are outlined below.

An ignitable waste is defined as one of the following (40 CFR 261.21):

- a liquid with a flash point of less than 140°F excluding an aqueous alcohol solution with less than 24% by volume of alcohol
- a substance that ignites "through friction, absorption of moisture or spontaneous chemical changes and . . . burns so vigorously and persistently that it creates a hazard" (40 CFR 261.21)
- an ignitable compressed gas specifically listed by the U.S. EPA
- an oxidizer specifically listed by the U.S. EPA.

Examples of substances that could be classified as ignitable wastes are acetone and methanol.

A corrosive waste is defined as one of the following (40 CFR 261.22):

- an aqueous acid (pH less than or equal to 2)
- an aqueous base (pH greater than or equal to 12.5)
- a liquid that corrodes steel at a rate greater than 0.250 inches per year at a temperature of 130°F.

Examples of substances that could be classified as corrosive wastes are ^{GLACIAL} acetic acid and ammonia.

A reactive waste is defined as one of the following (40 CFR 261.23):

- an unstable substance that undergoes violent change without exploding
- a substance that reacts violently with water
- a substance that combines with water to create an explosive mixture
- a substance that produces a significant quantity of toxic fumes when mixed with water
- a cyanide or sulfide containing substance that releases a significant quantity of toxic fumes on exposure to an environment with a pH range of 2 to 12.5
- an explosive substance that is either capable of detonation or specifically defined by the U.S. EPA as an explosive.

Examples of substances that could be classified as reactive wastes are trinitrotoluene (TNT) and nitroglycerine.

The designation of a waste as toxic is somewhat more obscure than the designations discussed above. Officially, the U.S. EPA defines a toxic waste as a waste that contains components that have demonstrated mutagenicity, carcinogenicity, or teratogenicity (40 CFR 261.11). Benzene is an example of a compound that could be classified as a toxic waste.

The generic toxic label also includes two other U.S. EPA classifications: a "toxicity characteristic" waste and an "acute hazardous" waste. These classifications are defined in the following way. If an extract of a representative sample of a waste contains concentrations of components listed by the U.S. EPA that equal or exceed the limits set by the U.S. EPA, then the waste is designated as a "toxicity characteristic" waste (40 CFR 261.24). The individual limits set by the U.S. EPA for the listed components represent the concentrations above which the listed components exhibit the characteristic of toxicity. An example of a component that has been listed by the U.S. EPA is lead. An "acute hazardous" waste is one that contains components that are either fatal or believed to be fatal to humans in small quantities (40 CFR 261.11). Potassium cyanide is an example of a compound that could be classified as an "acute hazardous" waste.

25

With lists of the hazardous waste criteria, the process of classifying a waste would appear to be straightforward. If a waste meets one of the hazardous waste characteristics or is specifically listed by the U.S. EPA, then it should be classified as hazardous. Because of the large number of exemptions, the hazardous waste classification system is not as simple as it appears. For example, household waste is specifically exempt, although some household waste such as turpentine, oven cleaner, and many automotive fluids would meet at least one of the criteria discussed above. However, because of its exemption status, this waste is not evaluated. As a result, many types of waste that are in principle hazardous do not have the official U.S. EPA hazardous waste label.

3.2 TYPES OF HAZARDOUS WASTE USED BY THE CEMENT INDUSTRY

For the hazardous waste to serve as a suitable supplemental fuel, it must be combustible and have a significant energy content. Although the recent regulations only require the hazardous waste fuel to have an energy content of 5,000 Btu per pound (U.S. EPA, 1991), typical hazardous waste fuel can have an energy content greater than 10,000 Btu per pound (Peters *et al.*, 1986). Since the primary function of the hazardous waste is to replace a portion of the conventional fuel, a cement production facility does not burn hazardous waste that is either corrosive, reactive, or toxic, unless it is also combustible with a significant energy content. Highly corrosive and reactive wastes are generally avoided, since they could damage either the cement kiln itself or the tanks, piping, and valves associated with the cement manufacturing process.

↑ Restrictions other than combustibility and energy content exist. For example, the chlorine content of a hazardous waste fuel is restricted. When chlorinated wastes, such as those containing carbon tetrachloride or trichlorobenzene, are burned in a cement kiln, hydrogen chloride (HCl) is typically generated. This acid gas reacts with potassium and sodium oxide in the kiln to form alkali salts, which volatilize in the burning zone and condense in the cooler portions of the kiln. If a large quantity of these salts are formed, due to high chlorine content in the waste, then blockages can occur in the kiln system. These blockages upset the cement manufacturing process (Weitzman, 1983). For this reason, the chlorine content of the waste is strictly monitored by the cement production facility.

Restrictions on the metal content of the hazardous waste also exist. As discussed in Section 7.2.1, the majority of the metals are incorporated into the process solids (i.e., clinker or CKD). Since the setting of the cement can be adversely affected when the concentrations of certain metals exceeds 0.1%, these metal concentrations in the hazardous waste fuel must be regulated (Kerton and Murray, 1983). This restriction alludes to a significant point. The cement produced by a company must meet strict performance standards set by the American Society for Testing and Materials (ASTM). Consequently, the cement industry does not burn any

hazardous waste fuel that would compromise the quality of its cement and impair its ability to sell the cement it produces.

In addition to the waste restrictions and requirements discussed above, the cement industry chooses not to burn polychlorinated biphenyl (PCB) waste (i.e., wastes containing greater than 50 ppm of PCBs). The major reason for this decision is the quality of the PCB wastes. PCB wastes are highly chlorinated and, as discussed above, these types of wastes are avoided.

When all of the restrictions and requirements are considered, only a select stream of hazardous waste can be effectively utilized by the cement industry. Examples of hazardous wastes burned by the cement industry are spent organic solvents that originate from the "paint and coatings, auto and truck assembly, solvent reclamation, ink and printing, cosmetics, toy, medical and electronic" industries (Engineering Digest, 1989). In general, only combustible wastes with a high energy, low chlorine, and low metal content are burned in a cement kiln.

3.3 FOSSIL FUEL VERSUS HAZARDOUS WASTE FUEL

Although petroleum coke, oil, and natural gas are sometimes burned, the most common fuel used by the cement industry is coal (Weitzman, 1983). Similar to the raw materials and the hazardous waste fuel, coal can contain significant quantities of metals and halogens. Thus, coal may contain antimony, arsenic, barium, beryllium, cadmium, chromium, lead, mercury, nickel, selenium, silver, thallium, vanadium, zinc, bromine, chlorine, fluorine, and iodine. Average concentrations of these components are listed in Table 3.1. Ranges are presented when these data were available. The actual metal and halogen concentrations of a specific coal depend on the area in which it is mined.

For comparative purposes, the metal and halogen concentrations in used oil are also presented in Table 3.1. The status of used oil (i.e., hazardous versus nonhazardous) depends on the constituents present (40 CFR 266.40). Although some metals such as zinc and lead might be higher in used oil, other metals such as thallium might be higher in coal.

Although coal contains metals and halogens, the majority of coal, as is the case for the hazardous waste fuel, is organic (Kirk-Othmer Encyclopedia of Chemical Technology, 1979). The organic compounds in coal are generally aromatic. Consequently, when coal is burned, aromatic compounds, such as toluene and benzene, are emitted (Branscome *et al.*, 1985).

For the same reasons discussed in Section 2.1 with regard to the raw materials, the presence of metals, halogens, and organic compounds in the coal can complicate the interpretation of the emission testing conducted at a cement kiln burning hazardous waste.

TABLE 3.1
CONCENTRATIONS (ppm) OF METALS AND HALOGENS
IN COAL AND USED OIL

CONSTITUENT	COAL	USED OIL	REGULATORY LIMIT
METALS			
Antimony	1.19 ^a	NDA ^b	
Arsenic	9-50	<0.01-100 ^c	5.0
Barium	24.5 ^a	0-3,906 ^c	100.0
Beryllium	2.27 ^a	NDA	
Cadmium	0.1-10	4	1.0
Chromium	5-80	<5-50	5.0
Lead	11-270	10-21,700	5.0
Mercury	0.24 ^a	NDA	0.2
Nickel	20-80	3-30	
Selenium	3.56 ^a	NDA	1.0
Silver	0.06 ^a	NDA	5.0
Thallium	0.2-4	<0.02	
Vanadium	30-50	NDA	
Zinc	16-220	240-3,000	
HALOGENS			
Bromine	7-11	NDA	
Chlorine	100-2,800	100-2,200	
Fluorine	50-370	NDA	
Iodine	0.8-11.2	NDA	

^a O'Connor, (1991).

^b NDA = no data available.

^c US EPA (1984).

Source: Sprung (1985), unless otherwise noted.

4.0 CHARACTERISTICS OF A CEMENT KILN

One of the most critical issues to address is whether the conditions in the cement kiln are adequate for the incineration of hazardous waste. The characteristics that make the cement kiln an appropriate combustion device for the treatment of hazardous waste are discussed below.

4.1 HIGH TEMPERATURE AND LONG RESIDENCE TIME

To ensure the destruction of organic compounds by incineration, general combustion criteria have been developed for both halogenated and nonhalogenated compounds. Halogenated compounds contain at least one of the following: bromine, chlorine, fluorine, or iodine. Nonhalogenated compounds do not contain any bromine, chlorine, fluorine, or iodine. The temperature and residence time required in a combustion chamber and the oxygen concentration required in the exit gas to ensure destruction of both classes of compounds are listed in Table 4.1.

TABLE 4.1
COMBUSTION CRITERIA

WASTE CLASSIFICATION	TEMPERATURE ^a	RESIDENCE TIME ^a	OXYGEN CONCENTRATION ^b
Nonhalogenated	1,832 °F (1,000 °C)	2 seconds	2%
Halogenated	2,192 °F (1,200 °C)	2 seconds	3%
PCBs	2,192 °F (1,200 °C)	2 seconds	3%
PCBs	2,912 °F (1,600 °C)	1.5 seconds	2%

^a In the combustion chamber.

^b In the gas exiting the combustion chamber.

Source: Brunner (1989).

Since PCBs (see Section 7.1.1.5) are considered to be the most difficult type of halogenated compounds to incinerate, the two combustion criteria developed for them are also listed in Table 4.1. From these two different criteria, one can see that the higher the temperature, the lower the residence-time and oxygen content required. If either criterion is met, then PCBs are considered to be destroyed (Brunner, 1989).

Hazardous waste incinerators are designed to meet these combustion criteria. Accordingly, the average operating temperature in the combustion chamber is 1,800 °F, with a range of 1,200 to 2,300 °F, and the average gas residence time in the combustion chamber is 2 seconds, with a range of 0.1 to 6.5 seconds (Oppelt, 1986).

To determine whether a cement kiln possessed the necessary operating parameters to destroy organic wastes, Weitzman (1983) calculated a cumulative gas residence time versus gas temperature profile for a cement kiln (dry process, 115-135 ft x 570 ft). This relationship is illustrated in Figure 4.1. According to this profile, the gas in a cement kiln spends approximately 3 seconds at temperatures equal to or greater than 2,200 F. These conditions exceed the gas temperature and time requirements for the destruction of both halogenated and nonhalogenated compounds given in Table 4.1. They also exceed the typical operating conditions for a hazardous waste incinerator. Although the oxygen content in the flue gas was estimated at only 1.7%, the longer gas residence time and higher temperature effectively compensate for the oxygen requirements. Weitzman (1983) concluded that the conditions in a cement kiln were more than adequate for the destruction of even the most difficult-to-destroy organic compounds (e.g., PCBs). Weitzman's (1983) conclusions have been substantiated by the results of actual field testing that demonstrates the ability of a cement kiln to destroy organic wastes (see Section 7.1).

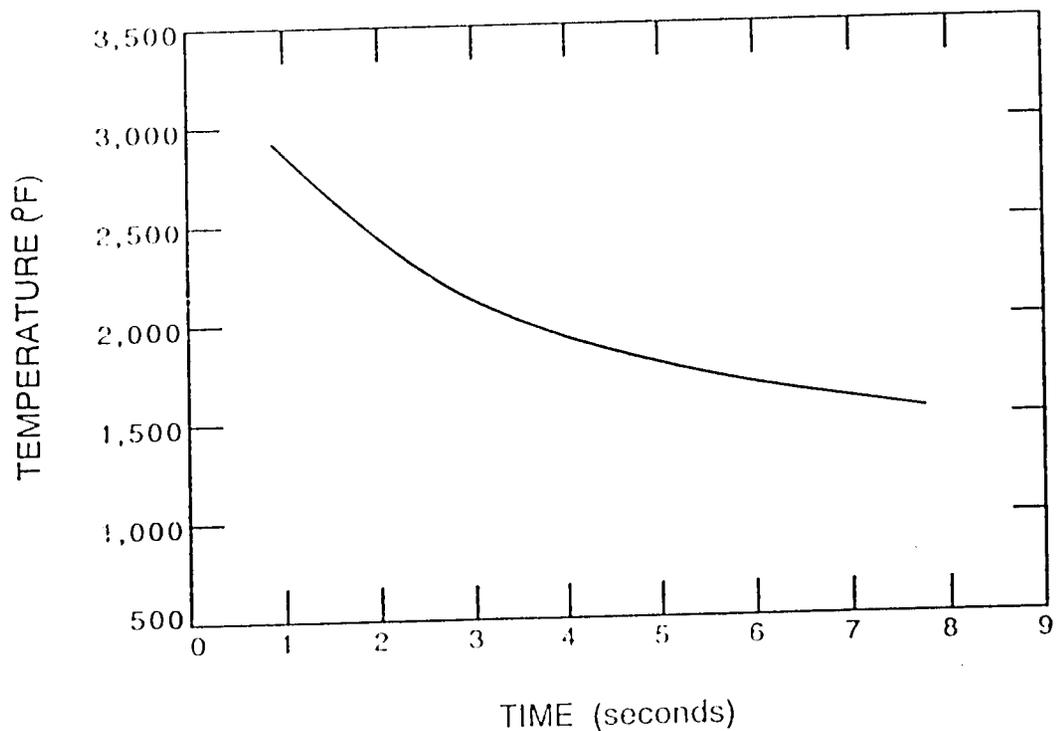


FIGURE 4.1 Cumulative Gas Residence Time Versus Temperature for a Cement Kiln
(Source: Weitzman, 1983)

The cement production process requires the kiln to be operated at the high temperatures needed to destroy organic hazardous waste. To produce clinker, the material inside the kiln must reach a temperature of approximately 2,700 F (1,482°C). Heating the material to this temperature requires a flame temperature of at least 3,000 F (1,650°C) (Engineering Digest, 1989). Thus, cement kilns operate at the conditions reputed to ensure destruction of the organic components, because these conditions are essential for the production of cement.

4.2 NATURAL ALKALINE ENVIRONMENT

One of the problems with the incineration of some hazardous waste is the generation of acid gases (e.g., HCl). Consequently, hazardous waste incinerators have acid scrubbing devices, which use alkaline compounds, such as sodium hydroxide or lime, to neutralize the acid gases (Brunner, 1989).

Cement kilns do not have acid scrubbing devices because the environment in the kiln is naturally alkaline. As discussed in Section 2.2, one of the main steps in the production of cement is the calcination of the calcium carbonate to produce lime, which is the same material used in hazardous waste incinerator acid scrubbing devices. Other alkaline components, such as magnesium oxide, are also generated in the production process. Therefore, as the acid gases travel from the burning zone through the calcining and drying zones, the majority of these gases are neutralized by the alkaline material in the kiln.

4.3 MINIMIZATION OF WASTE GENERATED

Another problem with the combustion of wastes in a hazardous waste incinerator is the generation of ash. Since this ash is derived from the combustion of hazardous waste, it is classified as hazardous waste and must be disposed of in a manner approved by the U.S. EPA (40 CFR 261.3).

No ash equivalent exists in the cement production process. The only byproduct of the manufacturing process is CKD. As discussed in Section 2.4, CKD primarily consists of raw material (e.g., limestone) and partially processed raw material (e.g., lime). CKD is typically recycled and fed back into the kiln in an effort to minimize the loss of the raw materials. Depending on the manufacturing process and the concentration of the alkali salts in the CKD, a portion of the dust may not be recycled but instead removed and either sold as a resource or managed in a manner approved by the U.S. EPA. However, whether all the dust is recycled or only a portion, the "waste" generated in the cement production process is minimized.

4.4 THERMAL STABILITY

Because the cement kiln is a large manufacturing unit with a high heat capacity, a significant change in kiln temperature in a brief period of time is not possible (Black and Swanson, 1983). Consequently, if an upset in the normal operating conditions occurs, any organic waste in the kiln will be adequately destroyed, provided the flow of hazardous waste to the kiln is stopped. Recently passed regulations require a facility to install an automatic shutoff to the hazardous waste feed to guarantee that the flow of waste is discontinued in the event of an upset (see Section 6.1.1).

5.0 BENEFITS OF BURNING HAZARDOUS WASTE IN CEMENT KILNS

The benefits of burning hazardous waste in cement kilns include recovering the energy value of the hazardous waste, conserving non-renewable fossil fuels, reducing manufacturing costs, and using an existing technology to incinerate large volumes of hazardous waste. These benefits are briefly addressed in the following sections.

5.1 RECOVERY OF ENERGY VALUE FROM HAZARDOUS WASTE

A large quantity of hazardous waste generated in the U.S. has a significant energy content. This source of potential energy is one of the primary reasons for the cement industry's interest in burning hazardous waste. Because the waste is burned as a fuel in a manufacturing process and, therefore, the energy value of the waste is recovered, this practice has been designated as "recycling."

This practice is consistent with the national waste management policy, whose primary goal is to reduce the quantity of waste that is generated. If waste is generated, then it should be recycled or reused. The preferred management option for the nonrecyclable portion of the waste is treatment by either incineration or physical, chemical, or biological methods. If incineration is chosen as the treatment option, then a device such as a cement kiln that recovers the energy value is preferred. The least preferred waste management option is long-term storage (e.g., landfilling). This preference is supported by the Hazardous and Solid Waste Amendments to the Resource Conservation and Recovery Act (RCRA). These amendments required the U.S. EPA to develop restrictions on the types of wastes that could be landfilled (U.S. EPA, 1989a). As a result, the amount of hazardous waste that must be treated prior to landfilling has dramatically increased.

5.2 CONSERVATION OF NONRENEWABLE FOSSIL FUELS

One of the most significant advantages of using hazardous waste as a supplemental fuel in the cement industry is the conservation of nonrenewable fossil fuels, such as coal and oil. The amount of fossil fuel that could be saved by this practice is substantial. For example, if 25% of the energy used in the production of cement in the U.S. were replaced by hazardous waste, then 3.8 million tons of domestic coal or 14.4 million barrels of domestic crude oil could be saved each year. (See Appendix A for the calculation of these values.) This estimate of fossil fuel savings is conservative because the regulations that govern the burning of hazardous waste in cement kilns allow more than 25% of the conventional fuel to be replaced by hazardous waste (U.S. EPA, 1991). A practice that could save this quantity of nonrenewable resources deserves serious consideration.

5.3 REDUCTION IN PRODUCTION COSTS

The production of cement is an energy intensive process. The portion of the manufacturing costs attributed to fuel can range from 20% to 25% (Engineering Digest, 1989). Consequently, cement production costs are heavily driven by fuel prices. As a result, "most cement plants have made the capital investment necessary to achieve fuel flexibility and can select energy sources according to cost" (Engineering Digest, 1989).

Since the hazardous waste fuel is substantially cheaper than any of the conventional fossil fuels, the industry has an incentive to use this potential source of energy. The replacement of even a fraction of the conventional fuel with hazardous waste fuel can significantly reduce manufacturing costs.

5.4 USE OF EXISTING TECHNOLOGY TO TREAT LARGE VOLUMES OF HAZARDOUS WASTE

The U.S. is facing a waste crisis. The rate at which hazardous waste is produced far exceeds the present capacity for treatment and disposal in a manner that prevents long-term exposure (U.S. Congress, 1989). Innovative ideas and new technologies to manage hazardous waste are needed. Unfortunately, the design and construction of new hazardous waste treatment and disposal facilities are extremely expensive processes.

One of the advantages of using cement kilns is that the technology and the facilities are already in place. In addition, the use of a cement kiln, as opposed to the construction of a new facility, does not result in the creation of a new source of emissions. Therefore, cement kilns provide an attractive option for the incineration of large volumes of certain types of hazardous waste.

The cement kiln option for the disposal of large volumes of hazardous waste does not promote the generation of hazardous waste. Interest in the reduction of waste might be lost when the generator also owns the treatment facility or when treatment is more profitable than reduction or recycling. However, such is not the case for cement production facilities because they do not generate the hazardous waste fuel they burn. Since the generator still must pay for treatment or disposal of the waste, the incentive for reduction or recycling remains. Therefore, cement kilns do not provide an incentive to generate more hazardous waste, but a means of treating some types of hazardous waste that cannot be minimized or otherwise recycled.

6.0 FEDERAL REGULATIONS GOVERNING CEMENT KILNS THAT BURN HAZARDOUS WASTE

Cement production facilities using hazardous waste as a supplemental fuel are required to meet a host of federal and state regulations that govern air emissions, waste transportation, waste storage, and worker safety. In February 1991, the U.S. EPA finalized the Boilers and Industrial Furnaces (BIF) rule, which applies additional requirements to the actual burning of hazardous waste in cement kilns as well as other boilers and industrial furnaces. This rule specifically sets stringent performance and operating standards for combustion devices that choose to burn hazardous waste for energy recovery. The BIF rule and other federal regulations that govern cement kilns burning hazardous waste as a supplemental fuel are discussed in the following sections.

6.1 THE BOILERS AND INDUSTRIAL FURNACES RULE

The U.S. EPA has classified a cement kiln as an industrial furnace. Accordingly, a cement production facility that uses hazardous waste as a supplemental fuel in its kilns must comply with the regulations defined in the BIF rule. These regulations include emission standards for organic compounds, metals, hydrogen chloride, chlorine gas, and particulates. In addition, the U.S. EPA states in the BIF rule that facilities burning hazardous waste as a supplemental fuel must comply with the rules and regulations applicable to any other waste treatment, storage, and disposal facility. This rule became effective August 21, 1991 [U.S. EPA, 1991 (p. 7134)].

In the following sections, the BIF regulations are discussed in detail. Although the BIF rule applies to a variety of combustion devices, the discussion focuses on those regulations that specifically affect the cement industry.

6.1.1 TOXIC ORGANIC EMISSIONS

The BIF rule requires that a facility demonstrate a 99.99% destruction and removal efficiency (DRE) for principal organic hazardous constituents (POHCs) in the waste stream. A DRE of 99.99% means that out of 1 ton put into the system, less than 4 ounces are actually emitted in the stack gas. Achieving this level of DRE "will ensure that constituents in the waste are not emitted at levels that could pose significant risk" [U.S. EPA, 1991 (p. 7146)].

The DRE is established in a trial burn, which is the demonstration that a facility is in compliance with the regulatory requirements. POHCs are representative of the compounds in the waste stream that are the most abundant and the most difficult to destroy. Accordingly, chlorinated and aromatic compounds, such as carbon tetrachloride and trichlorobenzene, are often chosen because they are typical components in the waste stream and difficult compounds to destroy. A DRE is determined for each of the selected POHCs by first measuring the mass of the selected POHC entering the combustion device in the waste stream and then measuring the

mass of that selected POHC exiting the combustion device in the stack. The DRE value is finally calculated according to the equation given below.

$$\text{DRE} = [(W_{\text{in}} - W_{\text{out}}) / W_{\text{in}}] \times 100$$

Where:

- W_{in} = the mass of the selected POHC entering the combustion device in the waste stream
- W_{out} = the mass of the selected POHC exiting in the stack gas.

A DRE of 99.99% must be demonstrated for each of the selected POHCs for the facility to demonstrate regulatory compliance.

A special permitting process exists for the incineration of "dioxin-listed" wastes. These wastes actually include two distinct classes of compounds: polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) (40 CFR 261 Appendix VII). In general, PCDDs are referred to as dioxins and PCDFs are referred to as furans. These wastes are considered to be acutely hazardous. Therefore, an even more restrictive DRE of 99.9999% must be demonstrated in a trial burn [U.S. EPA, 1991 (p. 7146)]. A DRE of 99.9999% means that out of every 100 tons put into the system, less than 4 ounces are actually emitted in the stack gas.

A high DRE does not ensure complete destruction of the organic constituents to carbon dioxide and water. If good combustion conditions are not maintained, products of incomplete combustion (PICs) may be emitted. The U.S. EPA defines PICs as "unburned organic compounds that were present in the waste, thermal decomposition products resulting from organic constituents in the waste, or compounds synthesized during or immediately after combustion" [U.S. EPA, 1991 (p. 7149)].

To guard against significant emissions of PICs, the BIF rule requires that the carbon monoxide levels and, where appropriate, the total hydrocarbon concentration in the flue gas be continuously monitored [U.S. EPA, 1991 (pp. 7150-7156)]. Compliance with one of two options is mandatory. Under option I, the carbon monoxide emission of a cement kiln burning hazardous waste cannot exceed 100 parts per million by volume (ppmv). Compliance with this option is difficult for many kilns that normally operate above this emission limit even under ideal combustion conditions with conventional fuel.

Consequently, the BIF rule offers a second option. Under option II, the carbon monoxide emission can exceed 100 ppmv, but the total hydrocarbon concentration must be continuously monitored and cannot exceed the technology based limit of 20 ppmv. The exact carbon monoxide level is established during the trial burn. An alternative total hydrocarbon level may be established on a case-by-case basis if the raw materials (e.g., shale) used in the process are found to contain organic compounds that significantly add to the hydrocarbon emissions.

Three final points incorporated into the BIF rule guard against the release of toxic quantities of organic compounds:

- If hazardous waste is fed to any other point than the hot end or the end where the fuel is traditionally delivered, then the total hydrocarbon content must be continuously monitored, even if the carbon monoxide concentration is below 100 ppmv [U.S. EPA, 1991 (p. 7158)].
- An automatic cutoff device in the waste fuel line must be installed and linked with the continuous carbon monoxide monitor and, if appropriate, the continuous total hydrocarbon monitor. Therefore, if the emissions limits are exceeded, then the waste fuel is cut off to the combustion device [U.S. EPA, 1991 (p. 7159)].
- Emission testing and dispersion modeling must be conducted if the facility has the potential for emitting significant quantities of PCDDs or PCDFs. This analysis must ensure that the hypothetical maximum exposed individual (MEI) is not subjected to a concentration of these compounds that would result in a lifetime cancer risk greater than 1 in 100,000 [U.S. EPA, 1991 (p. 7162)]. As defined in the BIF rule, the hypothetical MEI is assumed to reside at the location of maximum possible exposure for 24 hours per day, 365 days per year over a 70-year lifetime. This evaluation must be completed regardless of whether anyone actually lives at the point of maximum exposure [U.S. EPA, 1991 (p. 7170)].

All of these regulations were developed to ensure that the organic waste constituents in the hazardous waste fuel are destroyed and that no toxic organic compounds are released in quantities that would adversely affect public health.

6.1.2 TOXIC METAL EMISSIONS

The BIF rule sets emission standards for 10 metals: antimony, arsenic, barium, beryllium, cadmium, hexavalent chromium, lead, mercury, silver, and thallium [U.S. EPA, 1991 (pp. 7171-7179)]. The U.S. EPA selected these metals because of their potential for adverse effects to human health and the environment. These metals are classified as either carcinogenic or noncarcinogenic. Arsenic, beryllium, cadmium, and hexavalent chromium are classified as carcinogenic metals. Although some debate exists regarding the scientific basis of the risk standards (EPA, 1992), the standards for these four metals were developed by the U.S. EPA such that the hypothetical MEI would not be subjected to concentrations that would result in a lifetime cancer risk exceeding 1 in 100,000. The individual risks due to the exposure of each of these carcinogenic metals must be summed so that the total risk to the hypothetical MEI of developing cancer does not exceed 1 in 100,000.

Antimony, barium, lead, mercury, silver, and thallium are regulated according to their noncarcinogenic effects. The emission standards for these six metals are based either on oral reference doses (RfDs), which are levels below which no adverse health effects have been noted, or, in the case of lead, on the existing National Ambient Air Quality Standard (NAAQS)

The standards for both the carcinogenic and noncarcinogenic metals are met by compliance with one of the three tiers discussed below. These tiers are designed such that the less testing and analysis that is conducted, the more conservative the assumptions used by the U.S. EPA to set the allowed metal input into the kiln.

Under tier I, no emission testing, which determines the specific metals and their concentrations in the stack gas, and no site-specific dispersion modeling, which estimates the concentrations of the metals in ambient air, are conducted. In the absence of any testing, two assumptions are made. The first is that all metals entering the device are emitted in the stack gases. In other words, no removal of metals by the APCD is assumed and no incorporation of the metals into the process solids (i.e., CKD or clinker) is assumed. The second assumption is that worst-case dispersion of the metals occurs. Therefore, a facility that is permitted under tier I must comply with metal feed rates that were established using the most conservative assumptions.

Under tier II, emission testing is conducted. The emission testing must prove that metals are retained in the process solids (i.e., CKD or clinker) and that the APCDs are effective in removing metals from the flue gas. If the emission testing shows that the amount of metals fed into the system is more than what is emitted, then a higher metals concentration is allowed to be fed into the kiln. However, since no site-specific dispersion modeling is conducted, worst-case dispersion of the metals from the stack is assumed. Compliance with this tier, as opposed to tier I, would allow a greater concentration of metals to be fed into the kiln.

Under tier III, both emission testing and site-specific dispersion modeling are conducted. As a result, the concentrations of metals in the stack gas are determined and the concentrations of the emitted metals in ambient air are evaluated. Compliance with this tier would allow the maximum amount of metals to be fed into the kiln since allowances are made for the removal of metals by the process solids and APCDs and for local conditions such as climate and geography that affect dispersion of the emitted metals. In general, large facilities such as cement plants opt for compliance with this tier.

A special restriction exists for cement kilns. As discussed in Section 2.4, the CKD is typically recycled and fed back into the kiln. Because of this procedure, the concentration of the metals in the CKD could increase over time. Accordingly, the total amount of metals entering the kiln could increase over time. To account for this possibility, the BIF rule requires that the facility comply with one of the following criteria: daily testing of the collected particulate matter; daily emission testing; or establishing the metal equilibrium in the cement kiln prior to compliance testing so that the metal concentration would not change over time and would be representative of the metals being fed into the kiln at any time [U.S. EPA, 1991 (p. 7177)].

Regardless of the tier, the hazardous waste used at a facility must be analyzed for the 10 regulated metals. If a metal is omitted from the analysis, justification for this omission must be made.

6.1.3 HYDROGEN CHLORIDE/CHLORINE EMISSIONS

When chlorinated compounds are incinerated, either hydrogen chloride or chlorine is formed, depending on the combustion environment. To protect against significant emissions of either compound, the BIF rule sets emission limits for these compounds based on inhalation effects [U.S. EPA, 1991 (p. 7164)]. The rule specifies a three-tiered approach identical to that for the noncarcinogenic metals emissions discussed in Section 6.1.2 [U.S. EPA, 1991 (pp. 7179, 7180)].

6.1.4 PARTICULATE EMISSIONS

To prevent the potential for adverse effects to human health and the environment resulting from excessive particulate emissions, the BIF rule sets a particulate emission limit of 0.08 grains per dry standard cubic foot (gr/dscf).¹ This standard is another safeguard against the release of metals and organics to the environment because these components can adsorb to particulate matter [U.S. EPA, 1991 (p. 7144)].

6.1.5 INTERIM STATUS

- ii Facilities that were using or had made certain commitments to use hazardous waste as a supplemental fuel before the effective date of the BIF rule were allowed to apply for "interim status." This status allows facilities to continue using hazardous waste while obtaining the newly required permits. While operating under interim status, a facility must comply with the carbon monoxide, total hydrocarbon (if appropriate), metals, hydrogen chloride, chlorine, and particulate emission limits within a prescribed schedule [U.S. EPA, 1991 (pp. 7180, 7181)]. The only requirement that is not applicable to a facility under interim status is the demonstration of a 99.99% DRE. The U.S. EPA believes that if the carbon monoxide and total hydrocarbon standards are met, then the facility will be burning hazardous waste with a DRE of 99.99% [U.S. EPA, 1991 (p. 7183)]. However, a facility under interim status is not allowed to burn "dioxin-listed" wastes because a DRE of 99.9999% cannot be assured [U.S. EPA, 1991 (p. 7184)].

A special restriction exists for cement production facilities. The U.S. EPA has only conducted emission testing with facilities that feed hazardous waste directly into the kiln. Although future testing may demonstrate the complete destruction of the waste when fed to locations other than the kiln, a facility under interim status must feed the hazardous waste directly into the kiln in order to ensure complete destruction. Accordingly, the burning of hazardous waste in a precalciner is not allowed under interim status [U.S. EPA, 1991 (p. 7185)].

While interim status extensions may be granted, a facility has 1 year from August 1991 to complete compliance testing [U.S. EPA, 1991 (p. 7184)].

¹ Corrected to 7% oxygen.

6.1.6 THE BIF RULE AND THE BEVILL AMENDMENT

One of the biggest debates regarding the use of hazardous waste fuel in cement kilns is the regulation of CKD. Under the authority of RCRA, the U.S. EPA has mandated that any residue generated from the treatment, storage, or disposal of hazardous waste be classified as a hazardous waste regardless of whether the waste exhibits hazardous characteristics (40 CFR 261.3). A statutory exemption known as the Bevill Amendment excludes CKD (40 CFR 261.4). Therefore, it has not been classified as a hazardous waste regardless of whether hazardous waste has been used as a fuel in the cement production process.

Under the BIF rule, a facility must show that the CKD generated when burning hazardous waste fuel does not differ significantly from the CKD generated when burning conventional fuel [U.S. EPA, 1991 (pp. 7196-7200)]. A two-part test is outlined. For the first part of the test, a facility must show that the toxic² components in the CKD generated while burning hazardous waste are not present at statistically significant higher levels than the toxic components in the CKD generated while burning only conventional fuel. For the second part of the test, a facility must demonstrate that the concentrations of the toxic components in the CKD do not exceed the health-based standards set by the U.S. EPA. If a facility can demonstrate that the concentrations of toxic compounds in the CKD generated when burning hazardous waste do not exceed the health-based standards, then the facility does not have to prove that the CKD generated while burning hazardous waste has the same composition as the CKD generated while burning conventional fuel. Only if the CKD fails both parts of the test is it considered to significantly differ. If the CKD is found to significantly differ, then it loses the Bevill exemption and must be handled as a hazardous waste.

6.1.7 COMPARISON OF BIF REGULATIONS TO HAZARDOUS WASTE INCINERATOR REGULATIONS

At present, the BIF regulations are even more stringent than the regulations governing hazardous waste incinerators. Although a hazardous waste incinerator must demonstrate a DRE of 99.99% for selected POHCs and a DRE of 99.9999% for "dioxin-listed" wastes (40 CFR 264.343), no carbon monoxide or total hydrocarbon emission limits similar to those outlined in the BIF rule exist for hazardous waste incinerators.

The U.S. EPA has not specifically set any metal emission standards, similar to those outlined in the BIF rule (see Section 6.1.2), for hazardous waste incinerators. However, under the authority of the Clean Air Act (CAA), the U.S. EPA has set emission standards for arsenic, beryllium, lead, and mercury that would apply to hazardous waste incinerators (see Section 6.2).

² The usage of the word "toxic" is consistent with usage in the BIF rule. However, any substance can be "toxic" if present in sufficient quantities. Toxicity is a function of dose.

A hazardous waste incinerator is allowed to emit 4 pounds per hour of hydrogen chloride or demonstrate a removal efficiency of 99% (40 CFR 264.343). Unlike the hydrogen chloride emission standards set by the BIF rule (see Section 6.1.3), this standard is not a health-based standard.

Although a few of the standards are basically the same, such as the particulate emission limit, the majority of the standards for a cement production facility burning hazardous waste are more restrictive than those for a hazardous waste incinerator. Despite these differences, compliance with the existing regulations should ensure that no adverse impacts occur from either type of facility.

6.1.8 OUTCOME OF THE BIF RULE

Two significant outcomes should result from the enactment of the BIF rule. The BIF rule should prevent any poorly operated boiler or industrial furnace from burning hazardous waste and provide some assurance that the remaining facilities are operating in a manner that will ensure protection of both human health and the environment. In addition, a reduction in the halogen and metal content of wastes should result, since the BIF rule restricts the quantity of these components that can be burned at these facilities.

6.2 AIR POLLUTION CONTROL REGULATIONS

Before compliance with the BIF rule became mandatory, cement kilns burning hazardous waste were required to meet federal, state, and local air pollution control regulations that were established as a result of the CAA. Under authority of the CAA, the U.S. EPA established the NAAQS for pollutants such as particulates, lead, and sulfur dioxide. These standards were ceilings that were not to be exceeded anywhere in the U.S. and were set to protect both human health and the environment (Pedersen, 1987).

The CAA empowers the states to develop the regulatory framework to meet these standards. The State Implementation Plans, which are the result of this empowerment, "must include a description of the air quality . . . an emissions inventory of sources that emit the pollutant in question, emission limitations and compliance schedules to reduce pollutant emissions to a level low enough to achieve the NAAQS, a permit program for review of new source construction to insure new emissions will not cause a violation of NAAQS, monitoring and reporting requirements, and enforcement procedures" (Pedersen, 1987). State and local governments through the Prevention of Significant Deterioration program may also set emission limits such that no significant degradation of air quality occurs.

In addition to the NAAQS, the U.S. EPA has set New Source Performance Standards (NSPS) and National Emission Standards for Hazardous Air Pollutants (NESHAP). Both new sources and existing sources undergoing modifications that are considered to be significant contributors to air pollution are required to meet the NSPS. These standards are technology-based and

"must reflect the 'degree of emission reduction achievable' through the best technology" demonstrated (Pedersen, 1987)

The NESHAPs were originally established to account for hazardous pollutants (e.g., arsenic, beryllium, and mercury) emitted by a few sources such that an NAAQS was not warranted. These standards apply to both existing and new sources and must "be set at a level adequate to protect the public health with an ample margin of safety" (Pedersen, 1987). The list of these pollutants was significantly expanded in the CAA Amendments of 1990.

6.3 TRANSPORTATION REGULATIONS

Under authority of RCRA, the U.S. EPA regulates the transportation of hazardous waste, which includes hazardous waste to be used as a supplemental fuel in cement kilns. According to these regulations (40 CFR 263), a transporter must perform the following tasks:

- obtain a U.S. EPA identification number
- comply with the manifest system (i.e., a system which ensures the integrity of the shipment from the point of origin to its destination)
- maintain the appropriate records
- take immediate action in the case of a release to ensure the safety of the public and the environment
- remediate (i.e., clean up) any releases to the environment.

The U.S. EPA coordinates its efforts with the U.S. Department of Transportation (DOT), which under the authority of the Hazardous Materials Transportation Act establishes regulations for the transportation of all hazardous material which includes hazardous waste (49 CFR 100-177). In general, the U.S. EPA's "regulations incorporate and require compliance with the DOT provisions on labeling, marking, placarding, using proper containers, and reporting discharges" (Hall *et al.*, 1987).

In addition to the regulatory functions of the U.S. EPA and the DOT, several agencies perform nonregulatory functions to ensure the safety of the public and the environment in the transportation of hazardous materials (National Governors' Association, 1988). For example, as one of its many functions, the Interstate Commerce Commission investigates interstate carriers to ensure that the services, equipment, and facilities that they provide are adequate for meeting all the necessary regulations. The Federal Emergency Management Agency provides the necessary assistance to state and local governments to ensure their response to a hazardous materials emergency. If a release of hazardous materials occurs, the National Transportation Safety Board investigates the accident to determine the probable cause. These agencies are just a few of the many that are involved with some phase in the transportation of hazardous materials. For a discussion regarding the risks of transporting hazardous waste, see Section 8.5.

6.4 STORAGE REQUIREMENTS

Under authority of RCRA, the U.S. EPA has established strict hazardous waste storage regulations which apply to cement production facilities that store hazardous waste on site (40 CFR 266.35). General facility standards require the following:

- waste analysis (40 CFR 264.13 and 265.13)
- security provisions (40 CFR 264.14 and 265.14)
- facility inspections (40 CFR 264.15 and 265.15)
- personnel training (40 CFR 264.16 and 265.16).

A contingency plan and emergency procedures must also be established. "The contingency plan must be designed to minimize hazards to human health or the environment from fires, explosions, or any unplanned sudden or non-sudden release of hazardous waste or hazardous waste constituents to air, soil, or surface water" (40 CFR 264.51 and 265.51). Records must be maintained such that the fate of the stored waste is documented (40 CFR 264.73 and 265.73). Finally, the storage area must be designed and maintained such that the integrity of the groundwater is assured [40 CFR (264 and 265) Subpart F]. These requirements are just a few of the many that are in place, and were in place even before the BIF rule was developed, to ensure the safe storage of hazardous waste fuel at cement production facilities.

6.5 WORKER SAFETY REQUIREMENTS

The Federal Mine Safety and Health Administration establishes regulations that protect workers at quarries and cement production facilities, including those that use hazardous waste as a supplemental fuel. The regulations include standards for worker exposure to airborne contaminants and requirements for the use of protective clothing and equipment when dealing with hazards. These regulations and many more are documented in 30 CFR Parts 1 to 199.

Labor organizations that represent workers at cement production facilities have publicly endorsed the use of hazardous waste as a supplemental fuel in cement kilns. Both the United Paperworkers International Union and the International Brotherhood of Boilermakers, Iron Ship Builders, Blacksmiths, Forgers and Helpers have written letters to their congressional representatives urging them to endorse legislation that supports this practice. (See Appendix B for copies of these letters.)

7.0 FATE OF THE CONSTITUENTS IN THE HAZARDOUS WASTE FUEL

The hazardous waste used as a fuel by the cement industry consists mainly of organic material, but also contains various amounts of metal components. To determine whether or not a cement kiln can burn hazardous waste fuel effectively, the fate of both the organic and metal constituents must be determined. In other words, what happens to the components in the combustion process? The following sections address this issue.

7.1 ORGANIC CONSTITUENTS

Complete combustion of an organic compound composed only of carbon and hydrogen produces carbon dioxide and water. If the organic compound contains chlorine, then hydrogen chloride or chlorine gas is also produced, depending on the combustion conditions. In addition, if the organic compound contains nitrogen or sulfur, their oxides of these elements (e.g., NO_x or SO_x) are produced. An organic compound is considered to be destroyed if the products mentioned above are the only ones formed.

If combustion conditions are not conducive to the complete destruction of the organic compounds, PICs can be emitted from the combustion device. One of the steps in determining whether a cement kiln can burn hazardous waste effectively is the demonstration of the destruction of the organic components. This demonstration requires measurement of the DRE and the PIC emissions. The following sections evaluate the results from trial burns that establish DREs and investigate PIC emissions.

7.1.1 DREs FOR SELECTED POHCs

One of the criteria developed to evaluate the destruction of organic constituents in the hazardous waste is the DRE. The BIF rule requires that a cement kiln demonstrate a DRE of 99.99% for selected POHCs in a trial burn (see Section 6.1.1). The following sections address the problems that are encountered with determining the DRE and the results of trial burns from the 1970s, 1980s, and 1990s, as well as trial burns that focused specifically on PCBs.

7.1.1.1 PROBLEMS WITH THE DETERMINATION OF THE DRE

Before the results of the trial burns are reviewed, potential problems with the determination of the DRE in cement kilns should be noted. The procedure for the determination of the DRE was originally developed for hazardous waste incinerators. As illustrated in Section 6.1.1, only the concentrations of the organic constituents in the hazardous waste are considered when the DRE is calculated. For a cement kiln, this method can pose a significant problem. Organic constituents are present not only in the hazardous waste entering the combustion device, but also in the raw material and the other fuel. If the raw material or other fuel contains the

(1)

compound selected to calculate the DRE, then the concentration of this compound entering the combustion device will be underestimated by measuring its concentration only in the hazardous waste. This underestimate will result in the calculation of an artificially low DRE.

In addition, if the compound is present in the raw feed entering the cooler portion of the cement kiln, then the additional amount of the compound is most likely going to be volatilized rather than destroyed. This phenomenon results in a greater concentration in the stack gas and a lower calculated DRE.

This type of problem is not uncommon. For example, in 1976, Peerless Cement Company in Detroit, Michigan conducted a trial burn to determine whether PCBs (see Section 7.1.1.5) could be safely destroyed in their cement kiln (Lauber, 1987). PCBs were detected in the stack gases even when no PCB wastes were burned. The water from the Rouge River, which was used to slurry the raw material for their wet process kiln, was found to be the source of the PCBs. Since the slurry was fed into the cooler end of the kiln, the majority of the PCBs were volatilized rather than destroyed. As a result, the calculated DRE value was artificially low because the PCBs entering the kiln in the slurry water were not taken into account.

Similar to the "contamination" problems described above, selection of a POHC that is also a PIC produced from the combustion of conventional fuel leads to the calculation of an artificially low DRE. For example, toluene is typically produced when coal is burned. If toluene is chosen as the POHC to determine the DRE of a combustion device that is also burning coal as part of its fuel requirement, then an unrealistically low DRE will be obtained because the emission of toluene from the combustion of coal is not taken into account.

Regardless of these potential problems, the DREs demonstrated by many cement production facilities are extremely high. The following four sections review DREs established in a number of studies for a variety of POHCs.

7.1.1.2 RESULTS FROM TRIAL BURNS CONDUCTED IN THE 1970s

In the mid-1970s, a series of tests were conducted at the St. Lawrence cement plant in Canada to measure the destruction of various chlorinated waste streams being fed into their wet process cement kiln (Branscome and Mournighan, 1987; Lauber, 1987). The overall DRE established for the chlorinated compounds was greater than 99.986%. This value is artificially low because the water used to slurry the raw feed was contaminated with low molecular weight chlorinated compounds.

In 1978, a series of tests was conducted at the Stora Vika Cement Plant in Sweden to evaluate the efficiency of their wet process cement kiln in destroying various chlorinated waste streams (Ahling, 1979). Although chloroform was found in the stack gas, the majority of the chlorinated compounds were not detected. A DRE greater than 99.996% was determined for methylene chloride and a DRE greater than 99.998% was demonstrated for trichloroethylene. The results from these tests confirm the ability of the cement kiln to destroy the organic components in the

94

hazardous waste fuel as part of standard operations, even before U.S. regulations were in place requiring this level of destruction.

7.1.3.3. *Final Burn from Trial Burns Conducted in the 1980s*

Final burns conducted in the 1980s continued to demonstrate that high DREs could be obtained for the organic constituents in the hazardous waste fuel burned in cement kilns. The results of trial burns reported by Branscome *et al.* (1985) of one wet and one dry process cement kiln illustrate the typical values obtained for DREs. The POHCs selected for the trial burns were methylene chloride, 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113), methyl ethyl ketone, 1,1,1-trichloroethane, and toluene. As summarized in Table 7.1, the majority of the DREs were greater than 99.99%. DREs less than 99.99% resulted from either laboratory contamination problems or improper selection of the POHCs (see Section 7.1.1.D).

TABLE 7.1
AVERAGE DREs^a FOR A WET AND A DRY PROCESS CEMENT KILN

SELECTED POHCs	WET PROCESS KILN	DRY PROCESS KILN
Methylene chloride ^b	99.983%	99.96%
Freon 113	>99.999%	99.999%
Methyl ethyl ketone	99.988%	99.998%
1,1,1-Trichloroethane	99.995%	>99.999%
Toluene ^c	99.961%	99.995%

^a DREs were not adjusted to compensate for the presence of POHCs in laboratory blanks. This correction would result in higher DREs.

^b DRE artificially low because of laboratory contamination problems.

^c Emission of toluene attributed to the combustion of coal (i.e., level of emission did not change when a portion of the coal was replaced by hazardous waste fuel).

Source: Branscome *et al.* (1985).

Additional DREs were obtained in the trial burn for the dry process cement kiln. Since styrene, ethylbenzene, *m*-xylene, and benzaldehyde were also present in the waste stream, DREs were determined for each of these components, even though they were not specifically selected as POHCs. Similar to toluene, benzaldehyde was detected in stack emissions whether the fuel consisted solely of coal or a mixture of coal and hazardous waste. Regardless of this occurrence, a DRE of 99.998% was calculated for benzaldehyde. The other components were not detected in the stack gas and therefore the DREs were determined to be greater than 99.999%.

This result illustrates a significant point. Even when POHCs are not detected in the stack gas, a DRE of 100% is not obtained because all instruments used to analyze the stack gas have detection limits (i.e., the smallest possible quantities that can reliably be measured by the

instrument). Therefore, unless an instrument is developed that can detect infinitesimal quantities of a compound, demonstration of a DRE of 100% will be impossible.

7.1.1.4 RESULTS FROM TRIAL BURNS CONDUCTED IN THE 1990s

Trial burns conducted in the 1990s have focused on the selection of compounds as POHCs that would not typically be present as contaminants or generated as PICs from the combustion of conventional fuel. Use of this criterion has resulted in more accurate DREs being obtained.

Von Seebach and Tompkins (1991) recently reported the results of DRE testing of a dry process cement kiln equipped with a preheater. Carbon tetrachloride and trichlorobenzene were chosen as the POHCs. When hazardous waste fuel was fed to the burning zone of the kiln, DREs obtained were greater than 99.999% for carbon tetrachloride and greater than 99.995% for trichlorobenzene. To determine the limits of the system, DREs were also determined when these POHCs were fed to the entrance (i.e., cooler end) of the kiln along with tires. DREs obtained were greater than 99.999% for carbon tetrachloride and greater than 99.996% for trichlorobenzene.

Recent DRE testing conducted at a cement kiln owned by United Cement supports the foregoing results (Tracer Technologies, 1991). Sulfur hexafluoride was chosen as the POHC because of its thermal stability and ease of measurement in the stack gases. In addition, "contamination" problems and PIC interferences are unlikely with the use of this compound. DREs greater than 99.9998% were obtained in every case.

These test results illustrate that extremely high DREs can be obtained for cement kilns even when POHCs that are difficult to combust and destroy are used.

7.1.1.5 RESULTS FROM TRIAL BURNS THAT FOCUSED ON PCBs

The results of trial burns involving PCBs provide additional support for the ability of a cement kiln to destroy the organic constituents in the hazardous waste fuel. PCBs are a class of chlorinated organic compounds that have the general chemical structure shown in Figure 7.1. The most common trade name in the U.S. is Aroclor. A four-digit number that gives information on the chemical structure is associated with the trade name. For example, the designation Aroclor 1242 indicates that the compound is a chlorinated biphenyl (12) and that it contains 42% chlorine (42), or approximately three chlorines per biphenyl ring (Metck Index, 1983).

Because of their useful characteristics, such as thermal stability, exceptional dielectric properties, and nonflammability, PCBs were widely used in the U.S. (Black and Swanson, 1983). During the 1960s, the accumulation of PCBs in the environment and their toxicity in laboratory tests were recognized. As a result, the production of these compounds was banned by the U.S. Congress in 1976. At the same time, the Toxic Substances Control Act (TSCA), which regulates

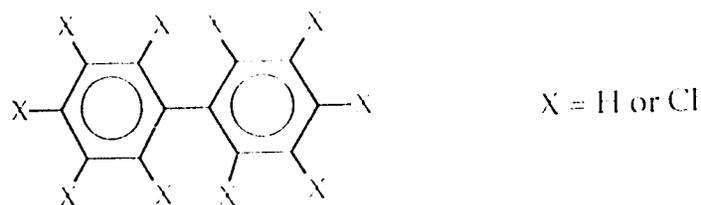


FIGURE 7.1 General Chemical Structure for PCBs

the disposal of PCBs, was passed. Incineration was recognized as the only acceptable method for the disposal of significant concentrations (i.e., greater than 500 ppm) of PCBs. A DRE of 99.9999% is required by TSCA for the incineration of these compounds. In other words, out of 100 tons that are fed into a combustion device, less than 4 ounces are allowed to be emitted in the stack gas. This level of destruction prevents future exposure to the vast majority of this waste.

The potential for using cement kilns to incinerate PCBs has been investigated. Since PCBs are such stable compounds, the ability of a cement kiln to destroy these compounds indicates the overall ability to destroy the majority of organic constituents in the hazardous waste fuel. The DREs determined from several trial burns conducted in other countries are listed in Table 7.2. The majority of cement kilns burning hazardous waste as fuel in the U.S. have chosen not to burn PCB wastes for the reasons discussed in Section 3.2. Regardless of this decision, the results indicate that cement kilns are effective at destroying PCBs. In addition, in all but one case, which is the earliest cement kiln test performed, the TSCA standard of 99.9999% was exceeded.

TABLE 7.2
DREs FOR PCBs

FACILITY	TYPE OF KILN	DRE	REFERENCE
St. Lawrence (Canada)	Wet process	99.986%	Lauber (1987)
Stora Vika (Sweden)	Wet process	99.99998%	Ahling (1979)
Degerhamn (Sweden)	Dry process	99.99999%	Lauber (1987)
Norcem (Norway)	Wet process	99.99997%	Lauber (1987)
Norway	Dry process	99.9999%	Benestad (1989)

The DRE values presented above for a variety of organic compounds, including PCBs, indicate that cement kilns can achieve a DRE of 99.99% or greater. These results signify that cement

kilns can achieve one of the criteria that indicates the destruction of the organic constituents in the hazardous waste fuel.

7.1.2 PRODUCTS OF INCOMPLETE COMBUSTION

A high DRE for selected organic components does not ensure that small quantities of PICs are not emitted in the stack gas. As discussed in Section 6.1.1, the BIF rule requires the continuous monitoring of carbon monoxide and, if applicable, total hydrocarbon emissions. The U.S. EPA (1991) notes that if these emission rates are kept within the allowed limits, good combustion conditions will be maintained and the emission of PICs will be minimized.

The Norwegian government has supported and encouraged the investigation of the practice of burning hazardous waste in cement kilns. Consequently, some of the most detailed test burns have been conducted by the Norwegian cement companies (Lauber, 1987; Benestad, 1989). The results of one of the most thorough investigations were reported by Benestad (1989). The results from these studies, conducted in 1983 and 1987 with a dry process cement kiln, indicate that the emissions of organic compounds and particulates are dependent on the operating conditions and not the fuel type (i.e., fossil versus hazardous waste) that is burned.

Several U.S. studies investigating the emission of PICs from cement production facilities burning hazardous waste as a supplemental fuel have been completed. The results from these studies are discussed in the following sections.

7.1.2.1 COMPREHENSIVE STUDIES

PIC emissions were investigated in the studies of the wet and the dry process cement kilns reported by Branscome *et al.* (1985). When coal was burned as the only fuel in the wet process kiln, toluene, benzene, xylene, biphenyl, naphthalene, and methyl naphthalene were among the compounds detected in the emissions. The rate of emission for benzene when either coal or hazardous waste was burned ranged from 15 to 50 milligrams per second (mg/sec). The rates of emission for the other compounds when either coal or hazardous waste was burned ranged from 1 to 10 mg/sec. The highest rates of emission of these components occurred when normal operating conditions were disrupted while burning coal. "No statistically significant increase in emission rates was observed when the waste fuel was burned" (Branscome *et al.*, 1985). The results for the dry process cement kiln were similar to the results for the wet process cement kiln. The only exception was that the rates of emission were an order of magnitude less (i.e., approximately 0.3 mg/sec) than the rates of emission detected in the wet process cement kiln.

Recently, the U.S. EPA (Garg, 1990b) reported the results of emission testing of a wet process cement kiln. The levels of emission of both volatile and semivolatile PICs were determined. A stable baseline with coal as the only fuel could not be established. Therefore, a combination of coal and diesel fuel was used to establish baseline conditions. No significant increase in either the number or concentration of PICs occurred when a portion of the fossil fuel was replaced by hazardous waste. The author noted that the number and the concentration of PICs for this

cement kiln appeared to be greater than those for a typical hazardous waste incinerator. However, this observation is based on tests involving eight incinerators but only one cement kiln. As a result, no generalization concerning PIC emissions from cement kilns versus those from hazardous waste incinerators can be made.

The U.S. EPA (Garg, 1990a) also reported the results of emission testing of a dry process cement kiln equipped with a precalciner. The emission of PICs was investigated under the following three operating conditions: no waste feed (i.e., coal only), liquid waste fired into the burning zone of the kiln, and liquid waste fired into the burning zone with containerized solid waste fed into the kiln entrance. In all the tests, the precalciner was fueled with coal. The gas in the main stack and bypass duct was analyzed for 110 compounds classified by the U.S. EPA as priority pollutants.

Twelve volatile compounds and one semivolatile compound were detected in the bypass duct for the three different operating conditions. Concentrations of PICs for the three different operating conditions were similar, except for higher emissions of benzene, monochlorobenzene, and toluene when both liquid and solid waste were fed to the kiln.

By comparison, 10 volatile compounds and 5 semivolatile compounds were detected in the main stack for the three operating conditions. PIC concentrations were similar among the different operating conditions. Overall, concentrations measured in the main stack were higher than the concentrations measured in the bypass duct. Benzene, ethylbenzene, and toluene in particular were significantly higher. Since the main stack receives gases from the kiln and the precalciner, whereas the bypass duct receives only kiln gases, the higher emissions of benzene and toluene were attributed to the combustion of coal in the precalciner. In general, the number and concentration of PICs detected in both the main stack and bypass duct were lowest when liquid waste was fired into the burning zone of the kiln.

The author concluded that both the type and concentrations of PICs from this cement kiln were comparable with the type and concentrations of PICs from a typical hazardous waste incinerator. Since the results of one cement kiln test were being compared with the results of a series of tests from eight incinerators, no generalizations concerning PIC emissions of cement kilns versus PIC emissions of hazardous waste incinerators can be made.

7.1.2.2 STUDIES FOCUSED ON THE EMISSION OF PCDDs AND PCDFs

Many studies evaluating PIC emissions focus on PCDDs and PCDFs. The general chemical structures for these two classes of compounds are shown in Figure 7.2. Based on the number and position of chlorine atoms on the ring structure, 75 isomers of dibenzo-*p*-dioxin and 135 isomers of dibenzofuran are possible (Miles *et al.*, 1987). As discussed in Section 6.1.1, the BIF rule requires any facility with the potential for emission of significant quantities of these compounds to conduct emission testing and dispersion modeling.

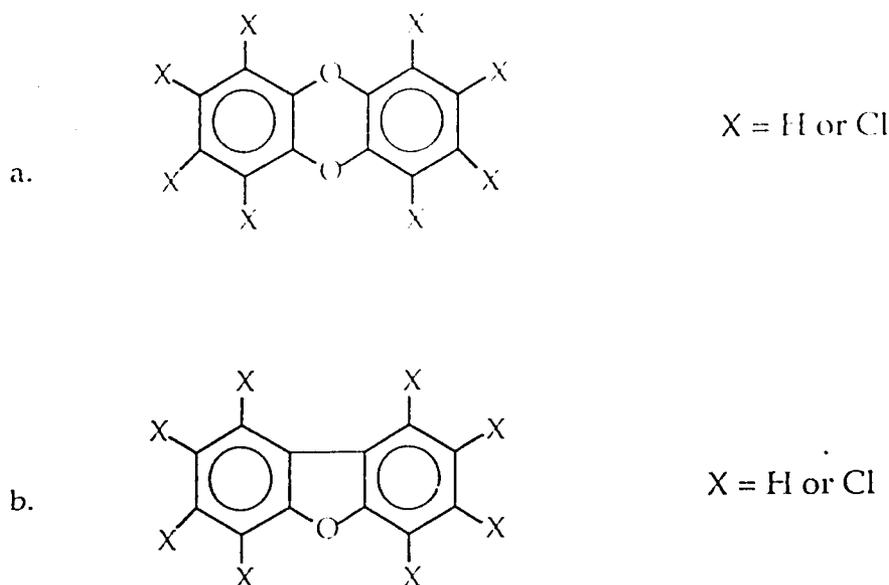


FIGURE 7.2 General Chemical Structures for PCDDs (a) and PCDFs (b).

The presence of PCDDs and PCDFs in the emissions of cement kilns burning hazardous waste as a supplemental fuel has been investigated. In trial burns at several different kilns, these compounds were not detected in the stack gas (Branscome *et al.*, 1985; Lauber, 1987). In general, when these compounds are detected, their concentration in the stack gas when hazardous waste fuel is burned is similar to their concentration in the stack gas when no hazardous waste fuel is burned (Garg, 1990a,b).

The U.S. EPA (Miles *et al.*, 1987) conducted an extensive study on the emission of PCDDs and PCDFs from combustion sources. The primary objective of the study was to identify the combustion sources that emitted these components and the quantity of these emissions. The secondary objective was to determine the factors that influenced these emissions. The results from their extensive literature survey and emission testing are summarized in Table 7.3. Cement kilns burning hazardous waste as a supplemental fuel do not appear to emit significant quantities of PCDDs and PCDFs. In fact, emissions from cement kilns are, in some cases, 10,000 times lower than the measured emissions from other combustion devices.

The U.S. EPA (Miles *et al.*, 1987) discovered two factors that significantly influence the emission of PCDDs and PCDFs. One of the factors was the combustion temperature. Devices that employed a low-temperature combustion process emitted the largest quantities of PCDDs and PCDFs. Since cement kilns operate with a high combustion temperature, long gas residence time, and sufficient mixing and oxygen content, the emissions of these compounds should not be significant.

TABLE 7.3
SUMMARY OF PCDD/PCDF STACK EMISSIONS BY SOURCE CATEGORY

SOURCE CATEGORY	NUMBER OF UNITS TESTED ^a		RANGE OF PCDD EMISSIONS	RANGE OF PCDF EMISSIONS
	In Study	Literature	(as measured, ng/m ³)	(as measured, ng/m ³)
Municipal Waste Incinerators				
European	0	8	71 - 48,997	37 - 9,831
U.S. and Canada	0	10	3.3 - 11,686	8.5 - 22,000
Boilers Cofiring Waste				
Commercial	0	3	1,400 - 17,000	170
Industrial	0	5	<0.002 ^b - 76.4	<0.002 - 5.5
Secondary Copper Cupola Furnace	1	0	11,900	60,700
Wood Combustion				
PCP-Treated Wood	0	2	<17 ^c - 1,520	<17 ^c - 587
Salt-Laden Wood-Fired Boiler	1	0	195	83.2
Sewage Sludge Incinerators	3	2	ND ^d - 812	ND ^d - 1,374
Wire Reclamation Incinerator				
(wire and transformer feed)	1	0	704	866
Industrial Solid Waste Incinerator	1	0	625	2,390
Wire Reclamation Incinerator				
(wire-only feed)	1	0	173	305
Hospital Incinerators	0	4	15 - 69	25 - 156
Hazardous Waste Incinerators:				
Rotary Kiln	0	2	7.7 - 8.6	11.2 - 19
Drum and Barrel Reclamation Incinerator	1	0	5	27
Carbon Regeneration Furnace				
Without Afterburner	0	1	0.18	0.3
With Afterburner	1	1	1.6 - 3.7	0.05 - 3.3
Black Liquor Boiler	3	0	0.8 - 2.9	0.6 - 2.1
Cement Kilns	0	3	<1 ^e - 1.35	<1 ^e - 0.74
Lime Kilns	0	1	<0.34 - <2.0	--
Utility Boiler Cofiring Waste	0	1	<0.031 - <0.10	<0.31 - <0.10
Fossil Fuel Combustion				
Coal-Fired Utility	0	4	<0.10 - <0.70	<0.10 - <0.70
Pulverized Coal	0	1	<4.2 - <7.9 ^f	<0.67 - <1.3 ^f
Oil-Fired Utility	0	1	<4.2 - <7.9 ^f	<0.67 - <1.3 ^f
Incinerator Ship	0	1	<0.0009 - <0.086 ^g	<0.3 - <3.0

"--" = data not reported.

^a Analytical data for noncatalytic woodstoves tested in this study were not reported.

^b Numbers preceded by "<" indicate detection limits.

^c Detection limits reported in terms of parts per billion by volume.

^d Not detected. Detection limits not reported.

^e Detection limits reported in terms of ng/ul of sample injected into GC-MS for analysis.

^f 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin/2,3,7,8-Tetrachlorodibenzofuran scan only.

^g Detection limits reported in terms of ng/ml injected into GC-MS for analysis.

Source: Miles *et al.* (1987).

The other factor was the composition of the feed material. Ahling (1979) investigated the emission of PCDDs and PCDFs from a cement kiln when burning compounds (e.g., chlorinated phenols and phenoxy acids) believed to give rise to emissions of these components. No tetra- or hexachlorodibenzo-*p*-dioxins or furans were detected. Although the presence of hepta- and octachlorodibenzo-*p*-dioxins and octachlorodibenzofuran was indicated, confirmation of these components in the stack gas was impossible because they were not formed in sufficient quantities for positive identification.

Both the comprehensive studies and the studies that focused on PCDDs and PCDFs indicate that cement kilns burning hazardous waste fuel do not appear to emit a greater quantity of these PICs than cement kilns burning only conventional fuel.

7.2 METALS

Although a metal compound is changed in the combustion process, a metal, like any element, is not destroyed in a combustion device. Accordingly, metals will be present in either the emissions, the CKD, or the clinker. As discussed in Section 6.1.2, the BIF rule places limits on the concentration of 10 metals that can be emitted from the stack.

In addition, the concentrations of 12 metals in the CKD are indirectly regulated by the BIF rule (see Section 6.1.6). The facility must prove that the concentrations of these metals in the CKD do not significantly change when burning hazardous waste or show that the concentrations of these metals that leach from the dust do not exceed the health-based limits set by the U.S. EPA.

The BIF rule does not regulate the composition of the clinker produced from a cement production facility burning hazardous waste. However, as discussed in Section 3.2, the concentrations of metals in the clinker are limited because the quality of the cement cannot be adversely affected if the cement is to meet ASTM standards.

Regardless of these regulations and requirements, determining the fate of the metal constituents is important. In Section 7.2.1, the general behavior and distribution of metals in the cement kiln are discussed. The remaining sections address metal emissions and the metal concentrations in CKD and cement, as well as the metal concentrations in CKD and cement leachate.

7.2.1 GENERAL BEHAVIOR OF METALS IN THE CEMENT KILN

Since lead was considered to be the major metal component in waste fuel that was also associated with adverse health effects, the earliest investigations focused on the fate of this metal. Branscome and Mournighan (1987) have reviewed the results of the early tests. The results from the St. Lawrence cement company in Canada represent the general trend. When waste oil containing a high concentration of lead, but a low halogen content, was burned in their dry process cement kiln, no increase in lead emissions was observed. The majority of the lead was retained in the clinker. However, when chlorinated wastes with a low lead content were burned in their wet process cement kiln, lead emissions increased. In this case the

majority of the lead was retained in the CKD. Similar results from one dry process and two wet process cement kilns also reviewed by Branscome and Mournighan (1987) support this observation.

These results indicate that lead emissions can increase when burning chlorinated solvents. In addition, the distribution of the lead shifts from the clinker to the CKD because of the formation of the more volatile lead chloride. The most significant observation, however, is that the majority of the lead is retained in the process solids (i.e., clinker or CKD). Branscome and Mournighan (1987) conclude that a cement kiln can retain at least 99% of the lead in the process solids, whereas a boiler burning waste oil will retain only 40 to 50% of the lead from the waste oil in the ash. The other 50 to 60% of the lead is emitted from the stack as opposed to the 1% emitted from a cement kiln stack.

The more recent studies have focused on the metals that might be present in the raw materials or fuel involved in the cement production process. Sprung (1985) investigated the behavior of arsenic, cadmium, chromium, lead, nickel, thallium, and zinc. The majority of these metals fed into the kiln were retained in the process solids. Sprung's (1985) investigation indicated that the distribution of a metal between the clinker and the CKD can depend on the quantity of the metal fed into the kiln, the chloride content, or the manufacturing process. For example, the distribution of zinc was relatively insensitive to both the production process and the chloride content, and was largely bound in the clinker. However, the distribution of lead in the process solids depended on both the manufacturing process and the chloride content. Arsenic, chromium, and nickel behaved like zinc; cadmium behaved like lead. Thallium was the most volatile of the metals investigated. Less than 5% of the thallium intake was bonded in the clinker. Because of the high volatility of this metal, Sprung (1985) recommended that its intake be strictly monitored.

The most recent and extensive study investigating the fate of metals in the cement kiln system was carried out by von Seebach and Tompkins (1991). Three dry process cement kilns equipped with precalciners, two dry process cement kilns equipped with preheaters, and one wet process cement kiln were used in the investigation. Hazardous waste was burned in two of the kiln systems. The metals investigated were antimony, arsenic, barium, beryllium, cadmium, chromium, lead, nickel, selenium, silver, vanadium, and zinc. The concentration of metals fed into the kiln systems was varied by at least 1 order of magnitude. The total input and output of the metals were analyzed to estimate the retention in the process solids versus the concentrations in the emissions. In all but one case, greater than 99% of the metals was retained in the process solids. Selenium was the exception. Its retention rate was greater than 95%. No difference in the emissions of these metals was noted when a portion of the coal was replaced by hazardous waste fuel. Although the emission of the metals was generally less than 1% of the metals fed into the kiln, the authors suggest that the input of antimony, cadmium, lead, selenium, silver, and zinc be carefully monitored regardless of the fuel being burned.

The fate of the more volatile metals (e.g., mercury and thallium) were also examined by von Seebach and Tompkins (1991) under the test conditions described above. Variability between

the kiln systems made the test results difficult to interpret. Regardless of this problem, the retention of thallium averaged 90% and the retention of mercury averaged 61%. Because of the lower retention of these metals within the process solids, the authors noted that the input of these metals into the kiln should be carefully monitored and recommended further investigation of the behavior of these metals.

The studies discussed above focused on the fate of the metals fed into the cement kiln. The results indicate that the majority of the metals entering in either the raw feed or fuel are retained in the process solids and that the emissions are not significantly different when a portion of the conventional fuel is replaced by hazardous waste.

7.2.2 EMISSIONS

Although the results of the literature studies discussed above indicate that metal emissions do not significantly change when burning hazardous waste fuel, metal emissions continue to be a major issue. Consequently, the Combustion Research Institute (CRI), a division of Environmental Toxicology International, has established a database to evaluate potential differences in metal emissions due to burning hazardous waste.

The raw data are summarized in Table 7.4. From a cursory inspection of the summary table, the

TABLE 7.4
COMPARISON OF METAL EMISSIONS (mg/sec)
FROM CEMENT KILNS (CKs)

METAL	CKs BURNING CONVENTIONAL FUEL				CKs BURNING HAZARDOUS WASTE FUEL			
	Avg	Std Dev	Min	Max	Avg	Std Dev	Min	Max
Antimony	0.685	1.58	<0.0100	5.76	0.808	1.78	<0.0100	5.08
Arsenic	0.991	1.65	<0.06736	5.70	0.592	0.890	<0.00723	2.80
Barium	10.7	37.7	0.0354	166	19.9	47.3	0.0218	144.76
Beryllium	0.0438	0.108	<0.000500	<0.369	0.0452	0.110	<0.000499	<0.326
Cadmium	0.344	0.376	<0.0220	1.29	0.309	0.317	<0.0218	1.34
Chromium	20.6	58.5	<0.0100	264	12.5	52.4	<0.0100	299.1
Lead	1.95	2.37	0.0527	12.0	5.83	10.4	0.0210	50.8
Mercury	0.984	2.39	0.0537	10.7	2.14	2.96	0.132	9.84
Nickel	17.3	40.1	<0.0663	138	11.0	34.5	0.0696	171.4
Selenium	0.0719	0.0678	<0.00736	0.260	0.0455	0.0684	0.00029	<0.195
Silver	0.555	1.04	<0.0220	3.96	0.886	2.26	<0.0217	7.94
Thallium	1.40	1.95	<0.00736	5.77	0.806	1.78	<0.00723	5.08
Vanadium	0.333	0.221	<0.0886	<0.620	0.359	0.245	<0.0868	0.62
Zinc	2.97	2.51	0.334	7.80	1.53	1.58	0.147	6.48

NOTE: Data reported at less than the detection limit were assumed to be present at the detection limits in order to calculate the averages and standard deviations. This procedure will overestimate the actual concentrations present.

104

averages and ranges of metal emissions for cement kilns burning only conventional fuel appear to be similar to the averages and ranges of metal emissions for cement kilns replacing a portion of their conventional fuel with hazardous waste. In fact, average emissions are lower for seven metals when a portion of the conventional fuel is replaced with hazardous waste.

The raw data used to compile the summary table were evaluated to determine statistically significant differences in the metal emissions (Springborn, 1991). The statistical model attempted to minimize the variation between kilns due to differences in engineering or testing methods. As a result, the model identified those differences in metal emissions due only to replacement of conventional fuel with hazardous waste fuel.

One final note on the evaluation of these data concerns values reported at less than the detection limit. When a facility indicated that the result was less than the detection limit, the detection limit was used in the generation of the summary table and in the evaluation of the data for statistical significance. This method ensured that the most environmentally conservative result was achieved.

The results of the statistical analysis, which are summarized in Table 7.5, indicate that for the majority of metals no statistically significant differences exist in the emissions from cement kilns burning hazardous waste as opposed to those burning only conventional fuel. The two exceptions are lead and mercury, which appear to exhibit statistically significant higher emissions from cement kilns using hazardous waste fuel. Although statistically significant differences in the lead and mercury emissions were noted, the average emissions for these two metals presented in Table 7.4 indicate that the differences are less than an order of magnitude. As discussed in Section 8.2.4, these differences are not substantial in terms of potential for adverse health effects. The statistical analysis also suggested that selenium emissions from cement kilns burning hazardous waste fuel are significantly lower than those from kilns burning only conventional fuel.

The lack of a significant difference for a majority of the metal emissions might be surprising in light of the results of a trial burn conducted in 1983 at a wet process cement kiln, in which emissions of cadmium, copper, lead, mercury, and selenium were significantly higher when burning hazardous waste fuel (Bolstad *et al.*, 1985). Although these emissions increased, the nickel emissions were found to significantly decrease when hazardous waste fuel was burned. These differences could be due to the quality of the hazardous waste burned in the early 1980s. In her review of results from trial burns conducted in Norway in 1983 and 1987 with a dry process cement kiln, Benestad (1989) noted that the concentrations of lead and cadmium decreased significantly in the typical waste fuel between 1983 and 1987. As a result of this decrease, significant differences in lead and cadmium emissions in the 1987 Norwegian tests were not observed when hazardous waste was burned. These results suggest that the hazardous waste fuel in the U.S. may have experienced the same trend.

the kiln systems made the test results difficult to interpret. Regardless of this problem, the retention of thallium averaged 90% and the retention of mercury averaged 61%. Because of the lower retention of these metals within the process solids, the authors noted that the input of these metals into the kiln should be carefully monitored and recommended further investigation of the behavior of these metals.

The studies discussed above focused on the fate of the metals fed into the cement kiln. The results indicate that the majority of the metals entering in either the raw feed or fuel are retained in the process solids and that the emissions are not significantly different when a portion of the conventional fuel is replaced by hazardous waste.

7.2.2 EMISSIONS

Although the results of the literature studies discussed above indicate that metal emissions do not significantly change when burning hazardous waste fuel, metal emissions continue to be a major issue. Consequently, the Combustion Research Institute (CRI), a division of Environmental Toxicology International, has established a database to evaluate potential differences in metal emissions due to burning hazardous waste.

The raw data are summarized in Table 7.4. From a cursory inspection of the summary table, the

TABLE 7.4
COMPARISON OF METAL EMISSIONS (mg/sec)
FROM CEMENT KILNS (CKs)

METAL	CKs BURNING CONVENTIONAL FUEL				CKs BURNING HAZARDOUS WASTE FUEL			
	Avg	Std Dev	Min	Max	Avg	Std Dev	Min	Max
Antimony	0.685	1.58	<0.0100	5.76	0.808	1.78	<0.0100	5.08
Arsenic	0.991	1.65	<0.00736	5.70	0.592	0.890	<0.00723	2.80
Barium	10.7	37.7	0.0354	166	19.9	47.3	0.0218	144.76
Beryllium	0.0438	0.108	<0.000500	<0.369	0.0452	0.110	<0.000499	<0.326
Cadmium	0.344	0.376	<0.0220	1.29	0.309	0.317	<0.0218	1.34
Chromium	20.6	58.5	<0.0100	264	12.5	52.4	<0.0100	299.1
Lead	1.95	2.37	0.0527	12.0	5.83	10.4	0.0210	50.8
Mercury	0.984	2.39	0.0537	10.7	2.14	2.96	0.132	9.84
Nickel	17.3	40.1	<0.0663	138	11.0	34.5	0.0696	171.4
Selenium	0.0719	0.0678	<0.00736	0.260	0.0455	0.0684	0.00029	<0.195
Silver	0.555	1.04	<0.0220	3.96	0.886	2.26	<0.0217	7.94
Thallium	1.40	1.95	<0.00736	5.77	0.806	1.78	<0.00723	5.08
Vanadium	0.333	0.221	<0.0886	0.620	0.359	0.245	<0.0868	0.62
Zinc	2.97	2.51	0.334	7.80	1.53	1.58	0.147	6.48

NOTE: Data reported at less than the detection limit were assumed to be present at the detection limits in order to calculate the averages and standard deviations. This procedure will overestimate the actual concentrations present.

106

averages and ranges of metal emissions for cement kilns burning only conventional fuel appear to be similar to the averages and ranges of metal emissions for cement kilns replacing a portion of their conventional fuel with hazardous waste. In fact, average emissions are lower for seven metals when a portion of the conventional fuel is replaced with hazardous waste.

The raw data used to compile the summary table were evaluated to determine statistically significant differences in the metal emissions (Springborn, 1991). The statistical model attempted to minimize the variation between kilns due to differences in engineering or testing methods. As a result, the model identified those differences in metal emissions due only to replacement of conventional fuel with hazardous waste fuel.

One final note on the evaluation of these data concerns values reported at less than the detection limit. When a facility indicated that the result was less than the detection limit, the detection limit was used in the generation of the summary table and in the evaluation of the data for statistical significance. This method ensured that the most environmentally conservative result was achieved.

The results of the statistical analysis, which are summarized in Table 7.5, indicate that for the majority of metals no statistically significant differences exist in the emissions from cement kilns burning hazardous waste as opposed to those burning only conventional fuel. The two exceptions are lead and mercury, which appear to exhibit statistically significant higher emissions from cement kilns using hazardous waste fuel. Although statistically significant differences in the lead and mercury emissions were noted, the average emissions for these two metals presented in Table 7.4 indicate that the differences are less than an order of magnitude. As discussed in Section 8.2.4, these differences are not substantial in terms of potential for adverse health effects. The statistical analysis also suggested that selenium emissions from cement kilns burning hazardous waste fuel are significantly lower than those from kilns burning only conventional fuel.

The lack of a significant difference for a majority of the metal emissions might be surprising in light of the results of a trial burn conducted in 1983 at a wet process cement kiln, in which emissions of cadmium, copper, lead, mercury, and selenium were significantly higher when burning hazardous waste fuel (Bolstad *et al.*, 1985). Although these emissions increased, the nickel emissions were found to significantly decrease when hazardous waste fuel was burned. These differences could be due to the quality of the hazardous waste burned in the early 1980s. In her review of results from trial burns conducted in Norway in 1983 and 1987 with a dry process cement kiln, Benestad (1989) noted that the concentrations of lead and cadmium decreased significantly in the typical waste fuel between 1983 and 1987. As a result of this decrease, significant differences in lead and cadmium emissions in the 1987 Norwegian tests were not observed when hazardous waste was burned. These results suggest that the hazardous waste fuel in the U.S. may have experienced the same trend.

TABLE 7.5
METAL EMISSIONS COMPARISONS ^a

METAL	CK/HWF ^b vs. CK/CF ^c
Antimony	No significant difference
Arsenic	No significant difference
Barium	No significant difference
Beryllium	No significant difference
Cadmium	No significant difference
Chromium	No significant difference
Lead	CK/HWF > CK/CF ^d
Mercury	CK/HWF > CK/CF ^d
Nickel	No significant difference
Selenium	No significant difference ^e
Silver	No significant difference
Thallium	No significant difference
Vanadium	No significant difference
Zinc	No significant difference

^a Conclusions based on a 95% confidence level (i.e., 95% confidence that the results were not obtained by random chance).

^b CK/HWF = cement kiln burning hazardous waste fuel.

^c CK/CF = cement kiln burning only conventional fuel (e.g., coal).

^d CK/HWF > CK/CF = emissions from cement kiln burning hazardous waste greater than emissions from cement kiln burning only conventional fuel.

^e Statistical trends suggest CK/HWF < CK/CF.

As more data are collected and compiled in the CRI database, the results presented above could change. This assumption is supported by the fact that a preliminary statistical analysis of data initially compiled in the CRI database indicated that no significant differences existed in any metal emissions (Kelly and Pascoe, 1991). As more data are collected and compiled from compliance burns, which represent the worst-case scenarios with the highest metal inputs, additional significant differences in the metal emissions might be indicated.

7.2.3 CEMENT KILN DUST

Two separate issues exist regarding the CKD generated by a cement production facility. One is the concentration of metals in the CKD and the other is the potential of the metals to leach from the CKD. These issues are discussed below.

7.2.3.1 METAL CONCENTRATIONS IN CKD

On behalf of the PCA, the Construction Technology Laboratories recently completed a research project to evaluate the metal concentrations in CKD (PCA, 1991). Preliminary data that have

been compiled in the CRI database support the results and conclusions of the PCA report. A summary of the results of the PCA report and the CRI database are presented in the following sections.

PCA Results

Samples of CKD from 97 North American kiln systems were collected and analyzed for the PCA report (PCA, 1991). The results, which are summarized in Table 7.6, represent samples from both cement kilns burning hazardous waste and those burning only nonhazardous fuels.

TABLE 7.6
METAL CONCENTRATIONS (ppm) IN CKD:
1991 INVESTIGATION

METAL	AVERAGE ^a	MINIMUM ^b	MAXIMUM ^c
Antimony ^d	2.0	0.3	3.4
Arsenic	18	2	159
Barium	172	35	767
Beryllium	0.65	0.13	3.54
Cadmium	10.3	0.1	59.6
Chromium	41	8	293
Lead	360 ^e	34	7,390 (2,680 ^f)
Mercury	0.660	0.004	25.500
Nickel	22	1	60
Selenium	28.14	2.68	307.00
Silver	10.53	4.80	40.70
Thallium	43.24	1.40	776.00

^a Average of measurable values.

^b Minimum of measurable values.

^c Maximum of measurable values.

^d Majority of values were below detection limit.

^e Anomalously high value (7,390 ppm) excluded from calculation of average in accordance with standard statistical procedures. Average value if value of 7,390 ppm is included is 434 ppm.

^f Second highest value.

Source: PCA (1991).

The averages presented in Table 7.6 are artificially high because only measurable values were used in the calculations. For example, antimony was detected in 9 out of 95 samples analyzed. Only these nine values were then used to calculate the average listed in Table 7.6. This procedure resulted in highly conservative average metal concentrations in CKD.

199

Although the majority of the metal concentrations listed in Table 7.6 appear to be low, the lead concentration (i.e., 360 ppm) may appear to be high. To put this value in perspective, Mix and Murphy (1984) calculated the lead concentration that might be present in the CKD from a cement kiln replacing a portion of its conventional fuel with hazardous waste fuel. The value that they obtained was 682 ppm. They commented that "this level of contamination is typical of surface soil concentrations in U.S. cities and perhaps a third the value of urban street dust." The average lead concentration measured in the more recent PCA report is roughly half of the value calculated by Mix and Murphy in 1984.

On examination of the maximum values, the PCA (1991) concluded that the most significant factor in determining the metal concentrations in CKD is the amount of CKD that is recycled to the kiln. If a cement production facility uses raw materials and fuels that contain volatile metals (e.g., cadmium, lead, selenium, and thallium) and recirculates the majority of the CKD, then the metal concentrations in this CKD will be higher than those at a facility that recirculates only a portion of their CKD.

A perspective on the average metal concentration: measured for the PCA report can be obtained by comparing the recent PCA results to the results from the U.S. Bureau of Mines study conducted in 1982 (see Section 2.4 for description of their study). The U.S. Bureau of Mines study analyzed 113 samples of CKD collected from 102 cement production facilities. The results of this earlier study are presented in Table 7.7.

TABLE 7.7
METAL CONCENTRATIONS (ppm) IN CKD:
1982 INVESTIGATION

METAL	AVERAGE ^a	MINIMUM	MAXIMUM
Antimony ^b	7.5	<1.6	70
Arsenic	24	1.3	518
Barium ^b	--	<55	<55
Beryllium ^b	--	<2	<2
Cadmium	23	<1.5	352
Chromium	42	11	172
Lead	264	<26	1750
Mercury ^c	0.52	<0.13	1.0
Nickel	30	<12	91
Selenium	No data	No data	No data
Silver	8.3	<3	17
Thallium	-- ^d	<60	185

^a Average of measurable values.

^b Majority of values were below the detection limit.

^c Only 10 samples analyzed for mercury.

^d Unable to calculate average (lack of data).

Source: Haynes and Kramer (1982)

Comparison of the average metal concentrations determined in the U.S. Bureau of Mines study to the average metal concentrations determined in the PCA report reveals that no substantial (i.e., order of magnitude) changes have occurred over a period of 10 years. Regardless of the significant changes in facility design, fuels, and raw materials, the metal concentrations in CKD have remained relatively constant.

CRF Results

The CRF database has been designed to evaluate potential differences in metal concentrations of CKD due to burning hazardous waste in cement kilns, although very little data have been compiled to conduct this evaluation. Available compiled data are summarized in Table 7.8. This summary should be reviewed with caution because it represents a small sample of the cement industry and may not be representative of the whole industry.

TABLE 7.8
COMPARISON OF METAL CONCENTRATIONS (ppm) IN CKD

METAL	CKS BURNING CONVENTIONAL FUEL				CKS BURNING HAZARDOUS WASTE FUEL			
	Avg	Std Dev	Min	Max	Avg	Std Dev	Min	Max
Antimony	16	36	<1	105	15	38	<1	124
Arsenic	25	12	12.8	44.1	23	19	1.67	65
Barium	161	49.8	119	271	137	57.4	56.1	279
Beryllium	1.0	0.96	<0.5	2.63	1.6	0.88	<1	3.93
Cadmium	5.6	7.3	1.9	25	9.3	11	<0.5	40
Chromium	53	18	27.3	84.4	50	29	17.6	113
Lead	83.1	41.0	23.2	144	277	228	66.9	788
Mercury	0.4	0.6	0.0369	<2	0.4	0.8	0.0218	3
Nickel	40	7.7	26	50.5	22	11	6.27	47.1
Selenium	9.4	4.6	3.48	16.8	15	16	<0.5	39.1
Silver	6.0	7.5	<1	25	2.5	3.4	<1	10
Thallium	10.5	25.1	0.594	67.5	7.8	19	<1	60.5
Vanadium	127	35.5	56.5	167	63.0	33.7	10.1	101
Zinc	149	84.6	68.3	297	150	52.5	96.3	241

NOTE: Data reported at less than the detection limit were assumed to be present at the detection limit in order to calculate the averages and standard deviations. This procedure will overestimate the actual concentrations present.

A cursory inspection of Table 7.8 indicates that the average metal concentrations in CKD for cement kilns burning only conventional fuel do not differ substantially from the average metal concentrations in CKD for cement kilns burning hazardous waste fuel. None of the averages differ by even an order of magnitude. In addition, the ranges of metal concentrations are not substantially different.

Thus, the preliminary data from the CRI database support the conclusion of the PCA report that the use of hazardous waste fuel is not the determining factor in the metal concentrations of the CKD generated at a cement production facility.

7.2.3.2 METAL CONCENTRATIONS IN TCLP EXTRACTS FROM CKD

Although the concentration of a metal in the CKD is important, the potential for this metal to leach from the CKD is equally or more important. In other words, the presence of a component does not necessarily indicate the effect (Kelly, 1991). As a result, the U.S. EPA has developed the Toxicity Characteristic Leaching Procedure (TCLP) to estimate the potential of a substance to leach from a matrix, such as soil or concrete, and cause adverse effects (40 CFR 261 Appendix II). Briefly, this test requires that the sample be reduced to a specified size and then continuously extracted with the appropriate acidic solution for approximately 18 hours. The resulting mixture is then filtered and the liquid extract analyzed for the specified contaminants. The maximum metal concentrations allowed in the TCLP extract are given in Table 7.9. These limits are health-based standards.

TABLE 7.9
METAL CONCENTRATION LIMITS FOR THE TCLP EXTRACT

METAL	CONCENTRATION (ppm)
Antimony	1
Arsenic	5
Barium	100
Beryllium	0.007
Cadmium	1
Chromium	5
Lead	5
Mercury	0.2
Nickel	70
Selenium	1
Silver	5
Thallium	7

Source: U.S. EPA (1991); p. 7234 Appendix VII.

[Technical correction to Appendix VII: U.S. EPA, 1991, Federal Register (July 17) 56 : 32691.]

For the PCA report discussed above, the U.S. EPA TCLP test was performed on each of the CKD samples and the metal concentrations in the TCLP extract determined. The results are summarized in Table 7.10.

TABLE 7.10
METAL CONCENTRATIONS (ppm) IN TCLP EXTRACTS FROM CKD

METAL	AVERAGE ^a	MINIMUM ^b	MAXIMUM ^c
Antimony ^d	0.012	0.003	0.031
Arsenic ^d	0.066	0.003	0.636
Barium	1.04	0.12	9.19
Beryllium ^d	0.0004	0.0001	0.0029
Cadmium ^d	0.0289	0.0001	0.2200
Chromium	0.10	0.01	1.29
Lead	0.349	0.002	9.718
Mercury	0.00183	0.00015	0.02230
Nickel ^d	0.13	0.06	0.32
Selenium	0.152	0.006	1.711
Silver	0.07	0.03	0.17
Thallium	0.38	0.01	4.50

^a Average of measurable values.

^b Minimum of measurable values.

^c Maximum of measurable values.

^d Majority of values were below detection limit.

Source: PCA (1991).

Although the averages are overestimated by using only the measurable values for the calculations, none of the average values exceed the TCLP health-based standards listed in Table 7.9. In addition, the maximum concentrations of all but two metals do not exceed these standards.

Lead and selenium are the only exceptions. Two out of the 95 samples analyzed exceeded the TCLP standard for lead. Both of these samples were collected from a cement production facility that operates two cement kilns. One of the kilns is operated with only conventional fuel and the other with a mixture of conventional and hazardous waste fuel. The maximum lead concentration in the TCLP extract resulted from the CKD sample collected from the cement kiln that burns only conventional fuel.

Similar to the lead scenario, only 2 out of the 95 samples analyzed exceeded the TCLP standard for selenium. Both of these samples were collected from a facility that operates a cement kiln with only conventional fuel and another cement kiln with conventional and hazardous waste fuel. The maximum selenium concentration in the TCLP extract resulted from the kiln that burns only conventional fuel.

An important result of the PCA report was that no statistical correlation appeared to exist between the quantity of metals in the CKD and the quantity of metals that leached from the

CKD. For example, the CKD sample that contained the highest concentration of lead did not produce the TCLP extract with the highest lead concentration. In fact, the CKD sample that contained 7,390 ppm of lead yielded a TCLP extract that contained 0.135 ppm of lead, which is more than an order of magnitude below the health-based TCLP standard. This result reinforces the fact that leachability is more than just a function of the metal concentration in the CKD.

The results of the PCA report are relevant in light of the public concern regarding contamination of groundwater from three Superfund hazardous waste sites that contain waste CKD. Two of these sites are located in Mason City, Iowa, and the third is in Salt Lake City, Utah. The site in Salt Lake City contains chromium refractory kiln bricks, which were classified as hazardous waste, and CKD. The other two sites in Mason City contain only CKD. Although some leaching of metals has been detected, the primary concern at these sites is due to the alkalinity of the waste CKD and not metal leaching from the CKD (E&E/FT, 1988; Iowa Department of Natural Resources, 1990; Utah Department of Health, 1990).

Some debate exists over the applicability of the TCLP test as a tool to predict the potential of metals to leach from the CKD. For example, Mix and Murphy (1984) state that the CKD disposal site is likely to become very alkaline. Lead would have a high solubility under these conditions and the TCLP test does not adequately account for alkaline environments. Regardless of this debate, the U.S. EPA has designated the TCLP test as appropriate for determining the hazardous characteristic of waste which includes waste CKD.

7.2.4 CEMENT

Similar to the issues regarding CKD, the issues regarding cement involve the actual concentrations of the metals in the cement and the potential of the metals to leach from the cement, once the product has been used in a construction project or other application where people can be exposed to it. Both of these issues are addressed below.

7.2.4.1 METAL CONCENTRATIONS IN CEMENT

Recognizing the public concern over metal concentrations in cement, the Construction Technology Laboratories investigated cement metal concentrations in conjunction with their study of CKD (PCA, 1991). In addition, CRI has begun to compile data to evaluate the potential differences that might arise due to burning hazardous waste. The data from the PCA report and the CRI database are summarized in the following sections.

PCA Results

For the PCA report, cement samples were collected from 97 North American kiln systems representing both kilns burning hazardous waste and kilns burning only nonhazardous fuel (PCA, 1991). The results of the analysis are summarized in Table 7.11.

TABLE 7.11
METAL CONCENTRATIONS (ppm) IN CEMENT

METAL	AVERAGE ^a	MINIMUM ^b	MAXIMUM ^c
Antimony ^d	2.4	0.7	4.0
Arsenic	19	5	71
Barium	280	91	1402
Beryllium	1.1	0.3	3.1
Cadmium ^d	0.34	0.03	1.12
Chromium	76	25	422
Lead	11	1	75
Mercury ^d	0.01409	0.00005	0.03900
Nickel	31	10	129
Selenium ^d	1.42	0.62	2.23
Silver	9.20	6.75	19.90
Thallium ^d	1.08	0.01	2.68

^a Average of measurable values.

^b Minimum of measurable values.

^c Maximum of measurable values.

^d Majority of values were below detection limit.

Source: PCA (1991).

The averages presented above are overestimates because only measurable values were used in the calculation procedure. In particular, the averages for antimony, cadmium, mercury, selenium, and thallium are highly conservative because the majority of the values were below the detection limit.

Similar to the results of the CKD analysis, no direct correlation between the use of hazardous waste fuel and the maximum metal concentrations could be discerned. For example, the maximum barium concentration resulted from a facility that did not use any waste fuel or waste ingredients. The factors that contribute to the observed metal concentrations in cement include the raw materials used, the fuels burned, the system design, and the operation of the facility.

CRI Results

The CRI database has been designed to evaluate the potential for differences in cement metal concentrations related to the use of hazardous waste. Because the concern regarding burning hazardous waste in cement kilns is a fairly recent one, very little data exist with which to evaluate this issue. However, a summary of the data that have been collected for metal concentrations in clinker is presented in Table 7.12. Since cement is simply ground clinker mixed with a small amount of gypsum, the metal concentrations in clinker are expected to be representative of the metal concentrations in cement. The information presented in this table should be reviewed with caution because it represents only a limited number of test results.

115

TABLE 7.12
COMPARISON OF METAL CONCENTRATIONS (ppm) IN CLINKER

METAL	CKs BURNING CONVENTIONAL FUEL				CKs BURNING HAZARDOUS WASTE FUEL			
	Avg	Std Dev	Min	Max	Avg	Std Dev	Min	Max
Antimony	1.5	0.44	<1	2.18	3.29	1.76	1.91	6.435
Arsenic	11.2	2.55	7.91	14.9	25	22	2.12	62.5
Barium	144	15.6	130	168	139	42.9	76.5	194
Beryllium	0.5	0	<0.5	<0.5	1.6	0.76	<1	3.18
Cadmium	3	0	<3	<3	0.7	0.2	<0.5	<1
Chromium		NO	DATA		71.1	38.6	43.8	128
Lead	6.7	4.7	<1	14.3	17	42	<1	163
Mercury	0.2	0	<0.2	<0.2	0.2	0	<0.2	<0.2
Nickel		NO	DATA		49.6	7.57	40.4	56.3
Selenium	0.6	0	<0.6	<0.6	9.1	12	<0.5	27.5
Silver	3	0	<3	<3	1.4	0.67	<1	2.49
Thallium	0.5	0	<0.5	<0.5	1	0	<1	<1
Vanadium	156	19.5	131	180	82.3	23.2	46.7	127
Zinc	23	17	4.44	50.3	64.9	34.2	13.55	113.7

NOTE: Data reported at less than the detection limit were assumed to be present at the detection limit in order to calculate the averages and standard deviations. This procedure will overestimate the actual concentrations present.

The average metal concentrations in clinker produced from cement kilns burning hazardous waste do not appear to differ substantially from the average metal concentrations in clinker generated from kilns burning only conventional fuel. The ranges also appear to be approximately equivalent. Similar to the results of the PCA investigation, the majority of the clinker metal concentrations for cadmium, mercury, selenium, and thallium were below the detection limit for both cement kilns burning hazardous waste and those burning only conventional fuel.

The data from the CRI database support the conclusions of the PCA report. Differences in clinker metal concentrations are more than just a function of the type of fuel that is burned in the production process.

7.2.4.2 METAL CONCENTRATIONS IN TCLP EXTRACTS FROM CEMENT

One of the major public concerns is the potential of the metals in the cement to leach into the environment once the cement has been used in a construction project (e.g., road, building, or patio). For the PCA report, the U.S. EPA TCLP test was conducted on each of the cement samples collected from the 97 kiln systems (PCA, 1994). The results are summarized in Table 7.13.

TABLE 7.13
METAL CONCENTRATIONS (ppm) IN TCLP EXTRACTS FROM CEMENT

METAL	AVERAGE ^a	MINIMUM ^b	MAXIMUM ^c
Antimony ^d	0.013	0.003	0.063
Arsenic ^d	0.027	0.005	0.084
Barium	1.35	0.49	4.27
Beryllium	0.0005	0.0001	0.0030
Cadmium ^d	0.0020	0.0003	0.0123
Chromium	0.54	0.07	1.54
Lead ^d	0.011	0.002	0.11
Mercury ^d	0.00055	0.00010	0.00497
Nickel ^d	0.11	0.06	0.17
Selenium ^d	0.011	0.001	0.025
Silver	0.07	0.05	0.12
Thallium ^d	0.010	0.002	0.028

^a Average of measurable values.

^b Minimum of measurable values.

^c Maximum of measurable values.

^d Majority of values were below detection limit.

Source: PCA (1991).

Although the averages presented above are overestimated by having used only measurable values in the calculations, none of the average metal concentrations in the TCLP extracts exceeded the health-based standards listed in Table 7.9. As indicated by the maximum values, none of the TCLP extracts from cement exceeded any of the TCLP limits.

The results of the PCA report are supported by an earlier study conducted by Hansen and Miller (1990). They evaluated the leaching of seven metals from mortar cubes (i.e., cubes composed of cement and sand). When cement is used in a construction project, it is generally mixed with water, sand, and gravel to produce concrete. Cement is actually the glue that binds the solid materials together. The typical concentration of cement in concrete is 10 to 15% by weight of dry solids. By comparison, the concentration of cement in the mortar cubes analyzed by Hansen and Miller (1990) was 27% by weight of dry solids. Consequently, the results of their study are conservative estimates of the quantity of metals that would leach from cement in a construction project.

The mortar cubes were provided by facilities that burned fossil fuel and by facilities that burned hazardous waste as a supplemental fuel. The potential of the metals to leach from the cubes was evaluated by the U.S. EPA TCLP test. Since the samples were crushed as part of the standard procedure, the amount of surface area exposed is unrealistically high compared with real life conditions. Again, the results represent the worst case environmental conditions.

The differences in the results obtained for cement kilns burning only conventional fuel as opposed to those obtained for kilns using hazardous waste fuel did not appear to be significant. In fact, the results were almost identical. More importantly, none of the concentrations of the metals in the TCLP extracts exceeded the health-based standards.

The results of both the PCA report (PCA, 1991) and the Hansen and Miller (1990) study indicate that the leaching of metals from cement is extremely low.

7.3 ACID GAS EMISSIONS

Because of their ability to cause adverse effects at high concentrations, hydrogen chloride (HCl) and sulfur dioxide (SO₂) are two acid gases of regulatory concern in the emissions from cement kilns. The results from HCl and SO₂ emission testing for both wet and dry process cement kilns are discussed below.

7.3.1 HCl EMISSIONS

When chlorinated solvents are burned, HCl is produced. As discussed in Section 4.2, the alkaline environment of the kiln acts to neutralize the majority of the HCl generated. Accordingly, the gas typically reacts with calcium, sodium, and potassium oxide in the kiln to produce calcium, sodium, and potassium chloride, respectively. These salts are volatile at the temperatures inside the kiln and are typically removed with the CKD. Occasionally, calcium chloride or waste HCl is intentionally added to a cement kiln to control the alkali content of the cement being produced.

The results of several HCl emission tests for both wet and dry process cement kilns were reviewed by Branscome and Mournighan (1987). Despite the variability that existed between kilns as well as within the same kiln, HCl emissions appeared to increase when chlorinated wastes were burned. The majority of the chlorine, however, appeared to be retained in the process solids (i.e., clinker or CKD).

If wastes with a low chlorine content are burned, then HCl emissions do not increase when conventional fuel is supplemented with hazardous waste fuel. Benestad (1989) reported the results of HCl emission testing conducted for a Norwegian dry process cement kiln. When only coal was burned, the HCl emission rate averaged 8.5 milligrams per cubic meter (mg/m³). When waste oil was burned, the average HCl emission rate decreased to 4.4 mg/m³. The average HCl emission rates for the typical waste (7.9 mg/m³) and the PCB waste (6.9 mg/m³) were less than the average HCl emission rate for coal. Therefore, the emission of HCl can actually decrease depending on the waste material burned.

One potential problem with the HCl testing is interference from other compounds (e.g., ammonium chloride, potassium chloride, and sodium chloride) generated in the cement production process that can yield the chloride ion. To measure the emission of HCl, a sample of the stack gas is basically passed through a solution into which the HCl dissolves. The

concentration of chloride ion in the solution is determined. The amount of chloride ion detected in the solution is then equated to the amount of HCl emitted from the stack of the facility. Since the test is not specific for chloride ions from HCl, any chloride ion in the solution will be designated as a chloride ion originating from HCl. The U.S. EPA methods manual (U.S. EPA, 1990a), which describes these test procedures, specifically notes "volatile materials, which produce chloride ions upon dissolution during sampling, are obvious interferences in the measurement of HCl." Therefore, if this type of interference occurs, an unrealistically high HCl emission will be recorded.

The U.S. EPA (Garg, 1990a,b) recently reported the results of emission testing of one wet and one dry process cement kiln where the possibility of this type of interference was investigated. The results of the tests suggested that what was being measured as HCl was actually ammonium chloride. The author of these reports concedes that at the stack gas temperatures, ammonium chloride would be completely dissociated into HCl and ammonia. However, on cooling in the ambient air, the HCl and ammonia would recondense to form ammonium chloride. Therefore, ammonium chloride and not HCl is actually being emitted to the environment.

The results and conclusions of these U.S. EPA tests have been substantiated by the investigations of von Seebach and Gossman (1990). By determining the presence and quantity of other ions in the solution besides the chloride ion, they discovered that the source of the chloride ion was not HCl but ammonium chloride and other chloride salts. They concluded that this method of testing for HCl in the cement kiln environment is inappropriate and yields incorrect results.

On the basis of these test results, the U.S. EPA has initiated further investigation of the standard method being used to measure HCl emissions from a cement kiln (Segall, 1991). In these tests, the HCl emissions will be measured by the standard U.S. EPA method. At the same time, the system will be continuously monitored with an instrument that specifically measures HCl. Results of these tests should reveal the nature of the actual emissions.

The test methods for measuring the emission of HCl were originally designed for hazardous waste incinerators. Before any definite conclusions can be made concerning HCl emissions from cement kilns, the applicability of these test methods for cement kilns must be validated to ensure that they can also accurately measure HCl emissions at cement kilns.

7.3.2 SO₂ EMISSIONS

Similar to HCl, the vast majority of SO₂ is removed by the alkaline environment in the cement kiln. Although the type of fuel burned in a cement kiln does affect the emissions of SO₂, many other factors are involved. Some of these factors include oxygen input, kiln temperature, composition of raw material and fuel, and concentration of HCl in the kiln (Brancome and Mournighan, 1987).

Branscome and Mournighan (1987) summarized the results of the SO_2 emission testing of three wet process and three dry process cement kilns. The emission of SO_2 decreased dramatically in one of the dry process and two of the wet process cement kilns when hazardous waste was burned. No change in the emission of SO_2 was observed in the other two dry process cement kilns when hazardous waste was burned. In only one case, the other wet process cement kiln, was a significant increase observed when hazardous waste was burned. The increase was attributed to two factors: a decrease in oxygen input and a significant quantity of HCl already present in the kiln.

Although the type of fuel is just one factor that affects SO_2 emissions, replacing a portion of the sulfur-containing fossil fuel with hazardous waste that does not contain a significant amount of sulfur can result in a significant decrease in SO_2 emissions.

7.4 PARTICULATE EMISSIONS

As discussed in Section 6.1.4, excessive particulate emissions have the potential for causing adverse effects to human health and the environment. Accordingly, particulate emissions are stringently regulated (see Sections 6.1.4 and 6.2).

Burning chlorinated wastes potentially increases particulate emissions. As explained in Section 7.3.1, when chlorinated wastes are burned, HCl is generated. This acid gas reacts with the alkaline components in the kiln to form alkali salts. These salts volatilize at the temperatures in the kiln's hot end and condense in the kiln's cooler end. Typically, the gases in the kiln carry these particles to the APCD where they are collected. However, alkali salts are fine particles with a different resistivity than the normal particulates generated. Consequently, the efficiency of an APCD, such as an electrostatic precipitator (ESP), may be affected.

Weitzman (1983) discussed the effect of burning chlorinated wastes using the results of the emission testing conducted at the St. Lawrence wet process cement kiln in Canada and the Stora Vika wet process cement kiln in Sweden. Both of the cement kilns were equipped with ESPs. When the amount of chlorinated waste fed to the kilns was increased, the particulate emissions increased as well. Weitzman (1983) concluded that the particulate emissions were dependent on the amount of chlorinated waste burned.

More recent test results have shown that particulate emissions do not necessarily increase when chlorinated wastes are burned (Branscome and Mournighan, 1987). A corresponding increase in particulate emissions did not result when chlorinated wastes were burned in a San Juan wet process kiln equipped with a baghouse (i.e., an APCD with fabric filters). More importantly, these recent studies have shown that particulate emissions in cement kilns equipped with ESPs do not necessarily increase when chlorinated wastes are burned. No increase in particulate emissions was observed when chlorinated wastes were fed to one wet and one dry process cement kiln both equipped with ESPs. The lack of an increase in particulate emissions has been attributed to adjustments made to the APCD to compensate for the differences in particulate matter that occur when burning chlorinated wastes. Thus, the more recent test results indicate that particulate emissions can be controlled regardless of the fuel that is burned and the APCD with which the kiln is equipped.

8.0 POTENTIAL EFFECTS TO HUMAN HEALTH

Humans may be exposed to chemicals from cement production facilities in emissions, byproducts of the manufacturing process, or the finished product. Exposure to the hazardous waste used as fuel may also occur during transportation of fuels to the facility. Persons exposed to high concentrations of facility emissions or process solids can experience adverse health effects. Typically, high concentrations are found only in the workplace, generally in countries other than the U.S., and not in locations where public health would be affected. High occupational exposures are nonetheless useful for elucidating some of the potential human health effects from cement production when adequate public health studies are unavailable. The following sections address impacts to public health due to burning hazardous waste as a supplemental fuel in cement kilns.

8.1 BACKGROUND

Despite the decades of operations and extensive public exposure to cement plant emissions in this country, often at higher levels than are found today, neither clinical nor epidemiological studies have been performed that examine the effects on public health of a cement production facility burning either conventional or hazardous waste fuel. Evidence of problems with local public health has not been sufficient to cause concern or to trigger public health studies, and no major health agency has considered cement plants to be a threat to public health. This lack of concern may result in part from the low rate of occupational illness in the cement industry (i.e., 24.8 incidences per 10,000 workers), which is less than one-fourth the average incidence rate for any type of manufacturing (i.e., 108.3 incidences per 10,000 workers). These occupational illness rates, as well as many others, are listed in Table 8.1.

The available studies on cement plants in other countries conclude that lack of emission controls can result in extremely high concentrations of particulates in ambient air. Exposure of local communities to these emissions has resulted in increased cases of respiratory diseases, skin diseases, eye irritation, and gastrointestinal tract diseases (Borka, 1986; Krishnamurthy and Rajachidambaram, 1986; Mishra and Tiwari, 1986; Anda, 1987). Since the 1970s, the increasingly strict controls on emissions from cement plants have considerably reduced the potential for public exposure to hazardous emissions in the U.S.

With the recent increase in the use of hazardous waste as a supplemental fuel in cement kilns, the issue for public health has become whether the chemicals emitted from cement plants burning hazardous waste might now be a threat to public health. This concern is largely based on the supposition that such plants emit much greater amounts of potentially toxic chemicals than those using only conventional fuel.

TABLE 8.1
OCCUPATIONAL ILLNESS RATES, 1989^a

Meat products	689.4	Drug manufacture	60.0
Ship and boat building, repair	411.1	Chemicals and allied products	57.5
Motor vehicle and equipment manufacture	373.1	Paper and allied products	53.0
Plumbing and heating products manufacture	346.5	Petroleum refining	52.0
Household appliances manufacture	275.3	Guided missile, space vehicles, parts manufacture	49.5
Footwear manufacture	274.7	Photographic equipment and supplies	48.7
Leather tanning and finishing	239.9	Soaps, cleaners and toilet goods	37.4
Hats, caps and millinery	196.5	Computer and office equipment	37.3
Men's and boys' furnishings	185.1	Watches, clocks, watchcases, and parts manufacture	37.3
Engine and turbine manufacture	174.3	Agricultural chemicals	36.9
Metal forgings and stampings	172.4	Painting and paper hanging	32.4
Preserved fruits and vegetables	145.6	Costume jewelry and notions	28.3
Toys and sporting goods manufacture	144.7	Concrete, gypsum, and plaster products manufacture ^b	24.8
Office furniture manufacture	132.4	Newspaper printing and publication	22.3
Pens, pencils, office and art supplies	121.3	Residential building construction	17.8
Musical instrument manufacture	104.9	Services	16.7
Iron and steel foundries	100.5	Transportation and public utilities	16.0
Forestry	86.7	Women's and misses' outerwear	15.9
Greeting cards printing and publication	79.2	Cut stone and stone products	14.9
Bakery products	75.6	Retail trade	7.7
Girls' and children's outerwear	68.9	Finance, insurance and real estate	6.1
Tire and inner tube manufacture	68.1	Asphalt paving and roofing materials	5.5
Coal mining	62.6		

^a Incidence rates per 10,000 full-time workers.

^b This category includes manufacture of ready-mix concrete and Portland cement.

Source: U.S. Department of Labor (1991).

This issue is addressed by reviewing the available information on the potential health threats from cement plants supplementing their fuel with hazardous waste and from those burning only conventional fuel. Three major sources of exposure are evaluated in this review:

- Stack emissions from the cement plant
- CKD, the byproduct of the cement manufacturing process
- Cement, the final product.

12/2

Another potential source of exposure to hazardous waste fuel at cement plants may be transportation of the fuel to the facility. This source is evaluated by reviewing statistics on spills and accidents of hazardous materials transportation.

For each major source of exposure, the potential effects to human health are discussed below relative to both burning hazardous waste and burning conventional fuel. Potential exposures are also viewed in light of recent U.S. EPA regulations (i.e. the BIF rule) that further reduce emissions from cement kilns. Despite the absence of epidemiological studies, the analysis suggests that the threat to public health from burning hazardous waste fuel in properly operated cement kilns does not differ from the threat associated with the use of only conventional fuel.

8.2 CEMENT PLANT EMISSIONS

Humans may be exposed to cement plant emissions from both the stack and from fugitive emissions. The following sections discuss the components of stack and fugitive emissions, the factors affecting their dispersion into ambient air, and the potential threats to human health due to exposure to these emissions.

8.2.1 STACK EMISSIONS

The constituents in emissions from cement plant stacks that are of human health concern are divided into three broad categories: organic chemicals, metals, and particulates. The organic chemicals include unburned compounds present in the waste, thermal decomposition products, and compounds newly created from the burning process. In general, ten metals are of concern. Four are regulated as carcinogens—arsenic, beryllium, cadmium, and hexavalent chromium; six are regulated as noncarcinogens—antimony, barium, lead, mercury, silver, and thallium. Particulates are of concern for two reasons. Excessive inhalation of dust particles in general can be harmful to health, and toxic metals and organic chemicals adsorbed to particulate surfaces may be released when they contact skin or lung tissue. However, in the U.S., emissions from cement plants are passed through APCDs that remove the vast majority of the particulates, thus mitigating exposure to the high levels of particulates associated with adverse effects (see Section 7.4).

Once released from the stack, emissions are diluted by ambient air and may be transported as a plume away from the facility. Any potential health effects to the public are directly related to the amount of exposure after transport away from the stack. The meteorological conditions at the facility, such as wind speed and direction, and the local terrain are major factors that affect the direction of transport, the amount of dilution, and shape of the emitted plume.

As the plume migrates away from the facility, it continues to disperse, and emitted compounds become further diluted in ambient air. Concentrations to which the public may be exposed are dependent on the extent of dilution and on the deposition of gases and particulates on soils and

surface water by gravity, wind, and precipitation. These modes of dispersion and deposition are illustrated in Figure 8.1.

The components remaining in the air after dilution and deposition are the major source of direct exposure to compounds from the facility. Chemicals in the remaining gases and suspended particulates may be inhaled, or they may come in direct contact with skin.

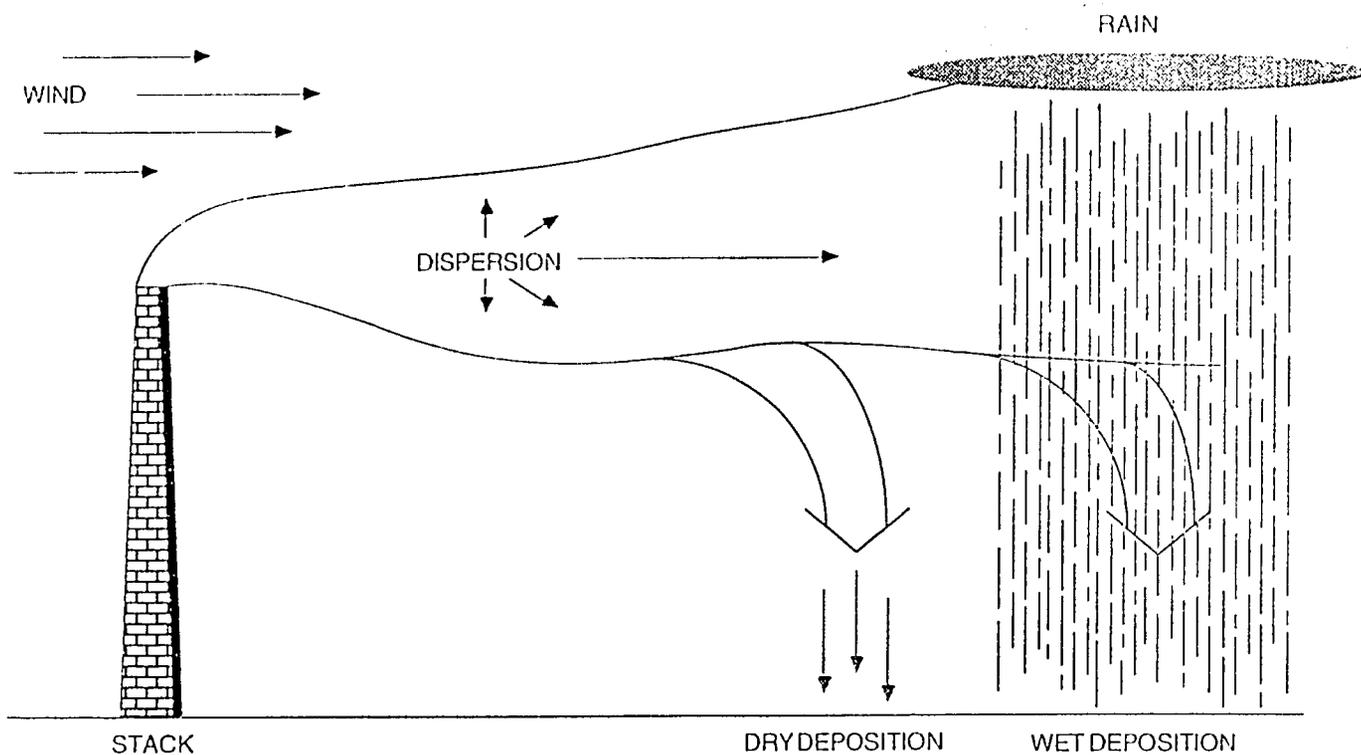


FIGURE 8.1 Modes of Dispersion and Deposition for Facility Stack Emissions.

Contact with emitted compounds may also occur through ingestion of water or of food grown in soils on which contaminants were deposited. Ingestion is considered an indirect route of exposure. Another indirect route of exposure is inhalation of resuspended dusts. This exposure occurs when constituents that have been transported away from a facility are deposited on local soils and then resuspended in the air by wind erosion, where contact follows by inhalation. Resuspended dusts from stack emissions in these cases do not contribute substantially to public exposure (Clement, 1988). The public health threat is low largely because the particles have been diluted with soil material, the organic chemicals have been degraded or volatilized, and both organic chemicals and metals may have leached to deeper soils.

Despite the large quantity of metals present in the production of cement, cement kilns contribute relatively small quantities of metals to public exposure in the U.S. compared with other sources. For example, cement kilns contribute about 0.1% to the atmospheric chromium

emissions in the U.S., of which 0.2% is estimated to be in the most toxic hexavalent form (ATSDR, 1987). In contrast, combustion of coal and oil from all sources accounts for 66% of the atmospheric chromium, or about 660 times greater than the contribution from cement kilns. Similarly, cement kilns contribute approximately 0.2% to the atmospheric lead in the U.S. as compared with the 89.4% from gasoline combustion (ATSDR, 1990), or 446 times greater than the contribution from cement kilns.

8.2.2 FUGITIVE EMISSIONS

Fugitive emissions arise from sources other than the stack and are usually associated with normal plant operations, storage, upsets, or leaks at the facility. Fugitive emissions associated with the actual kiln contain essentially the same chemical constituents as stack emissions; however, they may contain more particulates than do stack emissions, since fugitive emissions do not pass through the APCDs. Fugitive emissions associated with storage and transfer of the hazardous waste fuel to the kiln would contain the same components as the waste.

The population exposed to fugitive emissions at cement plants consists primarily of workers at the facility rather than the general public. Fugitive emissions occur at lower elevations and have larger particle sizes than stack emissions, resulting in dispersion over a smaller ground area. Offsite transport and exposure to the general public are thereby minimized, as is the potential for adverse health effects. Any nonstack emissions that manage to escape a facility are dispersed in the environment by the same factors that govern dispersion of stack emissions (i.e., local climate, geography, and chemical properties of the emissions).

8.2.3 REGULATED RISKS TO HUMAN HEALTH

The potential for current stack emissions from cement plants to adversely affect public health is governed partly by the recently enacted BIF rule. The BIF rule regulates emissions from cement kiln stacks on the basis of potential risk to public health (see Section 6.1). The limits set in the BIF rule are described as risk-based since they start from an acceptable risk limit and work backward to maximum allowable emissions. By contrast, a risk assessment starts with emissions and works forward to quantify the risks to health without a predetermined outcome. Through the use of risk-based exposure limits, the BIF rule attempts to prevent exposures of the public to high levels of emissions from cement plants that could cause long-term illness or cancer. Even though higher emissions from cement plants may have existed prior to regulations, adverse health effects associated with the emissions have not been documented. Thus, reduced exposure under the new BIF rule is expected to result in still lower potential for adverse health effects.

For selected POHCs in hazardous waste, the U.S. EPA determined for the BIF rule that with a 99.99% DRE, exposure for a lifetime to the maximum concentrations in emissions generally would result in a risk of developing cancer of 1 in 1,000,000 or less [U.S. EPA, 1991 (p. 714b)]. This level of risk is equal to the U.S. EPA's most conservative definition of "acceptable" risk and is well below other types of federally regulated risk, as described in Section 8.2.5. The BIF rule

125

further states that a 99.99% DRE will "ensure that constituents in the waste are not emitted at levels that could pose significant risk in virtually all scenarios" [U.S. EPA, 1991 (p. 7146)].

The DRE required for "dioxin-listed" wastes under the BIF rule (and for PCBs under TSCA), is 99.9999%. These requirements limit exposure to such compounds to levels well below regulatory thresholds of public health concern. Because of these requirements, the U.S. EPA has stated that emissions of PICs "do not pose significant risks when BIFs and incinerators are operated under good combustion conditions" [U.S. EPA, 1991 (p. 7150)].

The BIF rule also regulates carcinogenic metal emissions on the basis of protecting public health. According to the rule, emissions of BIF-regulated metals from cement kilns are limited so that lifelong exposure to the maximum amounts of all BIF metals in ambient air through all pathways of possible exposure from a facility results in a risk of contracting cancer no greater than 1 in 100,000. For noncarcinogenic metals, the BIF standards are intended to prevent adverse health effects to the public even under maximum exposure to all possible exposure routes [U.S. EPA, 1991 (pp. 7169-7171)].

Of the BIF-regulated metals, thallium may be of particular concern for releases from cement kilns. Although some forms of thallium are considered highly toxic, with dermal contact being the primary route of entering the body, little is known about potential health effects from chronic low exposures (Kazantzis, 1986). As discussed in Section 7.2.1, the high volatility of thallium can result in less bonding in clinker, resulting in less removal of thallium to the process solids and its subsequent enhancement in the dust phases in the kiln (Sprung, 1985; Kirchner, 1987). Such elevated levels, which can be avoided by periodically removing CKD from the process, have been shown in the past to lead to excessive thallium emissions from cement kilns (Bambauer and Schäfer, 1984). For those kilns burning hazardous waste as a fuel, the emission of thallium is regulated under the BIF rules, requiring that public health impacts be avoided.

In summary, cement plants that meet the regulations described in the BIF rule are operating under conditions identified by the U.S. EPA as associated with risks below those of regulatory concern.

8.2.4 HEALTH ASSESSMENTS OF BURNING HAZARDOUS WASTE AND CONVENTIONAL FUEL

Although epidemiological studies of current public exposures to cement plants are not available, the potential risk to the health of residents living near cement plants has been estimated in a few recent studies. These studies are especially useful to evaluate the potential differences in exposure and associated risks between the use of conventional fuel and the use of hazardous waste for a portion of the fuel in cement kilns.

In two major studies involving both a dry and a wet process cement kiln (Garg, 1990a,b), the U.S. EPA found that the amount of PCBs, dioxins, and furans emitted while burning hazardous waste were similar to the amounts emitted when only conventional fuel was burned. The U.S. EPA (Garg, 1990b) also examined potential public health effects due to emissions from

126

burning conventional fuel (i.e., a mixture of coal and diesel) and conventional fuel mixed with hazardous waste in the wet process kiln. Under the conservative assumptions that a member of the public breathed dioxin emissions from the plant for a lifetime, the U.S. EPA estimated that risk of developing cancer when conventional fuel was burned was 2 in 1,000,000, and essentially the same 2 to 4 in 1,000,000 when hazardous waste was mixed with the conventional fuel.

A similar assessment of health risks was performed for a cement kiln in California. The investigators estimated plausible exposures for the inhalation route as well as from ingestion of soil, crops, and fish exposed to emissions deposited downwind of the site (Stein and Lowe, 1990). Estimated risks of developing cancer from metals and a number of organic compounds were equal for both hazardous waste fuel and conventional fuel, at 2 to 3 in 1,000,000. These risks are virtually the same as those estimated by the U.S. EPA (Garg, 1990b). More importantly, the investigators found that the estimated health risks actually decreased for the plant as the conventional fuel (i.e., petroleum coke) was increasingly replaced by hazardous waste fuel at amounts of 16% and 37% of the volume. Many of compounds present in the petroleum coke were not present in the hazardous waste fuel, resulting in an overall decrease in emission of hazardous constituents and risks.

Further evaluation of the potential difference in health effects between cement production facilities burning hazardous waste and those burning only conventional fuel may be made with the available data on metal emissions in the CRI database. As shown earlier in Table 7.5, which is based on emissions data collected through September 1991, the average amounts of most metals currently emitted from kilns burning hazardous waste are not significantly different from the amounts emitted from kilns burning only conventional fuel. Emissions for the two exceptions to this trend, lead and mercury, were two to three times higher for kilns burning hazardous waste as a supplemental fuel.

On the basis of this finding, the major concern for public health is whether the increases in lead and mercury emissions are sufficient to affect the health of people residing near cement plants. However, no health or epidemiology studies have been reported on cement kiln emissions in this country. In the absence of such studies, one way to evaluate the increased emissions is to compare them to similar emissions from a specific cement kiln for which potential public health risks have been estimated. Comparison of the average lead and mercury emissions in Table 7.4 with those from the cement kiln in California discussed above shows that they fall within a range of 0.75 to 1.5 times their concentrations in emissions from the California kiln. At the emission rates for the California kiln, the downwind concentrations of lead and mercury were estimated to be 2 orders of magnitude (mercury) to 4 orders of magnitude (lead) below their respective health criteria (Stein and Lowe, 1990). By extrapolation, one would expect that an increase in emissions of mercury and lead by a factor of 2 to 3 from kilns burning hazardous waste would still result in average offsite concentrations well below public health concerns, possibly by 2 to 4 orders of magnitude.

On the basis of this analysis, the potential health effects due to metals exposure from kilns burning only conventional fuel or a mixture of conventional and hazardous waste fuel appear

to be essentially the same. This conclusion is supported by the above review of current regulations of cement kiln stack emissions.

8.2.5 "ACCEPTABLE" RISK

In general, the studies discussed above indicate that the public's risk of developing cancer from cement kiln emissions, whether burning hazardous waste or conventional fuel, is less than a few in a million. The U.S. EPA and other regulatory agencies (e.g., U.S. Food and Drug Administration, California Department of Health Services) usually consider health risks near or below 1 in 1,000,000 to be *de minimus*, or below the level of concern for regulation by the government (Travis *et al.*, 1987; Kelly and Cardon, 1991). At this level, the incremental risk of developing cancer equates to an increased chance of 0.0003% after accounting for the approximately 33% chance of developing cancer in the U.S. from all sources. Risk levels less than 1 in 1,000,000 have typically not been regulated, and even levels up to 1 in 10,000 are seldom regulated. *De manifestis* risks, or risks that are of regulatory concern, have generally been considered to be a few in a thousand for developing cancer (Travis *et al.*, 1987). Risks from cement kilns burning hazardous waste are thus considerably below levels of "acceptable" risk by most regulatory standards, although the ultimate determination of acceptability is a value judgment and not a scientific decision.

In summary, analysis of current cement kiln emissions demonstrates that concentrations of emitted chemicals from facilities burning hazardous waste as a supplemental fuel are not substantially different from those burning conventional fuel. Since the threat to public health from conventional fuel sources has been accepted by the U.S. EPA as negligible and within acceptable limits, it follows that the similar exposures from properly operated kilns burning hazardous waste under current conditions would also result in negligible health effects.

8.3 CEMENT KILN DUST

The major exposures of the public to CKD occur either to the dust itself or to chemicals that have leached from the dust. The following sections address the potential for adverse effects to human health due to exposure to dust or leachate.

8.3.1 DUST

As a byproduct of cement plant operations, CKD exposures are generally of concern to onsite workers because they may be exposed when dust is suspended in the air or during maintenance activities. Dusts may pose minor exposures to the public when contained in emissions that migrate offsite. Likely routes of exposure are inhalation, ingestion, and contact of the dust with skin.

8.3.1.1 OCCUPATIONAL STUDIES

Because earlier concerns regarding the effects of CKD on human health focused primarily on workers at cement plants, the only available information on potential health effects is from high-dose occupational studies. It must be kept in mind when evaluating these studies that past process conditions might have been substantially different from those at current plants burning hazardous waste as a supplemental fuel.

The primary occupational concern with exposures to CKD is dermatitis, as indicated in Table 8.2. The presence of such alkaline material as calcium oxide in CKD results in corrosive action when it contacts moisture in skin, lungs, eyes, and the intestinal tract. However, the alkalinity of CKD is not known to change with type of fuel, and the type of fuel burned, including hazardous waste, would not be expected to affect related health problems.

TABLE 8.2
OCCUPATIONAL ILLNESS RATES ^a FOR THE
CONCRETE, GYPSUM, AND PLASTER PRODUCTS INDUSTRY ^b

Skin Diseases or Disorders	14.0
Repeated Trauma Disorders	2.6
Respiratory Conditions Due to Toxic Agents	2.3
Physical Agents	1.7
Poisoning	1.1
Other	3.0
Total Cases	24.8

^a Occupational illness rate per 10,000 full-time employees, 1989
(Because of rounding, components do not add to total.)

^b This category includes manufacture of ready-mix concrete and Portland cement.

Source: U.S. Department of Labor (1991).

In addition to dermatitis, occupational exposures to very high levels of CKD have resulted in decreased lung function, increased incidence of lung diseases other than cancer, and intestinal disease (Amandus, 1986; Abrons *et al.*, 1988; Wright *et al.*, 1988). Some of the respiratory effects observed with occupational exposures at cement plants are also observable with high exposures to other types of dusts.

In general, the more serious adverse health effects of CKD are largely related to the presence of free silica. Concentrations of free silica in CKD may range from 4 to 6% (Utah Department of Health, 1990), and free silica is the primary factor in lung diseases in occupational exposures (Wright *et al.*, 1988). Free silica is toxic to immune system cells in the lungs and results in

silicosis (i.e., buildup of fibrous tissue). The fibrotic nodules that characterize silicosis can restrict lung function; in severe cases, the effect can be crippling and life-shortening. High exposures to silica dusts can also cause filling of alveolar air spaces with a lipid-protein material containing silica (ACGIH, 1986). Silica has been shown to cause lung cancer in rats in laboratory studies; however, human studies do not show a connection between lung cancer and silica exposures (Hahn, 1989).

8.3.1.2 PUBLIC HEALTH IMPACTS

No health studies have been performed on exposures of the public to CKD from cement plants, so it is difficult to know whether CKD from conventional or hazardous waste fuel has presented threats to public health. As noted earlier, public health effects have apparently not been high enough to trigger health studies or health agency concerns.

The major health concern during possible exposures of the public to CKD from kilns burning hazardous waste is related to the presence of free silica, as noted above for occupational exposures. The silica content of CKD is directly related to the content of silica in the raw feed, which does not change with the type of fuel used. If a minimal effect of the hazardous waste fuel on silica formation is assumed, then the silica content of CKD generated when burning hazardous waste fuel would be no different from the silica content of CKD produced when burning only conventional fuel. Consequently, the potential health effects from exposure to silica in CKD would be expected to be independent of the type of fuel used.

Since CKD effectively traps metals contained in the fuel source, exposure to metals in the CKD from hazardous waste fuel is a potential concern to public health. However, data are insufficient at this time to statistically determine whether metals contained in CKD from hazardous waste fuel differ from those in CKD from conventional fuel. At most, the data presented in Table 7.8 are suggestive of possible trends, with greater contents of certain metals (e.g., beryllium, cadmium, lead, and selenium) in CKD when hazardous waste fuel is used. However, inspection of the ranges of values for all the metals suggests that any apparent increases are not substantial, and no differences in potential effects on health would be expected.

In fact, the average lead content in CKD of 360 ppm (see Table 7.6) is actually less than the average concentration of lead (1,600 ppm) in soils in urban residential areas in the U.S. (U.S. EPA, 1989b). The same concentration of lead in soils (i.e., 360 ppm) is considered insufficient to cause a noticeable change in blood lead concentrations of exposed children or to affect a child's health (U.S. EPA, 1990b). Children are of primary concern for exposures to lead in soils because children tend to ingest soils and because they are relatively more susceptible than adults to its toxic effects on the central nervous system. In contrast, levels of up to 18,000 ppm have been measured in urban street dusts (U.S. EPA, 1989b).

To evaluate increases in cadmium content in CKD due to burning hazardous waste fuel, a comparison can be made between its concentration in CKD from hazardous waste fuel and its

concentration in CKD at contaminated waste sites for which risks to public health have been assessed. In such a comparison, the average concentration of cadmium in CKD from currently operating plants (see Table 7.8) is similar to the range of concentrations (4-13 ppm) for cadmium in CKD waste piles at an older cement plant in Utah (Utah Department of Health, 1990). According to the U.S. EPA, the cadmium concentration in the waste piles does not pose a risk to public health; the alkalinity of the waste is the major problem (Utah Department of Health, 1990). The cadmium concentration in CKD from cement plants currently burning hazardous waste as supplemental fuel would therefore not be expected to create a public health problem.

The U.S. EPA and other regulatory agencies generally have not considered concentrations of beryllium and selenium in waste CKD at older cement plants to be a concern for public health (E&E/FIT, 1988; Iowa Department of Natural Resources, 1990; Utah Department of Health, 1990). Their presence in CKD from plants burning hazardous waste and operating under current regulations would similarly not be expected to pose a health concern.

8.3.2 LEACHATE

The primary concerns regarding long-term exposure to small amounts of CKD are that it becomes corrosive following exposure to water and that some of the metals may leach into the environment. The corrosive properties of highly alkaline CKD leachate can result in contact dermatitis and other damage to ocular and intestinal tissues. The U.S. EPA regulations for allowable leachate concentrations of metals from CKD are intended to be protective of human health (see Table 7.9). As reported in Section 7.2.3.2 (see Table 7.10), the current average metal concentrations in CKD leachate do not exceed the U.S. EPA limits, and are often orders of magnitude lower than these limits. This comparison suggests minimal potential for adverse effects to human health from exposure to metals leached from CKD, particularly when present in concentrations at or below the U.S. EPA health-based limits.

The concern over corrosiveness of CKD is not a problem associated with current facility operations meeting BIF regulations, but is a potential concern with long-term uncontrolled disposal. Such concerns have been raised where contamination of surface and groundwater from improperly disposed CKD resulted in the elevation of pH to unacceptably high levels, exceeding drinking water quality guidelines (Iowa Department of Natural Resources, 1990; Utah Department of Health, 1990).

Cement plants that improperly dispose of CKD may also have elevated concentrations of the certain metals in waters and soils. However, even the elevated concentrations at such sites have been determined to be insufficient to pose a threat to public health (Iowa Department of Natural Resources, 1990; Utah Department of Health, 1990).

8.4 CEMENT

Cement poses a concern to public health primarily because of the metals incorporated in it or that may leach from it. Exposures to cement may be of importance not only to the public but to a number of occupations that involve the handling of cement.

8.4.1 DUST

Since cement is composed of ground clinker mixed with a small amount of gypsum, evaluations of health effects from ground clinker are used interchangeably with those from cement in the following discussion; very few studies are available on the effects of exposure to cement itself.

Human exposure to cement usually occurs by dermal contact, inhalation, or ingestion. Dermal contact with cement can occur while handling either wet or dry cement. Cement dust has a very fine texture, with 50% of the dust particles capable of being respired deep into the lungs. In addition, larger particles of inhaled cement dust may be swallowed or accumulate in mucus that is then transferred to the stomach during clearance of lung airways (Phalen and Prasad, 1989). Incidental ingestion of cement may occur with poor hygiene habits, such as handling of food items without washing hands after mixing cement.

8.4.1.1 OCCUPATIONAL STUDIES

Occupational studies have provided the bulk of information on human exposures to cement, supplemented with a few clinical studies of suicide cases. Occupational exposures were also identified as the source of most exposure information in a recent review of the potential exposures to cement and cement products (ESE, 1991).

The occupational investigators found increased respiratory and gastrointestinal disease in workers exposed to high concentrations of cement (McDowall, 1984; Amandus, 1986; Abrons *et al.*, 1988; Jakobsson *et al.*, 1990; Vestbo and Rasmussen, 1990). According to the studies, cement dust exposure in the workplace may cause bronchitis and a decrease in lung function. Although the evidence that lung cancer is associated with high occupational exposures to cement is contradictory, exposure to very high levels of cement dust may be associated with colorectal and stomach cancer. Ingestion of very large amounts of cement results in solidified masses in the stomach that may need to be surgically removed (Visvanathan, 1986).

The exposures examined in the occupational studies reviewed herein were much greater than would be encountered by the public near a cement plant. Many of the occupational studies could not separate exposures of the workers to CKD from exposures to cement or raw materials, and some of the studies were conducted in countries with unregulated working conditions. The fuels burned in the cement production process were frequently not identified in the older studies; it is not clear whether the observed health effects were associated with conventional or hazardous waste fuel.

For these reasons, the conclusions reached in the occupational studies may not necessarily apply to public exposures. In any case, public health effects can be expected to be much less severe than occupational exposures, but it cannot be said how much less.

8.4.1.2 PUBLIC HEALTH IMPACTS

Most public health effects from exposure to cement are associated with use of cement as a product (ACGIH, 1986; Lachapelle, 1986; Potts, 1986; Avnstorp, 1989). The components of concern in cement dust are the same as those of concern in CKD (i.e., alkalis, silica, and certain metals). However, the free silica content of cement must be less than 1% to meet ASTM standards (ASTM, 1990) - too low to cause the same degree of effect in the lungs as CKD. Health effects from exposures to cement dust include dermatitis, allergic skin responses to some metals (e.g., hexavalent chromium, nickel, cobalt), and alkali burns of the skin and eyes. As pointed out earlier, however, these health concerns are primarily of relevance to occupational exposures. The magnitude and length of public exposure to cement dust and cement products are not on the same scale as occupational exposures, nor are the consequent effects.

Since the public can contact cement and concrete as a final product, public health concerns center on the availability of the metals for transfer from the cement or concrete during human contact. However, the bioavailability of metals in cement made while burning hazardous waste fuel, and its concrete products, is likely quite limited (van der Sloot, 1994). Under the assumption that the bioavailability of metals from Portland cement is limited to 10%, ESE (1991) calculated concentrations that would be allowable in cement. These "acceptable levels" are derived from occupational exposure limits set by regulatory agencies (ESE, 1991). The proposed limits are from 1 to 3 orders of magnitude (i.e., 10-1,000 times) greater than the concentrations typically found in Portland cement. This comparison is illustrated in Table 8.3.

It should be noted that these "acceptable levels" are for comparative purposes only. Even making the worst-case assumption that all the metals are absorbed from cement following ingestion or other exposures (i.e., 100% bioavailability), as was done during an assessment of potential risks at a cement plant with improperly disposed CKD (Utah Department of Health, 1990), the concentrations of metals in cement produced while burning hazardous waste as a supplemental fuel would be below those usually associated with cancer risks of regulatory concern.

8.4.2 LEACHATE

When water or other liquids come into contact with cement dust or hardened concrete, impurities may leach out. Exposure to the leachate may occur by ingestion of contaminated soils or waters, or by direct contact with the leachate. Such exposure may be a concern for public health where large amounts of chemicals may leach. However, comparison of leachate data in Table 7.13 with the U.S. EPA limits in Table 7.9 suggests that none of the metals in the TCLP extracts exceeded the health-based standards, and that the potential is minimal for large

TABLE 8.3
COMPARISON OF PROPOSED "ACCEPTABLE" METAL CONCENTRATIONS WITH
AVERAGE METALS CONCENTRATIONS IN PORTLAND CEMENT

Metal	Acceptable Level ^a (ppm)	Portland Cement ^b (ppm)
Antimony	50,000	2.4
Arsenic	200	19
Barium	50,000	280
Beryllium	50	1.1
Cadmium	1,000	0.34
Chromium III	50,000	--
Chromium VI	100	--
Total Chromium	--	76
Lead	5,000	11
Mercury	5,000	0.01409
Silver	1,000	9.20
Thallium	10,000	1.08

^a Source: ESE (1991). Based on occupational exposure limits with assumed bioavailability of 10%.

^b See Table 7.11

amounts of chemicals to leach from cement. This analysis suggests that the metals present in cement produced when burning only conventional fuel or a mixture of conventional and hazardous waste fuel would pose no increased threat to human health.

8.5 RISKS OF TRANSPORTING HAZARDOUS WASTE

A concern has been raised that the use of hazardous waste fuel in cement kilns will significantly increase the health risks to local residents due to transportation spills and accidents. However, the data do not indicate that this is the case. For every mile traveled by truck or rail, the number of accidents, damages, and injuries involving hazardous waste are statistically less than the number involving hazardous materials (e.g., gasoline). In fact, "gasoline historically has killed or injured more people in transportation accidents than all other hazardous materials combined" (Hermann, 1991).

The U.S. Department of Transportation regulates hazardous waste as a subset of hazardous materials. Their statistics for the 10-year period ending 1990 indicate that hazardous waste accounted for 2.9% of all hazardous materials releases, 2.3% of the damages, and 0.8% of all deaths and injuries, with only one death reported due to interstate hazardous waste incidents

in 10 years (U.S. Department of Transportation, 1991). Yet in 1982, hazardous waste accounted for 5% of all truckloads and 7% of all miles traveled, indicating much safer accident statistics for hazardous waste per shipment or per mile travelled compared with hazardous materials (Roy, 1989). Furthermore, the industry's safety record has continued to improve over the past several years (Roy, 1989).

Two factors may explain the difference in transportation safety between hazardous waste and hazardous materials. One, hazardous wastes are generally spent or diluted byproducts, not concentrated raw materials, which makes them inherently less hazardous than most hazardous materials when spilled. Two, hazardous waste transport is more highly regulated than hazardous materials transport (Roy, 1989). Stricter transportation regulations generally reduce the number of accidents associated with a given type of shipment.

The above information suggests that the risks of transportation incidents and injuries will not likely increase due to transportation of hazardous waste to a facility, particularly for those facilities currently accepting shipments of commercial fuel designated as hazardous materials. For those facilities using nonhazardous materials to fuel the kiln, the statistical risks of hazardous waste accidents are sufficiently low that a major increase in risk to residents along the transportation route to a kiln is unlikely.

8.6 SUMMARY OF POTENTIAL HEALTH EFFECTS

The foregoing review of current literature on the health effects of emissions, CKD, and cement from properly operated cement production facilities using hazardous waste fuel and in compliance with regulatory requirements indicates minimal potential for adverse effects to human health. In fact, the potential health effects from kilns supplementing fuel with hazardous waste are not expected to be different from those that could be encountered from burning conventional fuel alone. This conclusion is based on a review of the concentrations of organic chemicals and metals in emissions from kilns using each type of fuel source, and a review of assessments of potential health risks from a variety of facilities under various operating conditions.

The potential for adverse health effects is higher in occupational settings; however, unsafe exposures are unlikely except at unregulated plants outside the U.S. The health effects from such high exposures would not be expected to occur to the public in this country with the extremely low concentrations of chemicals that must be achieved under current BIF and CAA regulations. The relatively low incidence of occupational illness within the cement industry and the overall reduction in emissions from cement plants over the last two decades leads to the following conclusion: the potential for impacts to public health from cement kilns are low and likely have decreased over the decades with increasing emissions control. The cement industry, already unique in its low incidence of occupational and public health impacts, does not pose a greater risk to public health due to burning hazardous waste at properly operated facilities.

9.0 CONCLUDING REMARKS

On February 21, 1991, the U.S. EPA finalized the BIF rule, which regulates the burning of hazardous waste in cement kilns. The BIF rule sets emission standards for organic compounds, metals, hydrogen chloride, chlorine gas, and particulates. These regulations are even more stringent than the present regulations for hazardous waste incinerators. In fact, a U.S. EPA assistant administrator in the Office of Solid Waste and Emergency Response stated that these "facilities will have to meet our most stringent requirements, ensuring public safety near these sites" (Bureau of National Affairs, 1991). Consequently, if a cement production facility that wants to burn hazardous waste cannot meet these performance standards, then it will not be permitted (i.e., allowed) to burn hazardous waste.

Regardless of the regulations, many want to know if the emissions, the byproduct of the production process (i.e., CKD), or the final product (i.e., cement) is changed in any way by using hazardous waste as a supplemental fuel. Recent studies have shown that the organic emissions from cement kilns burning hazardous waste do not appear to differ from cement kilns burning only conventional fuel. In fact, these studies indicate that organic emissions are not dependent on the fuel that is burned, but on the operating conditions.

The majority of the metals in the hazardous waste, as well as in the raw materials and conventional fuel, are retained in the clinker or the CKD. Consequently, recent studies indicate that the majority of metal emissions do not significantly increase when conventional fuel is supplemented by hazardous waste.

This observation leads to the question: are the concentrations of metals significantly different in the cement or CKD? The preliminary results from the CRI database indicate that, for the majority of metals of concern, substantial increases in metal concentrations do not occur. More importantly, a recent report by the PCA indicates that the type of fuel is not the primary determinant in the distribution and concentration of metals in either the CKD or the cement. In addition, the PCA study demonstrated that the leaching of metals from cement and CKD is not significant. None of the average metal concentrations in the TCLP extracts from either cement or CKD exceeded the health-based standards set by the U.S. EPA.

All of these results have important ramifications for the evaluation of health effects associated with the practice of burning hazardous waste in cement kilns. Since no substantial increases in organic and metal components have been observed in emissions, CKD, or cement when burning hazardous waste, no increases in adverse health effects are expected to occur. Assessments of health risks from emissions and CKD from facilities in the U.S. have supported this conclusion. Thus, the current evidence indicates that properly operated cement kilns do not pose a greater risk to public health when conventional fuel is supplemented by hazardous waste.

10.0 GLOSSARY

Acidic: possessing the ability to donate a proton (e.g., HCl) or accept a pair of electrons (e.g., SO_2); or having a pH less than 7.

Alkaline: possessing the ability to accept a proton or donate a pair of electrons; or having a pH greater than 7.

Alumina: common name for aluminum oxide (Al_2O_3); a necessary ingredient in the manufacture of cement.

Aromatic compound: an organic compound similar in molecular structure to benzene.

Air pollution control devices (APCDs): devices used to remove particulates from the gases of the cement kiln before release to the environment.

Baghouse: a type of air pollution control device that uses fabric filters to remove particulates from the flue gases.

Boilers and Industrial Furnaces Rule (BIF): regulations passed by the U.S. EPA in 1991 that govern the actual burning of hazardous waste in cement kilns.

British thermal unit (Btu): the amount of energy required to raise the temperature of 1 pound of water by 1°F.

Calcining zone: the thermal zone in the cement kiln in which carbon dioxide is liberated from carbonate species, such as calcium carbonate.

Calcium carbonate: CaCO_3 ; the major ingredient needed to manufacture cement.

Carcinogenicity: the potential of a substance to cause cancer.

Cement: mixture of ground clinker and a small amount of gypsum.

Cement kiln dust (CKD): the collection of particulate matter removed from the kiln gases by the air pollution control devices.

Chlorinated wastes: wastes that are composed primarily of organic compounds containing chlorine.

Clinker: nodules composed of tricalcium silicate, dicalcium silicate, tricalcium aluminate, and tetracalcium aluminoferrite that form in the sintering zone of the cement kiln.

Combustible: relating to the ease with which a material catches fire and burns.

Concrete: a mixture of cement, sand, and gravel.

Cooling zone: the last 10 to 20 feet of the cement kiln in which the clinker begins to cool.

Corrosivity: one of the four U.S. EPA hazardous waste characteristics (see Section 3.1).

Destruction and Removal Efficiency (DRE): a parameter developed by the U.S. EPA to determine the ability of a combustion device to destroy and/or remove the organic components of the hazardous waste feed.

Dioxin: the common name for polychlorinated dibenzo-p-dioxins (PCDDs). Production of these compounds has been associated with low temperature combustion processes and high exposure to these compounds has been associated with adverse health effects, particularly in laboratory animals.

Electrostatic precipitator (ESP): a type of air pollution control device that uses an electric charge to collect particulates.

Epidemiology: the study of the sources and distribution of disease in a population.

Flash point: the minimum temperature at which the vapor-air mixture above a volatile substance ignites when exposed to a flame.

Fossil fuels: fuels such as coal and oil that are generated by the decay of plant and/or animal matter under conditions of heat and pressure.

Fugitive emissions: nonstack emissions usually associated with normal plant operations or leaks at the facility.

Furans: the common name for polychlorinated dibenzofurans (PCDFs). Generation of these compounds has been associated with low-temperature combustion processes and high exposure to these compounds has been associated with adverse health effects, particularly in laboratory animals.

Gypsum: the common name for calcium sulfate dihydrate ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$), an essential ingredient of cement that controls the rate of setting.

Halogen: any one of the elements (i.e., fluorine, chlorine, bromine, iodine, and astatine) that occupy column VIIa of the periodic table.

Hazardous waste: material that no longer has commercial value and requires disposal and is either specifically listed by the U.S. EPA or meets one of the four hazardous waste characteristics defined by the U.S. EPA.

Heat-exchanging cyclones: a unit used in the cement production process that utilizes the kiln's hot exit gases to heat the raw materials prior to entering the kiln.

Hydrocarbons: compounds composed of carbon and hydrogen.

Ignitability: one of the four U.S. EPA hazardous waste characteristics (see Section 3.1).

Iron oxide: Fe_2O_3 ; one of the necessary ingredients in the production of cement.

Kiln: the manufacturing unit in which clinker is formed.

Leaching: the process by which a soluble component is "washed" from a solid material typically by percolation of a liquid through the solid material. The solution which contains the soluble components is known as the leachate.

Lime: the common name for calcium oxide (CaO); formed in the calcining zone of the cement kiln

Maximum Exposed Individual (MEI): a hypothetical individual that receives the maximum possible exposure to a chemical from all possible sources and pathways.

Mutagenicity: the potential of a substance to cause a mutation or an adverse change in DNA (i.e., genetic material).

Organic: composed primarily of carbon.

Polychlorinated biphenyls (PCBs): chlorinated aromatic compounds that were banned in the 1970s because of their toxicity to laboratory animals and long-term stability in the environment.

Portland cement: the most common variety of cement.

Precalciner kiln: identical to a preheater kiln except for a secondary firing in the tower of heat-exchanging cyclones which nearly completes the calcination of the feed material.

Preheater kiln: a cement kiln equipped with a tower of heat-exchanging cyclones which preheat and partially calcine the feed material.

Principal organic hazardous constituents (POHCs): organic compounds chosen to determine the DRE of a combustion device in a trial burn. POHCs are representative of the compounds in the waste stream that are the most abundant and the most difficult to destroy.

Process, dry: a cement manufacturing process in which the feed material enters the kiln system in dry powdered form.

Process, semidry: a cement manufacturing process in which water, typically 10% to 15%, is added to the ground dry feed material and then fed into the kiln system.

Process, wet: a cement manufacturing process in which water, typically 30% to 40%, is added to the feed material and then fed into the kiln.

Products of incomplete combustion (PICs): "unburned organic compounds that were present in the waste, thermal decomposition products resulting from organic constituents in the waste, or compounds synthesized during, or immediately after combustion" [U.S. EPA, 1991 (p. 7149)].

Reactivity: one of the four U.S. EPA hazardous waste characteristics (see Section 3.1).

Residence time: the amount of time that a gas spends in a particular location or at a particular temperature.

Silica: the common name for silicon dioxide (SiO_2); one of the necessary ingredients in the production of cement.

Sintering zone: the thermal zone in the kiln in which clinker is formed.

Teratogenicity: the potential of a substance to cause defects to the developing fetus.

Toxicity: one of the four U.S. EPA hazardous waste characteristics (see Section 3.1).

Toxicity Characteristic Leaching Procedure (TCLP): a U.S. EPA test developed to evaluate the potential of a component to leach from a substance.

11.0 REFERENCES

- Abrons, H.L., M.R. Petersen, W.T. Sanderson, A.L. Engelberg, and P. Harber. 1988. Symptoms, ventilatory function, and environmental exposures in Portland cement workers. British Journal of Industrial Medicine 45:368-375.
- Agency for Toxic Substances and Disease Registry (ATSDR). 1987. Toxicological profile for chromium. Draft. Oak Ridge National Laboratory, Oak Ridge, TN.
- Agency for Toxic Substances and Disease Registry (ATSDR). 1990. Toxicological profile for lead. Oak Ridge National Laboratory, Oak Ridge, TN.
- Ahling, B. 1979. Destruction of chlorinated hydrocarbons in a cement kiln. Environmental Science & Technology 13(11):1377-1379.
- Amandus, H.E. 1986. Mortality from stomach cancer in United States cement plant and quarry workers, 1950-80. British Journal of Industrial Medicine 43:526-528.
- American Conference of Governmental Industrial Hygienists (ACGIH). 1986. Documentation of the Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices. ACGIH, Cincinnati, OH.
- American Petroleum Institute. 1991. Personal Communication. (Telephone conversation with Nanette Cardon, Environmental Toxicology International, Inc., Seattle, WA regarding energy values for coal and crude oil. Values were quoted from U.S. Department of Energy. 1991. Monthly Energy Review). Washington, DC.
- American Society for Testing and Materials (ASTM). 1990. Annual Book of ASTM Standards. Section 4. Construction. Vol. 04.01 Cement; Lime; Gypsum. C150: pp. 118-122. ASTM, Philadelphia, PA.
- Anda, A. 1987. Effect of cement kiln dust on the radiation and water balance and yields of winter wheat. Acta Agronomica Hungarica 36(3-4):267-276 from abstract.
- Avnstorp, C. 1989. Prevalence of cement eczema in Denmark before and since addition of ferrous sulfate to Danish cement. Acta Dermato-Venerology 69:151-155.
- Bambauer, H.U. and H. Schäfer. 1984. Der Mineralbestand eines thalliumhaltigen Reingasstaubes aus der Zementproduktion [The mineralogy of thallium-containing stack fly ash from cement works]. Fortschritte der Mineralogie 62(1):33-50.
- Benestad, C. 1989. Incineration of hazardous waste in cement kilns. Waste Management & Research 7:34-36L.
- Black, M.W. and J.R. Swanson. 1983. Destruction of PCB's in cement kilns. Pollution Engineering June:50-53.

- Bolstad, J.N., J.T. Chelasko, M. Branscome, C.W. Westbrook, and R.G. Mournighan. 1985. Test results of hazardous waste combustion in two cement kilns. Presented at the 78th Annual Meeting of the Air Pollution Control Association. Held 16-21 June in Detroit, MI.
- Borka, G. 1986. Effect of cement dust on the growth development major metabolic processes and yield of winter barley in-situ and under controlled conditions. *Acta Agronomica Hungarica* 35(1-2):47-52 from abstract.
- Branscome, M. and R.E. Mournighan. 1987. Hazardous waste combustion in industrial processes: Cement and lime kilns. EPA 600/2-87-095. U.S. Environmental Protection Agency, Office of Research and Development, Hazardous Waste Engineering Research Laboratory, Cincinnati, OH. 67 pp.
- Branscome, M., W. Westbrook, R. Mournighan, J. Bolstad, and J. Chelasko. 1985. Summary of testing at cement kilns cofiring hazardous waste. In *Incineration and Treatment of Hazardous Waste: Proceedings of the Eleventh Annual Research Symposium*. EPA 600/9-85-028. pp. 199-205. U.S. Environmental Protection Agency, Office of Research and Development, Hazardous Waste Engineering Research Laboratory, Cincinnati, OH.
- Brunner, C.R. 1989. *Handbook of Hazardous Waste Incineration*. TAB Professional and Reference Books, Blue Ridge Summit, PA. pp. 48-50, 266-277.
- Bureau of National Affairs, Inc. (BNA). 1991. EPA to regulate boilers, furnaces in effort to close recycling loophole. *BNA Daily News*; January 4. BNA, Washington, DC.
- Clement Associates, Inc. 1988. South Coast Air Quality Management District: Multi-pathway health risk assessment input parameters guidance document. Prepared for South Coast Air Quality Management District and State of California, Department of Health Services. Clement Associates, Inc.
- Costner, P. and J. Thornton. 1990. Playing with Fire: Hazardous Waste Incineration. Greenpeace U.S.A., Washington, DC. 63 pp.
- CRC Handbook of Chemistry and Physics. 1982. 63rd ed. Eds. R.C. Weast and M.J. Astle. p. F-160. CRC Press, Boca Raton, FL.
- E&E/ITT. 1988. Site investigation: Lehigh Portland Cement Company, Mason City, Iowa. Final report. Prepared by E&E/ITT for Region VII EPA.
- Engineering Digest. 1989. Burning wastes in cement kilns. 35(5):16-22.
- Environmental Science & Engineering, Inc. (ESE). 1991. Evaluation of acceptable levels of trace elements in portland cement. Prepared for the Cement Kiln Recycling Coalition. ESE, St. Louis, MO.
- Environmental Toxicology International, Inc. (ETI). 1992. Comments on the draft U.S. EPA document entitled: "Guidance on metals and HCl controls for hazardous waste incinerators." ETI, Seattle, WA.

- Garg, S. 1990a. Emissions testing of a precalciner cement kiln at Louisville, Nebraska. EPA 530/SW-91-016. U.S. Environmental Protection Agency, Office of Solid Waste, Washington, DC.
- Garg, S. 1990b. Emissions testing of a wet cement kiln at Hannibal Missouri. Draft Interim Report. EPA 530/SW-91-017. U.S. Environmental Protection Agency, Office of Solid Waste, Washington, DC.
- Hahn, E.F. 1989. Carcinogenic responses of the lung to inhaled materials. In Concepts in Inhalation Toxicology. Eds. R.O. McClellan and R.F. Henderson. Chapter 12, pp. 313-346. Hemisphere Publishing Corp, New York.
- Hall, R.M., Jr., N.S. Bryson, and D.R. Case. 1987. Resource Conservation and Recovery Act. In Environmental Law Handbook. 9th ed. Chapter 2, pp. 56-100. Government Institutes, Inc., Rockville, MD.
- Hansen, E.R. and F.M. Miller. 1990. Leaching study of portland cement using the TCLP procedure. Paper presented at Emerging Technologies in Resource Recovery and Emission Reduction in the Cement Industry. Held 19-20 September in Dallas, TX. Sponsored by the Portland Cement Association.
- Haynes, B.W. and G.W. Kramer. 1982. Characterization of U.S. cement kiln dust. Information Circular 8885. U.S. Department of the Interior, Bureau of Mines, Avondale, MD. 19 pp.
- Hazelwood, D., F. Smith, and E. Gartner. 1982. Assessment of waste fuel use in cement kilns. EPA 600/2-82-013. U.S. Environmental Protection Agency, Office of Research and Development, Industrial Environmental Research Laboratory, Cincinnati, OH.
- Hermann, S.L. 1991. Is national computerized hazardous materials tracking needed? Hazmat World March:82-85.
- Huhta, R.S. 1991. International cement review. Rock Products April:55-80.
- Iowa Department of Natural Resources. 1990. Record of decision for Northwestern States Portland Cement Company site, Mason City, Iowa. Prepared for the U.S. Environmental Protection Agency, Washington, DC.
- Jakobsson, K., R. Attewell, B. Hultgren, and K. Sjöland. 1990. Gastrointestinal cancer among cement workers. International Archives of Occupational and Environmental Health 62:337-340.
- Kazantzis, G. 1986. Thallium. In Handbook on the Toxicology of Metals. 2nd ed. Eds. L. Friberg, G.F. Nordberg, and V.B. Vouk. Vol. II, Chapter 22, pp. 549-567. Elsevier, Amsterdam.
- Kelly, K.E. 1991. Risk assessment with respect to the use of waste-derived construction materials: Concentration vs. leachability. Paper presented at WASCON '91: The International Conference on Environmental Implications of Construction with Waste Materials. Held 10-14 November in Maastrich, The Netherlands.

- Kelly, K.E. and G.A. Pascoe. 1991. Assessing the health effects of cement kilns burning hazardous waste. Paper presented at Rock Products: The 27th International Cement Seminar. Held 2-5 December in Atlanta, GA.
- Kelly, K.E. and N.C. Cardon. 1991. The myth of 10^{-6} as a definition of acceptable risk (or, "In hot pursuit of Superfund's Holy Grail"). Paper presented at the 84th Annual Meeting of the Air and Waste Management Association. Held 16-21 June in Vancouver, B.C., Canada.
- Kerton, C.P. and R. J. Murray. 1983. Portland cement production. In Structure and Performance of Cements. Ed. P. Barnes. Chapter 5, pp. 209, 212. Applied Science Publishers, New York.
- Kirchner, G. 1987. Thalliumkreisläufe und Thalliumemissionen beim Brennen von Zementklinker [Thallium cycles and thallium emissions in cement clinker burning]. Special Edition, Zement-Kalk-Gips International 3:134-144.
- Kirk-Othmer Encyclopedia of Chemical Technology. 1979. 3rd ed. Vol. 6. pp. 235-239. Wiley-Interscience, New York.
- Krishnamurthy, K.V. and C. Rajachidambaram. 1986. Factors associated with reduction in photosynthetic oxygen evolution in cement dust coated leaves. Photosynthetica 20(2):164-168 from abstract.
- Lachapelle, J.M. 1986. Industrial airborne irritant or allergic contact dermatitis. Contact Dermatitis 14:137-145.
- Lauber, J.D. 1987. Disposal and destruction of waste PCBs. In PCBs and the Environment. Ed. J.S. Waid. Vol. III, Chapter 5, pp. 83-151. CRC Press, Boca Raton, FL.
- McDowall, M.E. 1984. A mortality study of cement workers. British Journal of Industrial Medicine 41:179-182.
- The Merck Index: An Encyclopedia of Chemicals, Drugs, and Biologicals. 1983. 10th ed. Eds. M. Windholz, S. Budavari, R.F. Blumetti, and E.S. Otterbein. p. 1091. Merck and Co., Inc., Rahway, NJ.
- Miles, A.J., M.H. Keating, and C.L. Jamgochian. 1987. National dioxin study tier 4 - combustion sources: Engineering analysis report. EPA 450/4-84-014h. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Monitoring and Data Analysis Division, Research Triangle Park, NC.
- Mishra, G.P. and S.B. Tiwari. 1986. Effect of cement dust on the human population. Indian Journal of Environmental Protection 6(2):92-94.
- Mix, T.W. and B.L. Murphy. 1984. Risks associated with waste-fuel use in cement kilns. Environmental Progress 3(D):64-70.

National Governors' Association (NGA). 1988. Hazardous Materials Transportation Regulatory and Enforcement Programs: A Governor's Guide. NGA, Transportation and Communications Capital Resources Policy Studies, Center for Policy Research, Washington, DC.

O'Connor, R. 1991. Personal communication (Telephone conversation with M. Buchanan, Environmental Toxicology International, Inc., Seattle, WA) Electric Power Research Institute, Palo Alto, CA. 30 October.

Oppelt, E.T. 1986. Hazardous waste destruction. Environmental Science & Technology 20(4):312-318.

Pedersen, W.F. 1987. Air Pollution Control. In Environmental Law Handbook, 9th ed. Chapter 6, pp. 292-329. Government Institutes, Inc., Rockville, MD.

Peray, K.E. 1986. The Rotary Cement Kiln. 2nd ed. Chemical Publishing Co., Inc., New York. pp. 6-16, 141-144.

Peters, P., G.M. Higgins, and J. Chadbourne. 1986. Hazardous waste as a supplemental fuel for cement kilns. Paper presented at the 12th National Waste Processing Conference. Held 1986 in Denver, CO. Sponsored by the American Society of Mechanical Engineers.

Phalen, R.F. and S.B. Prasad. 1989. Morphology of the respiratory tract. In Concepts in Inhalation Toxicology. Eds. R.O. McClellan and R.F. Henderson. Chapter 4, pp. 123-140. Hemisphere Publishing Corporation, New York.

Pike, J., A. Patterson, Jr., and M.S. Arons. 1988. Chemistry of cement burns: Pathogenesis and treatment. Journal of Burn Care Rehab. 9(3):258-260.

Portland Cement Association (PCA). 1991. An analysis of selected metals in Portland cement and cement kiln dust. Draft.

Potts, A.M. 1986. Toxic responses of the eye. In Casarett and Doull's Toxicology: The Basic Science of Poisons. 3rd ed. Eds. C.D. Klaassen, M.O. Amdur, and J. Doull. Chapter 17, pp. 478-515. Macmillan Publishing Co., New York.

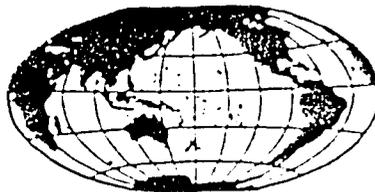
Roy, K.A. 1989. Ground transport: Trucking industry focuses on HMTA reauthorization. Hazmat World April:35-41.

Segall, R.R. 1991. Site-specific test protocol to evaluate ammonium chloride interference in EPA method 26. Dixie Cement Company. Prepared for U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Emission Measurement Branch, Research Triangle Park, NC.

Springborn, R.R. 1991. Personal communication. (Memorandum to E.K. Mantus, Environmental Toxicology International, Inc., Seattle, WA regarding the statistical analysis for investigating the effect of increasing hazardous waste fuel replacement on metal emission). 16 December.

- Sprung, S. 1985. Technological Problems in Pyroprocessing; Cement Clinker: Cause and Solution. Translation by T.V. Brodek. Beton-Verlag GmbH, Düsseldorf.
- Stein, D.A. and J. Lowe. 1990. Health risk assessment. Increased liquid waste fuel firing in the Lebec Cement Kiln. Prepared for National Cement Company, Lebec, California. Prepared by EBASCO Environmental and Dames and Moore, Sacramento, CA.
- Taylor, H.F.W. 1990. Cement Chemistry. Academic Press, New York. pp. 1, 2, 65, 66, 69, 96.
- Tracer Technologies. 1991. Evaluation of waste combustion in a cement kiln using sulfur hexafluoride. United Cement, Mississippi. Prepared for United Cement, Artesia, MS. Tracer Technologies, San Marcos, CA.
- Travis, C.C., S.A. Richter, E.A.C. Crouch, R. Wilson, and E.D. Klema. 1987. Cancer risk management: A review of 132 federal regulatory decisions. *Environmental Science & Technology* 21(5):415-420.
- U.S. Code of Federal Regulations. 1990. Title 30, Parts 1-199.
- U.S. Code of Federal Regulations. 1990. Title 40, Parts 260-299.
- U.S. Code of Federal Regulations. 1990. Title 49, Parts 100-177.
- U.S. Congress, Office of Technology Assessment. 1989. Coming clean: Superfund's problems can be solved . . . OTA-TTE-433. US. Government Printing Office, Washington DC. 217 pp.
- U.S. Department of Labor. 1991. Occupational injuries and illness in the U.S. by industry, 1989. Bulletin 2379. U.S. Department of Labor, Bureau of Labor Statistics.
- U.S. Department of Transportation. 1991. Personal Communication. (Telefacsimile to M. Buchanan, Environmental Toxicology International, Inc., Seattle, WA regarding hazardous materials releases by year and mode, 1981-1990). Washington, DC. 29 March.
- U.S. Environmental Protection Agency (U.S. EPA). 1984. Composition and management of used oil generated in the United States. U.S. EPA, Office of Solid Waste and Emergency Response, Washington, DC. p. 1-12.
- U.S. Environmental Protection Agency (U.S. EPA). 1989a. Land disposal restrictions: Summary of requirements. OS-520. U.S. EPA, Office of Solid Waste and Emergency Response, Washington, DC.
- U.S. Environmental Protection Agency (U.S. EPA). 1989b. Review of the national ambient air quality standards for lead: exposure analysis methodology and validation. OAQPS Staff Report. EPA 407/2-89-011.
- U.S. Environmental Protection Agency (U.S. EPA). 1990a. Methods manual for compliance with the BIF regulations. EPA 530/SW-91-010. U.S. EPA, Office of Solid Waste, Washington, DC. pp. 3-71, 3-98.

- U.S. Environmental Protection Agency (U.S. EPA). 1990b. Technical support document on lead. ECAO-CIN-757. U.S. EPA, Environmental Criteria and Assessment Office, Cincinnati, OH.
- U.S. Environmental Protection Agency (U.S. EPA). 1991. Burning of hazardous waste in boilers and industrial furnaces. Final rule. Federal Register (February 21) 56:7134-7240.
- Ullman, E. 1991. The Japanese cement industry. Rock Products April:47-51.
- Utah Department of Health. 1990. Declaration for the record of decision: Portland Cement Co. (Kiln Dust #2 & #3) Operable Unit I, Salt Lake City, Utah. Prepared for the U.S. Environmental Protection Agency, Region VIII.
- van der Sloot, H.A. 1991. Systematic leaching behavior of trace elements from construction materials and waste materials. In Waste Materials in Construction. Eds. J.J.J.M. Goumans, H.A. van der Sloot, and T.G. Aalbers. pp. 19-36. Elsevier, Amsterdam.
- Vestbo, J. and E.V. Rasmussen. 1990. Long-term exposure to cement dust and later hospitalization due to respiratory disease. International Archives of Occupational and Environmental Health 62(3):217-220.
- Visvanathan, R. 1986. Cement bezoars of the stomach. British Journal of Surgery 73:381-382.
- von Seebach, M. and D. Gossman. 1990. Cement kilns: Sources of chlorides not HCl emissions. Paper presented at AWMA Specialty Conference on Waste Combustion in Boilers and Industrial Furnaces. Held 18-20 April in Kansas City, MO.
- von Seebach, M. and J.B. Tompkins. 1991. Metal emissions are predictable. Rock Products April:31-35.
- Wedepohl, K.H. 1991. The composition of the upper Earth's crust and the natural cycles of selected metals. Metals in the natural raw materials. Natural Resources. In Metals and Their Compounds in the Environment: Occurrence, Analysis, and Biological Relevance. Ed. E. Merian. pp. 3-17. VCH, New York.
- Weitzman, L. 1983. Cement kilns as hazardous waste incinerators. Environmental Progress 2(1):10-14.
- Wright, W.E., L. Bernstein, J.M. Peters, D.H. Garabrant, and T.M. Mack. 1988. Adenocarcinoma of the stomach and exposure to occupational dust. American Journal of Epidemiology 128(1):64-73.



CEMENT KILNS FOR HAZARDOUS WASTE DISPOSAL

Opportunities and Constraints

by

Krish Ravishankar
Research Intern

and

Wayne Mitter
Consultant

December 1988

A project of the

**PACIFIC BASIN CONSORTIUM
FOR HAZARDOUS WASTE RESEARCH**

Under the auspices of the
Environment and Policy Institute
East-West Center
1777 East-West Road
Honolulu, Hawaii 96848

Tele: 808-944-73

Honolulu, Hawaii 96848

Publications: Tele: 808-944-71



147

CONTENTS

List of Figures and Tables	v
Acknowledgments	vii
Principal Abbreviations	viii
Abstract	ix
1. Introduction	1
1.1 Background	1
1.2 Purpose	3
1.3 Methods of Study and Analysis	3
1.4 Organization of the Report	4
2. Cement Production	5
2.1 Overview of the Industry	5
2.2 Process Description	5
3. Use of Wastes as Fuels	11
3.1 Waste Fuel Systems	11
3.2 Plant Modifications Required to Burn Hazardous Wastes	13
4. Operating Experience and Test Results	15
4.1 Introduction	15
4.2 Operating History, With Highlights of Test Burns	15
4.3 Test Results	24
5. Economics of Waste Fuel Use	39
5.1 General Economic Factors	39
5.2 Economic Data for Model Plant A	41
5.3 Economic Data for Model Plant B	44
6. Risk Assessment	47
6.1 Transportation Risks	48
6.2 Storage and Handling Risks	49
6.3 Other Risks	50
6.4 Kila Emission Risks	51
7. Cement Kilns in Selected Asia-Pacific Countries	59
8. Findings	63

148

9. Recommendations	67
Appendices:	
A. Sampling and Analytical Procedures	71
B. Protocol for a Trial Burn	81
References	97

119

FIGURES AND TABLES

Figures

1. Schematic of a typical cement plant	7
A-1. VOST schematic	73
A-2. Modified Method 5 schematic	75
A-3. HCl sampling train	77
A-4. Continuous monitor sample system	78

Tables

1. Data pertinent to incineration of chemical wastes	12
2. Operating history of cement kilns	16
3. Summary of DREs	26
4. Summary of POHC emission rates	27
5. Products of incomplete combustion	28
6. Emissions of particulate matter	30
7. HCl emissions	32
8. Summary of NO _x emissions	33
9. Summary of SO ₂ emissions	34
10. Summary of THC and CO concentrations	36
11. Cost estimates for waste disposal in a model cement kiln	42
12. Axial mean concentration of plume (C) 1 km downwind from source	55
13. Health risks from kiln emissions of four POHCs	56
14. POHC concentrations in typical polluted U.S. cities	58
15. Profile of cement plants in selected Asia-Pacific countries	60
16. Cement production in selected countries	62

B-1. Sampling methods and analysis parameters 88

B-2. A typical example of sampling personnel required 89

B-3. Capabilities necessary for trial-burn sampling
and analysis 90

B-4. Incinerator equipment/instrument requirements
for trial burn 91

B-5. List of data forms 94

151

ACKNOWLEDGMENTS

Helpful comments and suggestions on previous drafts of this document from the following are gratefully acknowledged:

Dr. Richard A. Cirillo, Executive Secretary, Pacific Basin Consortium for Hazardous Waste Research, Argonne National Laboratory, Argonne, Illinois.

Dr. Charles A. Wentz, Technology Assessment Manager, Argonne National Laboratory, Argonne, Illinois.

Dr. Malcolm Wilson, Alberta Environmental Centre, Alberta, Canada.

Dr. Hann Huang, Argonne National Laboratory, Argonne, Illinois.

Mr. Robert E. Mournighan, Technology Research Staff, U.S. Environmental Protection Agency, Cincinnati, Ohio.

Dr. Sylvia Edgerton, Mr. Richard Carpenter, and Dr. Kirk Smith, Environment and Policy Institute, East-West Center, Honolulu, Hawaii.

Special acknowledgment is also extended to James W. Kamas of Radian Corporation; Earl F. Bouse, Jr., of Pacific Basin Coal and Carbon Company; and to Andrew Beers of the New York State Legislative Commission on Toxic Substances and Hazardous Wastes from whose publications much information was borrowed.

The authors are indebted to Ms. Helen Takeuchi for her editorial skills in producing the final version.

PRINCIPAL ABBREVIATIONS

DRE	Destruction and Removal Efficiency
ESP	Electrostatic Precipitator
PAH	Polycyclic Aromatic Hydrocarbons
PIC	Products of Incomplete Combustion
POHC	Principal Organic Hazardous Constituents
VOST	Volatile Organic Sampling Train
THCs	Total Hydrocarbons
VOC	Volatile Organic Carbon
SDF	Solvent-Derived Fuels

ABSTRACT

This study was initiated by the Pacific Basin Consortium for Hazardous Waste Research (PBCHWR) to document current knowledge and operating experience in the United States, Canada, and elsewhere concerning the use of cement kilns for the destruction of hazardous waste. The report summarizes results of tests in the United States by the Environmental Protection Agency (EPA) and State agencies, and in Canada, Norway, and Sweden. The predominant types of wastes tested included chlorinated organic compounds and metal-contaminated waste oil. Kiln types included dry, wet, and preheat processes.

Parameters investigated in this study include destruction and removal efficiency (DRE) of principal organic hazardous constituents (POHCs), particulate and HCl emissions, metals, and the effect of burning hazardous waste on sulfur dioxide (SO_2), nitrogen oxide (NO_x), total hydrocarbons (THCs) and carbon monoxide (CO) emissions. Sampling and analytical procedures required to monitor and dispose of wastes safely are discussed. Technical and economic factors, and risks associated with the use of cement kilns to destroy waste materials are reviewed.

Potential applications of cement kilns for economic and environmentally sound disposal of some hazardous wastes in developing countries are examined. Many existing cement kilns in the Asia-Pacific region, when properly operated, have the potential to economically dispose of a substantial share of the organic chemical wastes generated in that region with acceptable risk of adverse effects on human health and the environment. More than twenty cement kilns in the United States are currently being used for hazardous waste disposal.

Site-specific feasibility studies, risk assessments, and trial burns are recommended in order to determine limiting conditions that may be applicable. Risk assessment can help determine whether potential benefits can be achieved at acceptable levels of risk.

This study constitutes the Consortium's initial phase of research on this topic.

1. INTRODUCTION

1.1 Background

High-temperature industrial processes have often been used for the disposal of organic wastes. Process heaters and boilers are among the most common industrial processes; however, since the equipment for these cannot tolerate more than trace quantities of organic chlorine, they cannot be used for many wastes currently generated.

Consequently, a number of other processes (e.g., cement kilns, lime kilns, aggregate kilns, and blast furnaces) that can destroy chlorinated wastes have been proposed. Cement kilns are of particular interest because of their potential for reducing the environmental impact of disposal in a cost-effective manner. The promising characteristics of cement kiln disposal include:

- Existing high-temperature combustion processes at 2,500° to 3,000° F (1,350° to 1,650° C), long gas residence times of up to 10 seconds or more, and strong turbulence in the kiln virtually assure the complete destruction of even the most stable organic compounds (Hazelwood et al. 1982).
- Rapid temperature drops are unlikely because of the huge thermal inertia.
- The alkaline environment in a kiln absorbs and neutralizes HCl from chlorinated waste combustion products.
- Kilns are operated under draft (slight vacuum); therefore, there is little outward leakage of fumes.
- Burning of liquid organic hazardous wastes as a replacement for primary fuels (oil, coal, or gas) allows for the recovery of substantial amounts of energy from these wastes. Liquid waste fuels typically being burned in U.S. cement plants have a heat value of 10,000 to 12,000 Btu/lb, a heat content comparable to coal (Peters et al. 1986).
- There is a potential for earning disposal fees from waste generators by treating wastes in a kiln.

- Cement kilns have the potential to dispose of large volumes of liquid organic wastes. A typical cement plant in the United States can burn 25,000 gallons (about 100 tons) of hazardous liquid waste per day (Beers 1987).
- Cement quality is relatively insensitive to the addition of most of the impurities found in hazardous wastes and waste oils (Mournighan et al. 1985).
- Bottom ash is incorporated into the clinker product, eliminating bottom-ash disposal problems. Any metals contained in the bottom ash are incorporated into the cement product in an inert form (Branscome 1985).
- Modification of existing cement kilns to accept hazardous waste fuels requires relatively small capital investment (Beers 1987).

The scope of this paper is limited to cement kilns. However, much of the discussion on opportunities and constraints is also applicable to lime kilns.

The combustion of hazardous waste in cement kilns has been investigated in Canada (Berry et al. 1975; MacDonald et al. 1977), Sweden (Ahling 1979; Piasecki and Davis 1987), Norway (Calonius 1984; Viken and Waage 1983), and New Zealand (Holden et al. 1983), as well as in the United States (Weitzman 1983; Lauber 1982; Hazelwood et al. 1982; Branscome et al. 1985; Mournighan and Branscome 1988; Argonne 1981). Some researchers report that disposal in cement kilns is often preferable to other hazardous waste disposal options, particularly for chlorinated organics (Black and Swanson 1983; Lauber 1982; USDOE 1983; Beers 1987; Holden et al. 1983).

Papers have also been published indicating actual and potential risks associated with hazardous waste combustion (Mix and Murphy 1984; Bouse and Kamas 1987). A number of kilns using different waste fuels have been tested under varied operating conditions (Day et al. 1985; Jenkins et al. 1982; Duckett and Weiss 1980; Peters et al. 1984; Branscome et al. 1984; Swanson Environmental 1976; Carter and Benson 1984; Stohrer 1986). Some of these tests have been very comprehensive. Purposes of tests have included determination of

156

effects of various wastes on stack emissions and on cement quality, determination of the fate of metals and chlorine, and identification of products of incomplete combustion and mechanisms of their formation (Branscome et al. 1985; Mournighan and Branscome 1988; Viken and Waage 1983; Higgins and Helmstetter 1982; Oppelt 1987; Peters et al. 1984).

Over the past decade, there has been a gradual increase in use of this technology in the United States. Bouse and Kamas (1987) have addressed opportunities and constraints, have documented the use of cement kilns for disposal of solvent-derived fuels (SDF) at seventeen U.S. sites, and have cited at least three additional plants that were scheduled to begin such disposal in 1987. Relatively slow acceptance of the process has been partly due to public perception of risks associated with the siting of any facility dealing with "hazardous" wastes.

1.2 Purpose

This investigation was initiated by the Pacific Basin Consortium for Hazardous Waste Research (PBCHWR), a group of research institutions. The purpose is three-fold: first, to assemble and analyze reports on current and past use of cement kilns for the destruction of hazardous wastes; second, to discuss some of the major issues associated with burning hazardous wastes in cement kilns; and third, to investigate the potential application of cement kilns for safe disposal of hazardous wastes generated in the Asia-Pacific region. This study constitutes the Consortium's initial phase of research on this topic.

1.3 Methods of Study and Analysis

To accomplish the stated purpose, it was first necessary to obtain technical reports of laboratory tests and demonstration projects. These reports included detailed descriptions of cement production processes, waste fuel handling systems, and technical capabilities and

limitations. Operational data, where available, were obtained to assess performance of kilns while burning wastes. Information was also sought on energy savings from substitution of waste fuel for primary fuel. Information was sought from the USEPA on regulatory measures, license and permit requirements, and state-of-the-art technology. A thorough search of the literature available in this field was made. Discussions were held with cement manufacturers, EPA personnel, and researchers at Argonne National Laboratory and the Portland Cement Association. Information was also sought from selected PBCHWR members about research or operating experiences in their countries.

Specific critical issues addressed in this study are (1) operating experience, waste types and characteristics, and test results--destruction and removal efficiencies (DREs), emissions, products of incomplete combustion (PIC); (2) sampling and analytical procedures; and (3) economics of waste fuel use.

1.4 Organization of the Report

First, a brief overview of the cement industry, the technology of cement production, and waste fuel handling systems are presented. Second, the operating history of burning hazardous waste in cement kilns and a summary of test results are discussed collectively under various emission categories of interest. Third, the economics of waste fuel burning is discussed. Fourth, risks associated with the burning of hazardous wastes in cement kilns are evaluated. Last, an overview of cement plants in selected Asia-Pacific countries is presented from which one can infer potential for hazardous waste disposal. Findings and recommendations follow.

2. CEMENT PRODUCTION

This section provides a brief overview of the cement industry in the United States and describes the technology of cement production.

2.1 Overview of the Industry

Portland cement is one of the largest scale mineral commodities produced in the United States with an annual production in 1985 of 74 million tons. About 200 cement plants with more than 325 kilns are located throughout thirty-eight states.

The cement industry is capital-intensive and is dependent on the construction industry. Energy costs normally amount to 33 to 40 percent of the total cost of cement manufacture, but in some cases may even be as high as 65 percent. Energy efficiency improvements have been made since 1950 when about 7.8 million Btus were required per ton of product. The estimate for 1979 was 6.5 million Btus per ton for the wet process cement kiln. This figure has probably continued to decline based on historical trends (USDOE 1980). Preheater modifications on dry process plants have reduced energy consumption to as low as 3 million Btu per ton in some instances (Branscome et al. 1985). In 1972, only 39 percent of the industry's energy was supplied by coal, but conversion to coal started in the 1970s. In 1978, pulverized coal accounted for 63 percent of the fuels used in cement production (USDOE 1980). Currently, more than 90 percent of the installed capacity uses coal as the primary fuel (Mournighan and Branscome 1988).

2.2 Process Description

Portland cement is produced by controlled high-temperature (2,500° to 2,800° F; 1,400° to 1,500° C) processing of a carefully

proportioned mixture of finely ground limestone, silica, alumina, and iron oxide-bearing raw materials in a rotary kiln.

For a typical U.S. cement plant, the raw materials--limestone, silica, and iron ore--are proportionately mixed together in approximately 4:1:0.07. The crushing and mixing may be either performed dry or wet (i.e., as slurry with 30 to 40 percent water). For several years, the wet process was preferred by the U.S. cement manufacturers because of its advantages in control of blending and ease of grinding (USDOE 1980). Recently, however, there has been increased conversion to improved forms of dry processing primarily because of lower energy requirements for the dry process (5.5 million Btu/ton for the dry process, as compared to 6.5 million Btu/ton for the wet process).

Thermal processing of the mixed raw materials may be viewed in three stages: drying, calcining, and clinkering. The first stage (drying) applies primarily to the wet process and requires temperatures in the neighborhood of 212° F (100° C). The second and third stages (calcining and clinkering) apply to both the wet and dry process. Calcining is the controlled heating of the mixture in order to dehydrate the materials and to drive off carbon dioxide from the limestone. Calcining temperatures are in the range of 1,000° to 1,800° F (550° to 1,000° C). Clinkering (sometimes called "burning") is the term for the chemical reactions that convert the raw materials into hardened granular masses of calcium aluminates and calcium ferrites. The clinker reactions take place at temperatures in the range of 1,800° to 2,500° F (1,400° to 1,500° C). The resulting clinker is then air-cooled and ground to a fine powder (90 percent <200 mesh) for use as portland cement. The solid's residence time varies from kiln to kiln and is controlled by the kiln's revolution. Typical solids residence times are on the order of 2 (range of 1 to 4) hours. Often, gypsum (i.e., calcium sulfate, CaSO₄) is added to the clinker during grinding in order to retard the setting time of the cement. Portland cement often contains 5 to 6 percent gypsum.

For most (about 80 percent) of the cement production in the United States, all three stages of thermal processing take place in a rotary kiln. Figure 1 is a schematic of a typical cement plant. The

1100

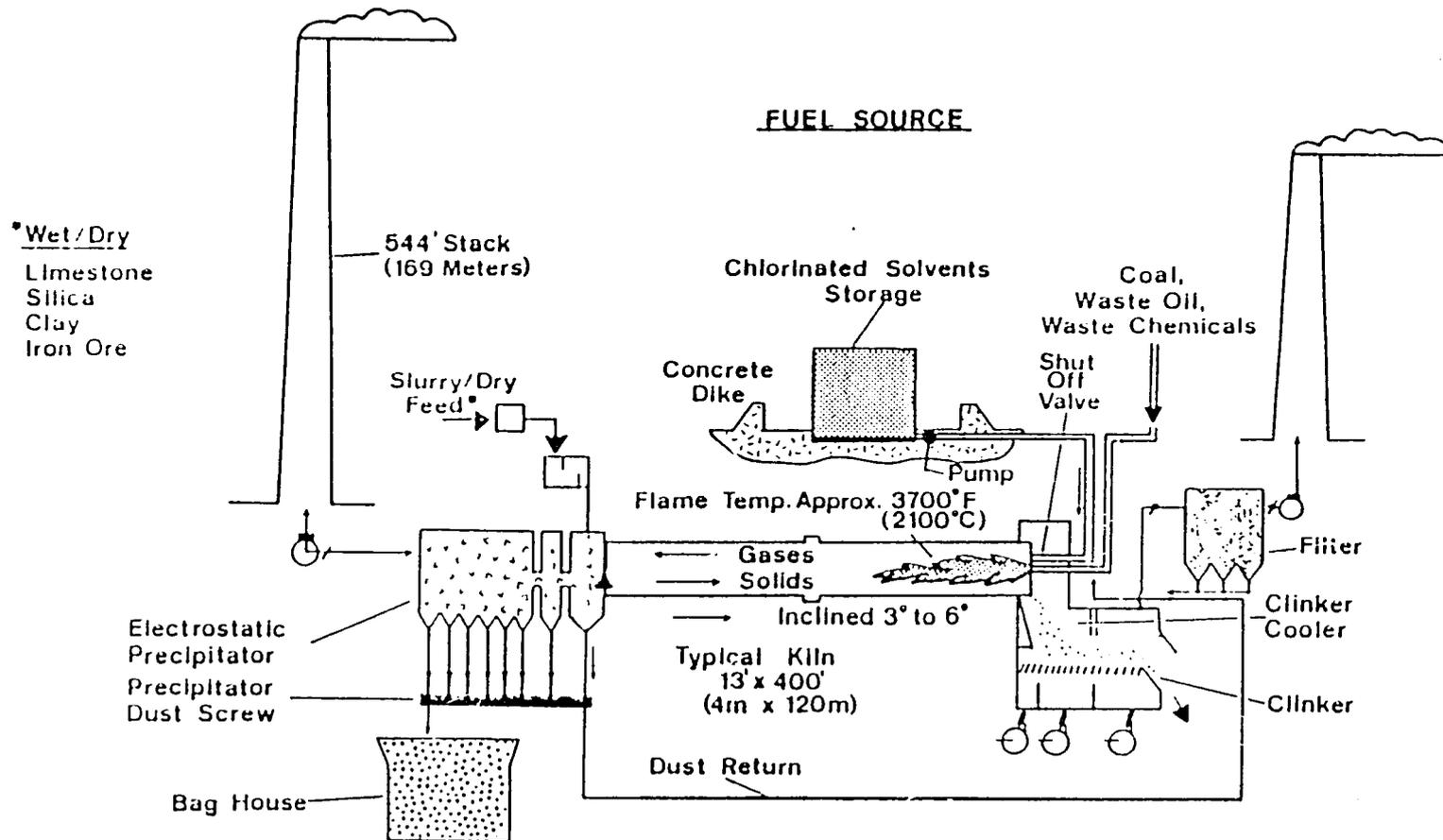


Figure 1. Schematic drawing of a typical cement kiln (Source: Lauber 1982. Reprinted by permission of the publisher.)

wet or dry mixture of raw materials enters the rotating cylinder at the upper (or back) end of the kiln and proceeds through zones of drying (only for the wet process), calcining, and clinkering until it reaches the lower (front) end of the kiln where it exits as clinker. Heat for the operation of the kiln is supplied by suspension firing of fuels through burners located at the lower end of the kiln. As indicated in the figure, the flow of the heated gases in the kiln is countercurrent to the flow of the solid raw materials. Gas residence times range from 3 to 8 seconds. Rotary kilns for cement-making range in size from 8 to 25 feet (2.4 to 7.6 m) in diameter and from 200 to 600 feet (60 to 183 m) in length, and are inclined at approximately 3 to 6 degrees.

Two features of the cement-making process are of special interest when coal and easily combustible solid wastes are used for fuel. First is the fact that much of the ash from combustion of these fuels becomes incorporated into the clinker. It is a standard practice in the cement industry to adjust the raw materials feed to account for incorporation of ash into the clinker (USDOE 1980). Second is the fact that the kiln itself acts somewhat as a scrubber for sulfur oxides, thus removing some potential pollutants from exhaust gases. This scrubbing effect is partially present in the calcining zone of the kiln where calcium carbonate is converted to calcium oxide (lime), which can react with the sulfur oxides to form calcium sulfite and sulfate. This scrubbing effect permits the kilns to use relatively high sulfur fuels (reportedly up to 4 percent) without exceeding air pollution codes (Ahling 1979).

The exhaust stream leaving the upper end of the kiln must undergo cleaning before discharge to the atmosphere. The most common types of air pollution control devices that are used to clean the exhaust are electrostatic precipitators (ESP), or baghouses, often preceded by a centrifugal separator. As much as 125 tons of particulates may be collected during the production of 1,000 tons of cement clinker. Most of these particulates (90 percent or more) are fine particles of cement or raw materials rather than particles of fly ash from the fuel. In some cases, the collected dusts are recycled through the kiln, but in other instances--for environmental and safety

162

reasons--the dusts are considered detrimental to the process and are therefore discarded as wastes.

Several U.S. and European cement manufacturers have begun modifying their plants to accommodate lower priced fuels and to incorporate energy-conserving process changes. In addition to shifting toward the use of the dry process, most of these modifications involve some separation of the three thermal processing phases carried out in a conventional rotary kiln. Such modifications include the use of preheaters (either suspension or grate type) and the use of so-called "precalciners" to carry out drying and calcination of the raw materials before the mixture enters the rotary kiln. The rationale for performing the three thermal processing stages in separate furnaces is that each furnace can be designed to optimize a specific function, and the rotary kiln can then be used for clinkering alone.

163

3. USE OF WASTES AS FUELS

3.1 Waste Fuel Systems

Many liquid hazardous wastes have heating values of 10,000 Btu/lb or more. Bouse and Kamas (1987) state "The annual estimated generation of all types of hazardous waste in the United States is 265 million short tons. Fifty-five percent of that total is estimated to be combustible. EPA data suggest that 26 million tons of hazardous waste fuel with a heating value 8500 Btu/ lb is available and that only 7 percent is presently committed to energy use."

Liquid organic wastes that are presently burned in cement kilns include:

- Spent halogenated and nonhalogenated solvents generated by a wide variety of manufacturing processes, including metalworking, degreasing, painting, and printing;
- Still bottoms from solvent recovery;
- Petroleum industry wastes;
- A number of used and off-specification organic chemicals; and
- Waste oils, consisting primarily of engine crankcase oils, but also including transmission fluids, hydraulic and compressor fluids and coolants.

Although cement kilns have the potential to incinerate all types of organic wastes, cement manufacturers have been interested to date only in burning high-Btu wastes. Due to a desire to avoid public opposition, these facilities have not burned "high-profile" hazardous wastes, such as polychlorinated biphenyls (PCBs), on an ongoing basis, despite the fact that test burns have demonstrated the ability of cement kilns to destroy these substances (Lauber 1987).

In order to properly burn complex chemical wastes in cement kilns, it is important to have technical data such as shown in Table 1. Instruments required to analyze waste fuel in an on-site laboratory include an atomic absorption spectrometer or emission

Table 1. Data pertinent to incineration of chemical wastes

Critical waste incineration parameters	Physical and chemical properties
Ultimate analysis	C, H, O, N, S, ash, and moisture
Metals	Ca, Na, K, Cu, V, Ni, Fe, Pb, Hg, Cr, Cd, As, etc.
Halogens	Chlorides, bromides, fluorides
Heating value	Btu/lb or cal/gram
Solids	Size, form, and quantity to be received
Liquids	Viscosity, specific gravity and impurities, H ₂ O
Gases	Density and impurities
Organic portion	Percent total organic carbon
Special characteristics	Corrosiveness, reactivity, flammability
Toxicity	TLV (Toxic Limit Value), carcinogenicity, aquatic toxicity, etc.

Sources: Lauber (1982).
Branscome et al. (1985).

165

annually were estimated at a little more than \$1 million (Henz 1986). Costs of permitting insurance, safety equipment, and public relations were additional.

On an experimental basis, selected solid wastes can be fed into a kiln together with primary fuel. For some solid wastes, a prekiln must be installed. The prekiln is set or programmed to suit the type of waste that is being destroyed. In some cases, combustion of the solid waste takes place in the prekiln, and in other cases only low-boiling substances from the solid waste are driven off in that kiln. There are two kinds of prekilns available, namely, rotary kilns and pyrolysis gasifiers (Ahling 1979; Weitzman 1983).

Despite the potential for burning solid hazardous wastes in cement kilns, any ongoing commercial burning of hazardous wastes in cement kilns has been limited, insofar as is known, to pumpable liquids containing minimal amounts of water. To accommodate solid wastes, major plant modifications would be required (USEPA 1986).

167

4. OPERATING EXPERIENCE AND TEST RESULTS

4.1 Introduction

A number of test burns have been conducted at cement facilities to determine the impact of burning organic hazardous wastes on emissions of many air pollutants, including organic constituents and products of incomplete combustion, lead and other metals, hydrogen chloride, particulates, and sulfur and nitrogen oxides.

Trial burns conducted at more than a dozen cement plants over the past 9 years in the United States, Canada, and Europe have demonstrated that these facilities have the capability to destroy greater than 99.99 percent of even the most difficult-to-incinerate organic substances (Beers 1987). Although exceptions to the 99.99 percent destruction and removal efficiency (DRE) were noted during some of the trial burns at two of these facilities, the majority of these tests demonstrated DREs approaching 99.999 percent. Those tests at which the 99.99 percent DRE were not obtained appear to have resulted from a failure to properly atomize wastes or other operating errors.

Small amounts of hazardous waste burned in an incinerator achieving a DRE of 99.99 percent may escape complete destruction and be emitted to the atmosphere. The resulting concentration of unburned waste in exhaust gases can range from 5 to 50 parts per billion (Fennelly 1986). These emission levels of unburned waste are below the New York State Department of Environmental Conservation's regulatory air emission standards for the classes of solvents and organic chemicals that cement facilities incinerate.

4.2 Operating History, With Highlights of Test Burns

Pyroprocessing of hazardous wastes in the cement kilns began in the 1970s in Canada, Europe, and the United States. An outline of this early experience is included in Table 2. Before 1980, waste fuel

Table 2. Operating history of cement kilns

Plant	Year	Process	APCD	Primary Fuel	Test Prog. Parameters					Fuel types tested
					PAH	POHCs	PICs	Cl	Metals	
St. Lawrence Cement Mississauga, Ontario	1974	Dry-Preheat	ESP	Fuel oil	x	-	-	-	-	Lubricating oil contaminated with metals
	1975-76	Wet	ESP	Fuel oil	x	x	-	x	x	Chlorinated aliphatics (ety. dichloride); chlorinated aromatics; PCBs
Peerless Cement Detroit, MI	1976	Wet	ESP	Coal	-	x	-	x	-	PCBs
Stora Vika Cement Sweden	1978	Wet	ESP	Coal	x	x	x	x	-	Chlorinated aliphatics; chlorinated aromatics; Chlorophenols and phenoxy acids; Freon 113
Norcem Cement Stemmenstad, Norway	1980-82	Wet	ESP	Fuel oil	x	x	-	x	x	Tar (alkanes, alkabenzenes, poly aromatics, hydrocarbons - PAH) PCBs (48% Cl)
Marquette Cement Oglesby, IL	1981	Dry	ESP	Coal	x	x	-	x	x	Chlorinated aliphatics, MEK, toluene
San Juan Cement Puerto Rico	1981-82	Wet	Baghouse	Fuel oil	x	x	x	x	x	Chlorinated aliphatics
Alpha Cement Cementon, NY	1982	Wet	ESP	Coal	x	-	-	x	x	Waste solvents (halogens = 590 ppm)
General Portland Los Robles, CA	1982	Dry	Baghouse	Coal	-	x	-	x	x	Aromatics and chlorinated aliphatics
General Portland Paulding, OH	1983	Wet	ESP	Coal	x	x	x	x	x	Chlorinated aliphatics, MEK, toluene
Lone Star Oglesby, IL	1983	Dry	ESP	Coal/Coke	x	x	x	x	x	Chlorinated aliphatics, MEK, toluene

169
Sources: Mournighan and Branscome (1988).
Branscome et al. (1985).
Viken and Waage (1983).

APCD: air pollution control device
ESP: electrostatic precipitator

was used at St. Lawrence Cement, Peerless Cement, and Stora Vika. The waste burned at all three locations included PCBs and other organics. Test data generally indicated acceptable performance in terms of kiln operations and emissions; however, since there was adverse public reaction to burning PCBs at St. Lawrence Cement and Peerless Cement, hazardous waste burning was discontinued at both locations (Berry et al. 1975; Bouse and Kamas 1987).

The 1980s have seen continued testing of waste fuels in cement kilns at several cement plants. Table 2 continues with the experience of the early 1980s. This section presents highlights of tests at each specific site, with pertinent comments on operating history and test results.

4.2.1 St. Lawrence Cement Company

From 1974-76 the St. Lawrence Cement Company, Mississauga, Ontario, burned waste chemicals in two separate kilns. The test in 1974 burned waste lubricating oils contaminated with lead and zinc in the company's dry process kiln with a 4-stage preheater. Test results indicated that these metals became incorporated into the clinker. Waste chlorinated hydrocarbons, consisting of approximately 45 percent PCBs, 12 percent aliphatics, and 33 percent chlorinated aromatics, were burned in 1975 in a wet process kiln.

Extensive tests were conducted during these trial burns of chlorinated organics. Stack tests performed during the trial burns indicated a destruction efficiency of at least 99.986 percent for the chlorinated hydrocarbons. PCBs were not found in the clinker. About 50 ppb of volatile low molecular weight compounds (carbon tetrachloride, chloroform, dichloromethane) were found in the emission samples. A mass balance carried out for chlorine indicated that essentially all the chlorine had reacted with the process solids. This demonstrated that acid gases such as HCl, which are generated by the pyrolysis and oxidation of chlorinated hydrocarbons, are effectively neutralized by process lime in the cement kiln (Mournighan and Branscome 1988; Hazelwood et al. 1982). This provides an

x

170

additional benefit. Some cement plants have a need to produce low alkali cement products. In such cases, the burning of chlorinated hydrocarbons directly results in the lowering of the alkalinity of the cement products.

During test burning of chlorinated wastes, the average replacement of primary fuel with waste fuel was about 12 percent, whereas the heating value of these wastes averaged about 10,000 Btu/lb. Fuel requirements for the kiln were reduced by about 65 percent of the actual energy content of the wastes burned (Hazelwood et al. 1982). It was demonstrated that chlorine can be added to a typical wet process kiln at rates of about 0.4 to 0.7 percent of clinker weight without disrupting kiln operations.

The burning of PCB waste at St. Lawrence was a technical success in that the wastes were destroyed to below analytical detection limits. For about 2 years, wastes with up to 10,000 ppm of PCBs, a most difficult compound to destroy, were burned completely without accident. Public opposition, including resentment, developed because they had not been informed. PCB operations were subsequently suspended after extensive public hearings.

4.2.2 Peerless Cement Company

In December 1976, a test burn of PCB wastes (a mixture of 40 percent archlor 1260 PCB with primary fuel) was conducted at the Peerless Cement Plant, Detroit, Michigan. The waste was pumped at a rate of up to 0.75 gal/min directly into the main coal flame of the kiln using an auxiliary burner. The burning zone of the kiln was at 2,650° F with a residence time of 10 seconds.

Stack emissions during PCB tests showed a DRE of 99.99 percent. However, when background stack tests were performed with no PCBs being injected into the kiln, some low-level PCB emissions were detected in the kiln emission stack. The paradox was that PCBs were detected in the plant's feed water used in the raw materials feed slurry.

Following these PCB waste destruction tests, considerable public opposition developed and hearings were held.

171

4.2.3 Stora Vika Cement Plant

Between February and July 1978, various chlorinated chemical wastes were burned at the Stora Vika Cement Plant, about 70 kilometers south of Stockholm, Sweden. Chlorinated aliphatics, PCBs, chlorophenols, and phenoxyacids were burned during these tests. Average chlorine content was 17 percent of waste fuel weight. Chlorine content in the wastes averaged 0.35 percent of clinker weight. There were no kiln operational problems so long as chlorine input was kept below 0.6 percent of clinker weight; at higher rates, alkali halogen rings began forming in the kiln. These problems disappeared when chlorine feed rates were reduced (Hazelwood et al. 1982). Destruction and removal of PCBs was 99.9999 percent.

Analyses were also conducted for dioxins and furans, but no detectable quantities were found. Dust emissions from the plant increased during the trial burns due primarily to an increase in potassium chloride concentrations in the kiln dust. Water was used to extract these chlorides from the dust before recycling.

4.2.4 Norcem Cement Plant

At the Norcem Cement Plant in Slemmestad, Norway, an energy-saving program using hazardous waste fuel was initiated in the early 1980s. By introducing 30 percent combustible hazardous waste, energy consumption of primary fuels was reduced from 1,000 to 700 kcal/kg of clinker (Viken and Waage 1983). A high temperature (above 1,400° C) in the combustion chamber was maintained for decomposition of stable materials such as PCBs and other polyaromatic hydrocarbons (PAH). DRE for PCBs was 99.9999 percent. Special efforts were made to detect dioxins and furans, but none were found. No organics were detected in the dust from the electro-filter or in the clinker. During the burning of these PAHs, instrumentation allowed detection of heavy organics in the stack emission at extremely low levels (e.g., PAH, ketones, alkanes at 14, 23, and 150 $\mu\text{g}/\text{Nm}^3$, respectively). The detected levels of these decomposition products did not vary greatly

172

from emissions under baseline conditions (i.e., without hazardous waste fuels).

4.2.5 Marquette Cement Company

During 1981, the Marquette Cement Plant, Oglesby, Illinois, burned chlorinated aliphatics, methyl ethyl ketone (MEK), and toluene as waste fuel in their dry process cement kiln. Test programs included POHC analysis, metal analysis, and THC analysis. DREs for various organics ranged from 99.94 to 99.999 percent. When lead contaminated waste oil was burned, reduction in lead emissions down to a level comparable with lead emissions from burning primary fuel (coal) only, was reported (Mournighan et al. 1985). Quantitative data was not included in the report available. The Marquette Cement Company is currently owned by Lone Star Industries.

4.2.6 San Juan Cement Company

During fall and winter of 1981 and 1982, the USEPA conducted several worst-case trial burns of highly chlorinated chemical wastes at the San Juan Cement Company in Puerto Rico.

The San Juan tests were conducted in a wet process cement kiln fired with bunker fuel (no. 6 oil) as the primary fuel. Eight test burns were conducted. Process temperature was 2,400° F. Gas residence time was 4 seconds. Chlorine content of some waste fuels was as high as 38 percent. The fuel mixture with the "most difficult to destroy" constituents included 1.4 percent methylene chloride, 4 percent chloroform, and 8 percent carbon tetrachloride.

One of the objectives of the program was to determine if polychlorinated dibenzodioxins (PCDD) and polychlorinated dibenzofurans (PCDF) were emitted as products of incomplete combustion while hazardous waste was being fired to the kiln.

113

The report of the San Juan tests states (Peters et al. 1984):

"CONCLUSIONS

Some of the results observed in this demonstration program were contradictory to results from other cement kiln incineration tests; e.g., lower DREs, no change in particulate emissions, and significant changes in SO_2 and NO_x emissions. The conclusions presented below apply only to this particular kiln and the results from this demonstration program.

1. The inability of this kiln to consistently achieve 99.99% DRE (a value which hazardous waste incinerators must demonstrate) of the POHCs is attributed to unatomized waste introduction to the kiln flame and the difficult incinerability of the POHCs. These compounds (CH_2Cl_2 , CHCl_3 , and CCl_4) are occasionally employed as fire retardants because of their ability to remove hydrogen atoms from the free-radical branching combustion reactions to form HCl. Combustion of chlorinated species containing less chlorine may have resulted in higher DREs.
2. Chlorinated dioxins and chlorinated dibenzofurans are not produced at detectable levels (1.6 ng/m^3) when a cement kiln firing chlorinated wastes is operating normally.
3. Cement kilns will absorb over 99% (about 99.7%) of the HCl formed during the combustion of chlorinated hazardous wastes. This absorption is partitioned between the clinker and baghouse dust.
4. At San Juan Cement Company, approximately 82% of the chlorine fed to the cement kiln appears in the clinker. This limits the chlorine content of the total fuel to less than 1%. This may vary at different cement plants because quarry alkalinity (ability to absorb chlorine) varies at each cement plant.

174

5. Achievable fuel savings are a function of the chlorine content of the waste and each plant's ability to absorb chlorine. At San Juan Cement Company, a hazardous waste containing less than 5% will result in at least a 20% savings in fuel costs. Higher fuel savings may be possible for higher chlorine contents at other plants.
6. Production of salable cement product is possible when burning chlorinated hazardous wastes provided the plant's chlorine absorbability limit is not exceeded.
7. Atomization of the waste fuel would be desirable, if a flame configuration can be obtained which does not alter the primary fuel flame configuration.
8. High feed line pressure [1,380 to 2,070 kPa (200 to 300 psig)] is not required for waste injection to the kiln. This pressure requirement may change depending on the type of atomizing nozzle used.
9. There is no significant change in particulate emissions due to burning chlorinated hazardous wastes. This result was observed on a cement kiln equipped with a fabric filter air pollution control system. A cement kiln with an electrostatic precipitator may not achieve similar results due to a change in dust resistivity.
10. Emissions of sulfur dioxide, total hydrocarbons, and hydrogen chloride increased significantly when waste was burned. A cement kiln with a higher alkalinity feed than that at the San Juan Cement Company may not have an increase in SO₂ emissions.
11. Emissions of nitrogen oxides decreased significantly when waste was burned.
12. There is no change in particulate ambient air quality due to hazardous waste combustion in cement kilns.
13. The solid waste (baghouse dust) generated by hazardous waste burning and its RCRA extract (leachate) are suitable for landfilling."

12

4.2.7 Alpha Cement Company

During summer 1981, the burning of waste solvents was begun in the wet process cement kilns at Alpha Cement Company, Cementon, New York. During tests, up to 15 gal/min of waste solvents containing up to 2 percent chlorinated organics were burned at this demonstration project. These waste fuels were fired at up to 25 percent replacement of primary fuels. Front-end kiln temperatures were 2,200^o F and above. Gas residence time was 5 seconds. In the tests, DREs of 99.99 percent were achieved for the POHCs. The demonstration project indicated about 58 percent lower SO₂ emissions than when the primary fuel (coal) was burned alone.

The firm planned to conduct additional worst-case trial burns involving various higher halogenated principal organic hazardous compounds in the near future.

4.2.8 General Portland Cement Company

The cement kiln at General Portland Cement Company, Paulding, Ohio, uses the wet process with coal as the primary fuel. Beginning in 1983, normal operation of this kiln included co-firing of waste solvents as supplemental fuel.

An EPA demonstration test at this plant in 1983 included 4 days of baseline testing and 5 days of testing during the waste burn. The POHCs in the waste fuel included methylene chloride, MEK, toluene, and Freon 113. The waste fuel was fired through a separate burner pipe inside the coal burner with air atomization of the solvents. Process temperature was in the range of 2,500^o F to 2,600^o F with a gas residence time of 4 seconds.

Test results indicated DREs of 99.99 percent for Freon 113 and >99.99 percent for trichloroethane. There was no statistically significant difference between average POHC emission rates for the baseline and waste fuel burn. This was also true for PICs.

Most of the chloride (about 95 percent) was removed with the dust. Less than 5 percent left with the clinker and stack gas. There

were emissions of Cd, Cu, Hg, Pb, and Se when waste fuel was burned.

Dibenzofurans and dibenzodioxins found in the stack gas were at a concentration level of less than 0.17 ppb.

4.2.9 Lone Star Industries

The first trial burn in this plant at Oglesby, Illinois, was conducted in 1981 when it was formerly owned by Marquette Cement Company. In 1983 there was a second demonstration project at this plant, now owned by Lone Star Industries. The test used paint solvents composed of chlorinated aliphatics, MEK, and toluene. The waste was spiked with Freon 113 and fired through a separate pipe under the coal burner with pressure atomization. DREs were in the range of 99.999 percent.

4.3 Test Results

Test results have shown that use of waste fuels does not affect cement quality. Other specific test results for each of the demonstration projects are discussed here collectively under various categories of emissions interest.

4.3.1 DREs for POHCs

Destruction and removal efficiency (DRE) is a simple efficiency calculation based on the amount of a compound emitted from the stack after thermal destruction and gas treatment in the control device compared to the quantity of that compound entering the kiln with the waste. Demonstration projects for study of hazardous waste disposal in incinerators and cement kilns use the EPA-developed VOST (volatile organic sample train) and Modified Method 5 (MM5) techniques to determine the concentration of principal organic hazardous constituents (POHCs) in stack gases.

The DRE results for some of the demonstration projects are summarized in Table 3. The reported DREs are >99.99 percent for wastes with mostly chlorinated organics, >99.989 percent for chlorinated aromatics, and >99.986 percent for PCB mixtures.

4.3.2 POHC Emission Rates

POHC emission rates are summarized in Table 4. The tests at Paulding, Lone Star, and Los Robles showed that the difference in POHC emissions between baseline burns and waste burns was not statistically significant. During the trial tests at Stora Vika, the only compounds detected in the stack gas were chloroform and Freon. In burns at Peerless Cement, there were low-level PCB emissions during both the baseline and PCB burn. PCB was detected in the plant's feed water used in the raw materials feed slurry, which accounts for PCBs in baseline emissions. At San Juan, lower DREs were attributable to unatomized waste introduction to the kiln. Also, the most difficult-to-burn compounds were chosen as POHCs (i.e., CH_2Cl_2 , CHCl_3 , CCl_4).

4.3.3 PICs (Products of Incomplete Combustion)

The burning of complex mixtures of organic compounds yields emissions of compounds other than POHCs. Several tests at kilns have attempted to quantify concentrations of both volatile (boiling point $<100^\circ\text{C}$) and semivolatile organic compounds that are emitted under baseline and waste fuel conditions.

Table 5 lists the types of compounds that appeared as PICs in the tests. The results show that when hazardous wastes were burned, there generally were minor increases in PICs compared to baseline conditions. The results for baseline burns (i.e., no hazardous waste) indicate that many of the POHCs are by-products of coal combustion. Trace quantities of PICs were found at San Juan during kiln upset

Table 3. Summary of DREs

Plant	Waste Compound	Destruction and Removal Efficiency (DRE)
St. Lawrence Cement Mississauga, Ontario	Chlorinated aliphatics	> 99.99
	Chlorinated aromatics	> 99.989
	PCBs	> 99.986
Peerless Cement Detroit, MI	PCBs	99.9981-99.9986
Stora Vika Sweden	Methylene chloride	> 99.995
	Trichloroethylene	> 99.9998
	All chlorinated hydrocarbons	> 99.988
	PCBs	> 99.99998
	Chlorinated phenols	> 99.99999
	Phenoxy acids	> 99.99998
	Freon 113	> 99.99986
San Juan Cement Puerto Rico	Methylene chloride	93.292-99.997
	Trichloromethane	92.171-99.96
	Carbon tetrachloride	91.043-99.996
General Portland Los Robles, CA	Methylene Chloride	> 99.99
	1,1,1-Trichloroethene	> 99.99
	1,3,5-Trimethylbenzene	> 99.95
	Xylene	> 99.99
General Portland Paulding, OH	Methylene chloride	99.956-99.998
	Freon 113	> 99.999
	Methyl ethyl ketone	99.978-99.997
	1,1,1-Trichloroethene	99.991-99.999
	Toluene	99.940-99.988
Marquette Cement Oglesby, IL	Methylene chloride	99.94-99.99
	Freon 113	99.999
	Methyl ethyl ketone	99.997-99.999
	1,1,1-Trichloroethene	> 99.999
	Toluene	99.986-99.998
Lone Star Oglesby, IL	Styrene	> 99.999
	Ethylbenzene	> 99.999
	O-Xylene	> 99.999
	Benzaldehyde	> 99.998
Norcem Cement Norway	PCBs	> 99.9999

Sources: Branscome et al. (1985).

Mournighan and Branscome (1988).

179

Table 4. Summary of POHC emission rates

Test Location	POHCs	Baseline emissions (mg/s)	Waste burn emission (mg/s)
San Juan	Methylene chloride	1.4	94
	Chloroform	11.0	94
	Carbon tetrachloride	71.0	191
Paulding	Methylene chloride	0.6	1.1
	Freon 113	<0.02	<0.025
	1,1,1-Trichloroethane	0.04	0.149
	Methyl ethyl ketone	0.77	0.54
	Toluene	4.7	4.70
Stora Vika	Methylene chloride	*	<7.3
	Trichloroethylene	*	<0.3
	Chloroform	*	10.0
	PCBs	*	<0.04
	Chlorophenols	*	<0.025
	Phenoxy acids	*	<0.05
	Freon 113	*	0.03
Peerless	PCBs	0.1-0.75	0.13 - 0.55
Los Robles	Methylene chloride	<0.1 - 0.43	<0.003
	1,1,1-Trichloroethane	0.13- 0.34	0.005
	1,3,5-Trimethyl benzene	<0.1 - <7.5	<0.42
	Xylene	<0.1 - <3.1	<0.21
	Benzene	35 - 54	75.00
Lone Star	Methylene chloride	4.8	0.9
	Freon 113	0.43	0.075
	1,1,1-Trichloroethane	<0.025	<0.014
	Methyl ethyl ketone	0.17	0.14
	Toluene	1.5	0.98

* None of the target compounds except chloroform was found during the baseline test.

Sources: Branscome et al. (1985).

Mournighan and Branscome (1988).

Table 5. Products of incomplete combustion (PIC)

Tests	Baseline combustion	Waste combustion
San Juan, Puerto Rico	--	Benzaldehyde Phenol Alkylbenzene Benzoic acid Naphthene isomers Anthracene Polychlorinated dibenzofurans (Cl: 5,6,7 isomers)*
Los Robles, CA	Benzene Toluene Methylene chloride Trichlorethene	--
General Portland, Paulding, OH **	Methyl ethyl ketone Toluene Benzene Biphenyl Naphthalene	Methyl ethyl ketone Toluene Benzene Biphenyl Naphthalene
Lone Star, Oglesby, IL	Toluene Benzene Biphenyl * Naphthalene	Biphenyl Naphthalene
Stora Vika, Sweden	---	Chloroform*

Sources: Branscome et al. (1985).
Viken and Waage (1983).

*Trace quantities

**No increase due to waste fuel combustion

181

conditions, and trace quantities may have been present when chlorophenols and phenoxy-acids were burned at Stora Vika. However, tests at two other kilns (Oglesby and Paulding) and most of the analyses at San Juan and Stora Vika revealed no detectable quantities of PICs as determined by MM5 and VOST (Branscome et al. 1985; Mournighan and Branscome 1988).

4.3.4 Particulate Emissions

Emissions of particulates from cement and lightweight aggregate kilns may increase slightly when waste fuels are burned. This occurs because the presence of chlorine in the waste feed changes the resistivity of dust particles, which in turn reduces the effectiveness of electrostatic precipitators in capturing particles in exhaust gases. However, by making certain operating adjustments, facilities utilizing electrostatic precipitators have demonstrated the ability to meet regulatory standards for particulate emissions (Mournighan et al. 1985).

The effect of waste combustion on particulate emissions has been of interest because the earlier cement kiln tests (St. Lawrence and Stora Vika) indicated that burning chlorinated wastes increased emissions of particulates. Subsequent tests indicate that the burning of hazardous wastes does not affect the emission of particulates from facilities that utilize a baghouse filter or scrubber system to trap dust particles. A summary of particulate emissions in some of the tests is presented in Table 6. Average particulate emissions during waste burns, about 0.65 lb/ton of product in most of the later tests, were lower than during baseline burns (0.87 lb/ton of product).

4.3.5 Fate of Chlorine

Emissions of hydrogen chloride (HCl), a highly acidic compound, often present problems for commercial incinerators burning chlorinated organic wastes. However, HCl emissions from cement kilns are minimal.

122

Table 6. Emissions of particulate matter

Site	Test condition	Particulate matter			Cl (kg/mg clinker) into kiln
		gr/SCF	lb/h	lb/t	
St. Lawrence	Chlorinated aliphatics	0.21	123 ^a	3 ^a	4.0
	Chlorinated aromatics	0.086	45	1.1	5.5
	PCBs	0.078	44	1.1	2.5
	Baseline	0.038	21	0.5	-
	Lubricating oil	0.064	33	0.7	-
	Baseline	0.107	139	1.1	-
Marquette	Waste solvents	0.104	58	<1	1.1
	Baseline	0.093	50	<0.3	-
Alpha Cement	Solvents	0.041	44	0.8	-
	Baseline	0.050	53	1.1	-
San Juan	Wastes	0.043	22.4	0.66	5.5
	Baseline	0.041	21.7	0.64	-
Paulding	Wastes	0.030	18.9	0.65	2.2
	Baseline	0.030	19.6	0.64	0.2
Lone Star	Wastes	^b	^b	^b	1.2
	Baseline	0.17	116	2.0	0.2
Stora Vika	Aliphatics	0.039	21	0.33	4.4
	Baseline	0.009	4.7	0.21	0
	PCBs	0.024	12.7	0.53	3.6
	Baseline	0.011	5.9	0.25	0
	Chlorophenols and phenoxyacids	0.058	30.9	1.36	0.95
	Baseline	0.014	7.7	0.34	0
	Freon 113	0.062	33.3	1.39	1.7
	Baseline	0.022	11.7	0.49	0

Sources: Mournighan and Branscome (1988).
Branscome et al. (1985).

^a Ring formation and ESP difficulties

^b ESP malfunctioned

Because conditions within the cement kiln are highly caustic, virtually all of the chlorine entering the kiln is neutralized by alkalis to form calcium chloride, sodium chloride, and potassium chloride, substances which are not acidic. The Paulding test report indicated that most of the chloride was removed with the waste dust. Less than 5 percent was emitted with the clinker and stack gas.

Data in Table 7 show that during some waste burns there were increases in chloride emissions compared to baseline conditions, and in other cases there were decreases.

4.3.6 NO_x and SO₂ Emissions

Unlike coal, which typically contains significant amounts of sulfur, hazardous wastes usually contain little or no sulfur. Therefore, the use of hazardous waste as a supplemental fuel in cement manufacture provides the indirect benefit of reducing emissions of sulfur dioxide from the kiln (Branscome et al. 1985). Nitrogen oxide emissions generally are not affected by the burning of waste fuels.

NO_x and SO₂ emission results are summarized in Tables 8 and 9, respectively. Tests at Lone Star and Paulding showed higher NO_x concentrations during the waste burns. This was probably due to the higher O₂ input (Branscome et al. 1985).

SO₂ test emission results show that substitution of the sulfur-containing primary fuel with a low sulfur waste fuel decreased SO₂ emission in the tests at Alpha Cement, Marquette Cement, and General Portland at Paulding. The San Juan test showed an increase in SO₂ emissions when waste fuel was burned. The increase was attributed to a lower O₂ input (as evidenced by low NO_x emissions) and competitive acid gas scrubbing from HCl in a relatively low alkaline kiln when burning the highly chlorinated wastes (Mournighan and Branscome 1983).

Table 7. HCl emissions

Site	Test condition ^a	HCl		Notes
		(lb/h)	(lb/t)	
Alpha Cement	W	5.3	0.11	Organic halogens in fuel = 590 ppm
	B	2.4	0.05	
Marquette	W	115	1.9	Avg. 1.1 kgCl/mg clinker for waste burn; waste avg. = 4.5% Cl
	B	190	3.2	
San Juan	W	0.79	0.02	Avg. 5.5 kgCl/mg clinker for waste burn; waste avg. = 6.5 - 35.1% Cl
	B	<0.19	<0.06	
Los Robles	W	1.03	0.015	Waste = 2% Cl; avg. 1.1 kgCl/mg clinker
	B	0.55	0.007	
Paulding	W	4.62	0.16	Avg. 2.2 kgCl/mg clinker; waste avg. = 2% Cl
	B	1.25	0.04	
Lone Star	W	25.3	0.46	Avg. 1.2 kgCl/mg clinker; waste avg. = 1.9% Cl
	B	2.9	0.054	
St. Lawrence	W	<1	<0.02	6.8 kgCl/mg clinker, max. 0.7 kgCl/mg clinker for baseline
	B	<1	<0.02	

Source: Mournighan and Branscome (1988).

^aW = waste burn
B = baseline

105

Table 8. Summary of NO_x emissions

Site	Test condition ^a	NO _x		
		(lb/h)	(lb/t)	(ppm)
Marquette	W	275	4.6	544
	B	404	6.7	920
San Juan	W	31.3	0.9	68
	B	60.4	1.8	136
Los Robles	W	304	5.3	486
	B	444	8.2	680
Paulding	W	174	6.0	478
	B	140	4.6	371
Lone Star	W	472	8.6	814
	B	371	6.9	520

Source: Branscome et al. (1985).

^aW = waste burn
B = baseline

106

Table 9. Summary of SO₂ emissions

Site	Test condition ^a	SO ₂			
		(lb/h)	(lb/t)	(ppm)	
Alpha Cement	W	58.5	1.1	33	S in coal = 2.6%; S in waste = 0.2% S during waste burn = 2.0%
	B	138	2.7	78	
Marquette	W	11.5	0.19	18	S in waste = 0.08% S in coal = ?
	B	57.1	0.95	93	
San Juan	W	264	8	450	S in fuel oil = 2.15%
	B	170	5	279	
Los Robles	W	21.7	0.36	27	S in coal = 0.43%
	B	23.7	0.38	27	
Paulding	W	207	6.8	265	S in coal = 4.3%
	B	526	17.2	636	
Lone Star	W	14.7	.12	19	S in coal/coke = 2.7%
	B	5.6	.10	7	

Sources: Mournighan and Branscome (1988).
Branscome et al. (1985).

^aW = wasteburn
B = baseline

127

4.3.7 THCs and CO Emissions

Test results for THCs and CO are summarized in Table 10. THCs increased during waste fuel combustion at three test locations (San Juan, Paulding, and Lone Star), decreased at one test location (Marquette), and remained the same at another (Stora Vika).

The results of CO emissions indicate that combustion of waste fuels does not significantly affect CO concentrations.

4.3.8 Metals

Because waste oils and many hazardous wastes typically contain metallic constituents, most notably lead, concerns have been raised over emission of metals in cement kiln exhaust gases. The data on metal emissions from hazardous waste incinerators are less well developed than the data characterizing destruction and removal efficiencies for organic substances (Oppelt 1987). However, evidence published to date indicates that the burning of waste fuel in cement and lightweight aggregate kilns results either in no increase or in only a slight increase in air emissions of lead and other metals (Higgins and Helmstetter 1982). Studies have shown that greater than 99 percent of the lead contained in waste fuels is either incorporated in an inert form in the clinker product or is adsorbed onto kiln dust particles that are removed by air pollution control devices (Branscome et al. 1984). For comparison, a recent survey of trial burns in which wastes containing lead incinerated in cement kilns concluded that lead emissions from six of the seven facilities tested were less than lead emissions from several automobiles burning leaded gasoline (Mournighan et al. 1985).

4.3.9 Dioxins and Furans

Two types of highly toxic PICs, dioxins (TCDDs) and furans (TCDFs), have received special attention because they have been

181

Table 10. Summary of THC and CO concentrations

Site	Test condition	THC (ppm) ^a	CO (ppm)
Marquette	Waste burn	470 ^b	-
	Baseline	1,250 ^b	
San Juan	Waste burn	12.7	24-738 ^c
	Baseline	8.3	25-349 ^c
Los Robles	Waste burn	d	25-100
	Baseline	4	10-618
Paulding	Waste burn	21	190
	Baseline	10	212
Lone Star	Waste burn	5	24-49 ^c
	Baseline	2.5	35-40 ^c
Stora Vika	Chlorinated aliphatics	<10	300-1500
	Baseline	<10	1500
	PCBs	<10	100-1500
	Baseline	<10	100
	Chlorophenols/ phenoxyacids	10	50-500
Baseline	10	50	
Freon	Baseline	<10	100-500
	Baseline	<10	100

Source: Branscome et al. (1985).

^a Expressed as ppm methane unless otherwise noted

^b Total nonmethane hydrocarbons

^c Range of test averages

^d Not measured

identified in air emissions from a number of solid waste incinerators. However, a survey of test results from trial burns conducted at cement kilns and other industrial hazardous waste incinerators indicates that emissions of dioxins and furans from these facilities are not significant (Oppelt 1987). The dioxin isomer of greatest concern (2,3,7,8-TCDD) has not been detected in emissions from any of seventeen hazardous waste incinerators where tests for these substances have been conducted. Although other isomers of dioxins and furans have been identified in stack gases at several of these facilities (including during a trial burn conducted in 1985 at the Lehigh Cement facility in Cementon, New York), emissions from hazardous waste incinerators appear to be approximately 3 orders of magnitude less than those reported for municipal incinerators (Oppelt 1987).

5. ECONOMICS OF WASTE FUEL USE

This section examines the economic feasibility of burning hazardous wastes in cement kilns. From the viewpoint of a cement plant manager, there must be a reasonable assurance of increased profit or reduced cost to the plant before expenses for burning wastes can be incurred. One U.S. cement plant with 1.5 million ton/yr cement capacity anticipates an annual net savings of \$3 million by providing 35 percent of its energy requirements with liquid chemical wastes (Beers 1987).

A report by Hazelwood et al. (1982) indicates that burning hazardous liquid wastes in cement kilns generally can be economically attractive (i.e., for the waste generator, cement kiln disposal costs less than commercial incinerator disposal; and for the cement plant manager, net energy costs are reduced substantially). Bouse and Kamas (1987), Mournighan and Branscome (1988), Ahling (1979), Viken and Waage (1983), and Henz (1986) have confirmed this economic attractiveness.

5.1 General Economic Factors

Energy costs in the cement industry normally amount to 33 to 40 percent of total cement production costs, and in some cases may be as high as 65 percent (Bouse and Kamas 1987). Organic wastes burned in cement kilns can reduce fuel cost substantially and thus affect the economics of waste disposal. The amount of waste fuel that may be used at a particular plant depends primarily on the characteristics of the waste and the ability of the plant to store and pump wastes in the required quantities.

Fees charged for waste disposal at cement kilns vary with heating value, toxicity, water content, chloride content, sediment content, metals and solids content, and waste sampling and analysis required. Fees vary widely from region to region depending on the availability and continuity of waste supply.

Capital costs for plant modifications (i.e., for storage, handling, fuel injection, and laboratory equipment) are required to burn waste fuels, but no additional capital costs for control of particulate emissions are necessary at a cement plant. Electrostatic precipitators and fabric filters are already an essential part of the engineering design in modern cement plants. However, some increased operating and maintenance costs may be necessary in order to accommodate waste fuels. Compliance testing will also increase costs.

Waste characteristics are necessary concerns in the design and construction of waste transport and handling system. For example, if sludge accompanying a waste to be burned must be disposed of separately, some added capital and operating cost must be anticipated.

Additional insurance coverage in the form of environmental impairment liability is a cost factor in assessing the economics of cement kilns for waste disposal.

One set of factors that influences costs and fees has to do with the responsibility for laboratory analyses of primary fuels and waste fuels. In the case of primary fuel, the fuel supplier is responsible for laboratory analysis of the product that he sells to the cement kiln, and the fuel costs include necessary analytical costs. In the case of hazardous waste fuel, the burden of laboratory costs may fall on the cement kiln unless by some contractual arrangements these costs are to be assumed by the waste generator. Whoever is responsible for the quality of the waste (user or generator) must assume the analytical cost, which for most complex wastes is considerable. In addition, the cost of flue gas sampling and analysis for complex POHCs and PICs would be the responsibility of the cement kiln. These analyses are far beyond the scope and cost for normal environmental regulations of cement kilns. In some cases, proper sampling equipment may well cost \$100,000 or more. Continuous emission monitors might also be required, depending on applicable regulations. At about \$20,000 to \$50,000 for each parameter measured, users of supplemental waste fuels might not wish to accept the risk of assuming constant waste quality either from the standpoint of their own cement quality or from an environmental regulatory position. The cost of establishing a field laboratory for burning of some waste might be in

the range of \$500,000 to \$700,000 with annual operating costs in the range of \$100,000 to \$150,000 (pers. com. Malcolm Wilson, November 1983).

The continuity of waste fuel supply in the future may be affected by the impact of gradual reduction in the quantities of certain hazardous wastes (e.g., PCBs) whose manufacture, at least in the United States, has been terminated.

5.2 Economic Data for Model Plant A

Hazelwood et al. (1982) and Branscome et al. (1985) have developed a cost model for hazardous waste disposal in a hypothetical cement plant. This model demonstrates the relationship between costs, disposal fees, and return on investment. The features of the model are as follows:

- The small wet process kiln has an annual capacity of 230,000 tons;
- Waste fuels are delivered by truck;
- Coal is the primary fuel;
- Air and water pollution control systems--ESP, exhaust air, and waste-water treatment are available with excess capacity;
- Adequate space for siting of any needed facilities is available.

Table 11 presents cost estimates for the additional installed equipment and operating expenses necessary for hazardous waste disposal in the kiln.

Annualized cost is composed of fixed cost, including loan repayment over 5 years, interest, labor, utility, maintenance, and insurance costs related to waste burning. As shown in the table, annualized capital and operating costs are estimated to total approximately \$43,200. On a production basis, this would be equivalent to 19 cents/ton of clinker produced (for the one 230,000 tons/yr kiln utilized). Considering production cost of cement (about

Table 11. Cost estimates for waste disposal in a model cement kiln

Cost Elements	Estimated Cost
Capital Cost (Cost of Installed & Operating Equipment) *	
Area preparation (cleaning, leveling, trenching, tamping, etc.)	\$ 2,000
Concrete slabs (2)	3,200
Fuel tank	750
Steel industrial waste tank (25,000 gallons capacity)	12,000
Tank diking	1,600
Truck unloading connections	500
Waste tank float level (with high and low alarm)	3,000
Piping and small fuel oil transfer pump	900
Piping and waste feed pump	3,000
Grounding	500
Flame arrestors	200
Carbon dioxide fire protection system	2,200
Electrical equipment for	2,500
Normal fuel flow interruption	
Normal make-up air interruption sensor	
Transducers	
Pump starter shut off control	1,200
Waste flow meter and instrumentation	2,500
Miscellaneous, hardware (coding, painting, etc.)	450
Nozzle assembly	8,000
Engineering and Installation	1,200
Portable fire extinguishers (large)	2,100
Personal protective equipment	
Self-contained breathing apparatus (2)	
Goggles	
Gloves	
Boots	
Organic respirators	
Dust respirators	
Portable hydrocarbon detector/direct reading detector tubes	1,500
Total cost of installed and operating equipment	49,300
Annual Operating Cost *	
Labor: 330 days/yr. at 4 hrs/day at \$ 8.00/hr	\$ 10,600
Utilities: Electricity	3,000
Maintenance costs (5% of investment)	2,200
Total annual operating cost	15,800
Annualized capital cost with 5 years payback (\$ 49,300) @ 13%	\$ 12,400
Insurance cost	15,000
Total annual cost *	\$ 43,200
Cost per ton of cement produced: \$ 43,200 per year/230,500 tons per year	\$ 0.188/ton

Sources: Hazelwood et al. (1982).
Branscome et al. (1985).

*All cost estimates are at 1982 constant prices.

190

\$45/ton), this is an insignificant outlay. Nevertheless, to obtain a 15 percent return on this additional investment for construction and operation of the waste-handling system would require a total income from the operation of at least \$49,700 a year. Two cost scenarios are presented here to illustrate the positive net savings due to substitution of waste fuel for primary fuel.

The following data are common to both the cost scenarios:

- Kiln production--230,000 tons/yr;
- Unit fuel cost for primary fuel--\$2.46/million Btu;
- Chlorine limit--0.5 percent of kiln production, or 1,440 tons/yr;
- Heat value of waste--10,000 Btu/lb;
- Existing kiln monitoring systems and on-site laboratory facilities are adequate, so no additional investment is required for this purpose;
- Annual return of capital + 15 percent profit = about \$50,000/yr.

EPA has used these data in calculating revenues resulting from two levels of waste fuel use (two scenarios) and three levels of waste fuel cost (Hazelwood et al. 1982). The net savings estimated for the two scenarios are presented here.

5.2.1 Cost Scenario I

In the first cost scenario, it is assumed that a waste containing 20 percent by weight of chlorinated hydrocarbons is available and that 80 percent of the waste's heating value can be recovered.

The maximum amount of chlorinated waste that can be used, assuming a chlorine limit of 0.5 percent of clinker weight, is 1,440 tons/yr, divided by 20 percent, the $\frac{1}{5}$ of each mixed fuel which is chlorinated hydrocarbons (i.e., 7,200 tons of waste per year). The recovered heating value of the waste fuel used will total 1.15×10^{11} Btu. This is equivalent to 7.9 percent fuel substitution.

If the waste is delivered at no cost to the cement plant (i.e., disposal fee = 0), total savings will be \$283,000 per year. Net savings, subtracting investment costs plus a 15 percent return on investment, would be \$233,000 per year or 97 cents per ton of cement produced.

If the cement plant purchased the waste for \$1 per million Btu of waste, net savings would be 49 cents per ton of cement produced.

If the cement plant charged a disposal fee equivalent to \$1 per million Btu of waste fuel heating value (\$32/ton of waste), net savings would be equivalent to \$1.45 per ton of cement produced.

5.2.2 Cost Scenario II

In the second cost scenario, it is assumed that a waste containing 10 percent by weight of chlorinated hydrocarbons is available and that 90 percent of the waste's heating value can be recovered.

The maximum amount of waste that can be used is 14,400 tons/yr. The recovered heating value of this quantity of waste is about 2.59×10^{11} Btu or 17.8 percent of the kiln's fuel requirement.

Net savings per ton of cement produced will be:

- \$2.45 if the waste is delivered to the cement plant at no cost;
- \$1.37 if \$1 is paid per million Btu of waste fuel by the cement plant; and
- \$3.53 if \$1 is charged per million Btu of waste fuel by the cement plant.

5.3 Economic Data for Model Plant B

The economic data in these models are rough estimates with only partial information and should only be taken as guidelines for

economic analysis. The costs of equipment and facilities at any specific plant may vary considerably.

In the model, costs for sampling and analysis of wastes and emissions were not included. In a routine ongoing waste disposal operation, these sampling and analysis costs are relatively small. However, during a trial burn to establish satisfactory plant operating conditions for hazardous waste disposal, these sampling and analysis costs could be significant.

USEPA (1985b) has developed a cost model for another plant about double the size of Plant A, with higher required investment costs to burn hazardous wastes and with higher waste fuel substitution rates. The features of this model are:

- The medium-size wet process kiln has an annual capacity of 500,000 tons;
- 50 percent fuel substitution is assumed;
- Waste fuel feed rate is 1,900 gal/hr with a heat value of 10,000 Btu/lb;
- Waste fuel costs \$4 per MBtu; plant uses 2,500,000 MBtu/yr so waste fuel costs \$10 million/yr.

A. Capital costs for plant modification (1985 dollars)

Four 25,000-gal storage and blending tanks	\$ 240,000
One 150,000-gal working tank	150,000
Pumps, motor, and auxiliary equipment and instrumentation	180,000
Containment system, sumps, and paved areas	70,000
Laboratory building	100,000
Laboratory equipment and safety equipment	120,000
Fuel delivery system	50,000
Contingencies, 20%	<u>180,000</u>
	\$1,090,000

B. Annualized costs for plant modification
plus operations and maintenance

Materials and supplies	\$ 30,000
Maintenance	20,000
Operating labor and overhead	160,000
Capital recovery (@ 15% interest, 10-year life)	<u>220,000</u>
	\$ 430,000

In Model B, significant additional costs have been estimated as follows:

	<u>Annual cost first year</u>	<u>Annual cost in subsequent years</u>
Permits	\$ 250,000	\$ 40,000
Public education	100,000	10,000
Extraordinary measures (not defined)	350,000	100,000
	<u>\$ 700,000</u>	<u>\$ 150,000</u>

First year total costs = \$430,000 + \$700,000 = \$1,130,000

Subsequent year annual costs = \$150,000 + \$430,000 = \$580,000

A \$2.5 million/yr net fuel savings is reported for the 50 percent fuel substitution case. These savings in relation to costs clearly indicate attractive economies.

It is, however, important to establish the economics of waste disposal on a case-by-case basis for each individual cement kiln since many economic factors differ substantially from kiln to kiln.

1978

6. RISK ASSESSMENT

There are risks in any method of hazardous waste disposal. This section attempts to put the risks of cement kiln disposal in perspective.

The USEPA has conducted a risk assessment of the potential health effects of toxic organic and metals emissions based on trial burns conducted at nine hazardous waste incineration facilities. This risk assessment conservatively estimated that the increased cancer risk for an individual exposed to incinerator emissions over a 70-year period ranges from 1 in 100,000 to 1 in 1 million. Because this is a worst-case estimate, it likely overstates the actual risk of cancer resulting from emissions from hazardous waste incinerators. Although EPA's risk estimate was based on data from a relatively small number of facilities, other available risk assessments corroborate EPA's assertion that emissions from properly operated hazardous waste incinerators do not pose a significant threat to public health or the environment (Oppelt 1987).

Interestingly, the 99.99 percent destruction and removal requirement, which has generally been used for permitting hazardous waste disposal in cement kilns and incinerators, is not based on any risk assessment of the environmental hazards associated with emissions from a facility meeting this standard. Rather, the 99.99 percent DRE target was developed by EPA as an achievable standard based on the results of approximately 50 trial burns conducted during the 1970s. Some authors have argued that the 99.99 percent DRE standard is a highly conservative requirement, as existing air emission standards for many organic chemicals from industrial process sources are 10 to 100 times less stringent than this requirement (Beers 1987).

The remainder of this section provides details on risks of transportation, storage, handling, kiln emissions, and other risks.

6.1 Transportation Risks

Any waste that must be disposed of at a site other than its point of generation will require transport to the disposal site and will, during its transport, create a risk of spillage and/or fire. Such risks are not unique to a given method of off-site disposal and will be incurred whether the waste is to be disposed of by incineration, landfilling, or destruction in a cement kiln.

Wastes supplied to cement plants for disposal are likely to be transported by tank trucks over public highways or by rail. In the United States, compliance with federal or state environmental regulations serves to mitigate risks involved in transporting hazardous wastes. In addition, plants utilizing waste fuels should exercise managerial procedures that further reduce risks to the public. These procedures include selection of a reputable licensed waste hauler, identification of most favorable transport routing, and insistence on, and drill in, emergency contingency plans (Bouse and Kamas 1987).

In some cases, transporting of waste fuels from the source to the cement plant is the responsibility of the waste supplier; in other cases, it is the responsibility of the cement plant. In either situation, both parties are likely to share the responsibility for safe transport. Therefore, the cement manufacturer must be actively involved in selection of the fuel transporter and fuel transport methods. It is also likely that cement plants, when contracting for delivery of waste fuels, will assign the responsibility for safe transport to the waste supplier. Transportation risks will normally be the responsibility primarily of the waste hauler and secondarily of the waste generator. In the United States, the "cradle to grave" manifest system inherently formalizes this responsibility.

In planning for delivery of wastes, care should be taken to route shipment to minimize potential public exposure to hazards from transportation accidents. This will involve identification of alternative routes, assessment of roadway conditions, and analysis of population exposures along alternative routes. A principal concern in evaluating transport routes is likely to be the population along

200

proposed routes. Environmental impact assessment of transportation should incorporate risk factors involved in accidental spills.

Assuming an average waste fuel heating value of 10,000 Btu/lb or 90,000 Btu/gal, and a typical tank truck capacity of about 45,000 pounds or 5,000 gallons, it is possible to calculate the number of shipments required for various levels of waste fuel utilization at a cement plant. The number of shipments can be used to estimate total ton-miles of transport required. Probability of accidental spills in any given year can be estimated by the means of the Poisson distribution, which governs infrequent random occurrences as follows:

$$P_n = \frac{e^{-x} x^n}{n!}$$

where x = no. of accidents/yr of this type country-wide from trucking industry records or insurance company statistics;

n = no. of truckspill accidents expected over lifetime of the specific cement facility;

P_n = probability of an accidental spill during transport for that cement facility in any one year.

Based on historical accident rates, probability of a transportation accident resulting in a spill exceeding a certain level of damage can be estimated (Menzie 1979).

Risk is a function of probability and consequences of an unfavorable event. Consequences of the event must be calculated for specific types and locations of such events after functional analysis of a proposed operation.

6.2 Storage and Handling Risks

Storage and handling of waste fuels at cement plants entail risks similar to those encountered by many industries that use or generate flammable or toxic materials. Techniques commonly employed to

mitigate such risks are well developed and can be applied with minimal modification. Storage and handling requirements will differ according to characteristics of the waste being used. Variables to be considered in selecting appropriate equipment and handling methods include the waste's toxicity, flammability, corrosivity, reactivity, vapor pressure, viscosity, and solids content.

Principal concerns in storage and handling of fuels are the risks posed by spills and fires. A spill of waste fuel can result in the contamination of soil, groundwater or surface water, and release of hazardous vapors. Additional risks associated with waste fuel fires are those of property damage, personal injury, and gross contamination of air with combustion products.

Off-loading of tank trucks must be conducted in a way that minimizes vapor releases into the air. Closed transfer lines should be used between tank vents.

Through use of well-designed systems and procedures, probability and severity of accidental spills during storage and handling can be limited.

6.3 Other Risks

It is conceivable that there might be some potential contamination of the cement product with the hazardous waste fuel. In the review of plant histories, there is evidence that such a risk is insignificant (Mournighan and Branscome 1988; Berry et al. 1975; Lauber 1982).

The consensus among studies investigating cement dust disposal by on-site landfilling has been that although certain precautions may be necessary to prevent wind dispersal or direct runoff to surface water, the disposal of kiln dust from cement kilns burning hazardous waste does not appear to present a significant environmental risk (Hazelwood et al. 1982).

6.4 Kiln Emission Risks

Risk posed by stack emissions from cement kilns utilizing waste fuels will vary with characteristics of the waste used, rate of waste injection into the kiln, existing kiln chemistry, and efficiency of the particulate control devices employed for cleaning stack gases. Attention must also be effectively directed to fugitive emissions of kiln dust.

Toxic organic emissions could pose some risk to the community during upset operation due to a rapid movement of clinker down the kiln and into the clinker cooler. Also, substantial nonuniformities in waste fuel composition from batch to batch may increase the difficulty of maintaining stable operations. During such an upset, emissions of incompletely combusted toxic organic compounds are usually evident from the smoke and dust cloud accompanying their release. Continuous emission monitoring may be necessary. Prompt termination of waste feed flow to the kiln when an upset is detected can prevent waste fuel from further contributing to those products of incomplete combustion that might pose some risk. A number of investigators have studied the chemical reactions that occur under conditions of upset kiln operation (Mix and Murphy 1984; Branscome et al. 1985). These investigations serve as a guide to minimizing upsets and dealing with the impacts.

Incineration of chlorophenols and other chlorinated aromatics can result in the emission of dioxins or furans. Reports of trial burns reviewed during this study indicate that emissions from cement plants burning chlorinated waste fuels have shown no evidence of major health concerns (Mix and Murphy 1984).

Trial burns at the General Cement Plant, Paulding, Ohio, introduced waste fuels containing phosphorus and zinc. However, phosphorus and zinc emissions were relatively insignificant in relation to their concentrations in the raw materials used to produce cement clinker (Branscome et al. 1985). Therefore, their low amounts in waste fuels are expected to present no significant health risks.

Waste lubricating oils burned at the St. Lawrence and Stora Vika kilns were contaminated with lead and zinc. Lead emissions in the

kiln exhaust gases did not increase as a result of burning that waste oil. In all the trial burns using waste oil, most of the lead was encapsulated in the cement clinker. Some of the lead from the waste oils was found in the kiln dust. Kiln dust disposal problems may increase when hazardous waste fuels are used. However, kiln dust can be effectively managed, principally by recycling through the kiln or through landfilling. Because cement dust is a highly buffered alkaline material, the leachability of metal oxides from kiln dust is low (Peters et al. 1986).

6.4.1 Dispersion of Kiln Emissions and Health Risk Assessment

The magnitude and nature of health risks posed by air emissions of a cement kiln burning hazardous waste can be estimated by use of mathematical models. Many diverse air-dispersion models and exposure assessment methodologies are available to determine the dispersion concentrations of pollutants in the atmosphere (Kelly 1986; Dobbins 1979). These models feature a high degree of uncertainty in the absence of more definitive data. However, they are also generally recognized as the only tool currently available for procedures such as estimating the magnitude of environmental pollutant concentrations associated with exposure to air pollutants.

Using the Gaussian Plume Model to account for pollutant dispersion downwind of the source, off-site downwind emissions concentrations have been estimated for four principal organic hazardous compounds that are likely decomposition products from burning chlorinated organic hazardous wastes. These compounds (methylene chloride, chloroform, carbon tetrachloride, and benzene) are of principal concern because of their known or suspected carcinogenicity and their relatively high emission levels in most of the observed trial burns (Table 4). Hexachlorobenzene and pentachlorophenol have also been suggested as compounds of concern whose dispersion might well be investigated.

The Gaussian Plume formula provides only rough estimates of downwind concentrations. Unsteady emission rates, varying

204

meteorological conditions, chemical reactions, scavenging, washout, and uncertainty of plume trajectories are not accounted for.

Axial mean concentration of the plume (C) at one kilometer distance from the source is computed using the Gaussian Plume formula.

$$C = \frac{Q}{\pi u \sigma_y \sigma_z} \cdot \exp\left(\frac{-H^2}{2\sigma_z^2}\right)$$

Where C = Axial mean concentration ($\mu\text{g}/\text{m}^3$)

Q = Pollutant source emission rate (g/s)

u = Mean wind speed (m/s)

y = Lateral Gaussian Plume dispersion coefficient

z = Vertical Gaussian Plume dispersion coefficient

H = Stack height (m)

In the absence of more definitive location data, we have estimated axial mean concentration (C) for a windy location (Case 1) and for a worst-case location (Case 2) under night inversion conditions. Most actual cases are likely to fall within these extremes.

Hypothetical Case 1:

Cement plant location = Windy island

Average wind speed = 6 m/s

Mean stack height, H = 20 m

Dispersion classes (Dobbins 1979:223-226)

Day time class is C (Varying amounts of incoming solar and sky radiation with slight convective activity)

Night time class is D (Neutral stratification when net radiation flux is 0)

Dispersion coefficients (Dobbins 1979:226)

Day time: $\sigma_y = 106.96$; $\sigma_z = 73.10$

Night time: $\sigma_y = 75.47$; $\sigma_z = 27.33$

205

Hypothetical Case 2:

Cement plant location = Inland with night inversion

Average wind speed = 1 m/s

Dispersion classes * :

Day time = D (Neutral stratification)

Night time = E (Radiation inversion may form and will give rise to poor dispersion)

Dispersion coefficients ** :

Day time: $\sigma_y = 75.47$; $\sigma_z = 27.33$

Night time: $\sigma_y = 53.56$; $\sigma_z = 25.61$

Mean Stack Height (H) = 20 m

Axial mean concentration (C) values computed for two hypothetical cases are presented in Table 12. Using the values from Table 12, health risk for an individual can be estimated as follows:

Health risk $R = Q^* \times D$ where $Q^* =$ Unit risk factor (USEPA 1985a) $(\mu\text{g}/\text{m}^3)^{-1}$

$D =$ Dose $(\mu\text{g}/\text{m}^3)$

But $D = C \times A \times F$ where $C =$ Axial mean concentration $(\mu\text{g}/\text{m}^3)$

$A =$ Absorption efficiency of lungs

$= 0.75$ (approximately)

$F =$ Fraction of time spent outdoors (assume 0.15)

Therefore, Risk $R = Q^* \times C \times A \times F$
 $= Q^* \times C \times 0.11$

Table 13 presents the potential individual health risks from exposure to the four POHCs.

The risk value "R" calculated for carcinogens, at a given dose "D," indicates the number of additional cases of cancer to be expected within a population due to a lifetime (70 years) exposure to dose "D." A risk of 1×10^{-6} , for example, indicates that in a population of

Table 12. Axial mean concentration of the plume (C) 1 km downwind from source

POHICs	Hypothetical Case 1				Hypothetical Case 2			
	Day		Night		Day		Night	
	$\mu\text{g}/\text{m}^3$	ppb	$\mu\text{g}/\text{m}^3$	ppb	$\mu\text{g}/\text{m}^3$	ppb	$\mu\text{g}/\text{m}^3$	ppb
Methylene Chloride	0.6	0.2	1.8	0.5	11.0	3.2	15.9	4.6
Chloroform	0.5	0.1	1.6	0.4	9.9	2.0	14.3	2.9
Carbon Tetrachloride	0.8	0.1	2.4	0.4	14.3	2.3	20.6	3.3
Benzene	0.3	0.1	0.8	0.3	4.8	1.5	6.9	2.2

Note: These ppb concentration levels are all below regulatory air emissions standards in the State of New York.

200

Table 13. Health risks from kiln emissions of four POHCs (Estimated upper limit of maximum individual health risks of kiln emissions--R values) *

POHCs	Hypothetical Case 1		Hypothetical Case 2	
	Day	Night	Day	Night
Methylene Chloride	1.2 E -08	3.6 E-08	2.2 E-07	3.1 E-07
Chloroform	5.9 E -07	1.8 E-06	1.1 E-05	1.6 E-05
Carbon Tetrachloride	1.3 E -06	3.9 E-06	2.4 E-05	3.4 E-05
Benzene	1.9 E -07	6.0 E-07	3.6 E-06	5.2 E-06

* In using Table 13 for judging risks from cement kiln emissions, it is pertinent to note that these R values assume 70-year lifetime exposures at the assumed periodic concentrations for 15% of each day (or night). Offsite exposures to emissions from hazardous wastes in cement kilns are normally periodic and of short duration, compared to a 70-year lifetime.

258

1 million, one additional cancer may occur as a result of this exposure. Off-site pollutant concentrations calculated from the Gaussian Plume formula represent a maximum individual dose expected. The unit risk value or Q^* is the estimated probability of contracting cancer as the result of continuous exposure to a concentration of 1 microgram per cubic meter (1 ug/m^3) over a 70-year lifetime. It is derived from the potency for a specific chemical as calculated by the USEPA through use of conservative linear models that extrapolate bioassay data from animal studies to estimate response at low doses. This response is further extrapolated to estimate human health effects based on differences in body weight and inhalation rates. The unit risk is multiplied times the dose to give the health risk "R." Resulting risk estimates represent the upper limit of expected health effects from this exposure and are subject to uncertainties of several orders of magnitude. A risk of 1×10^{-6} or less is generally acceptable. Risks in the range 10^{-6} to 10^{-4} or less are currently considered acceptable for many situations (USEPA 1985a).

Table 13 shows that carbon tetrachloride and chloroform risks are calculated to be 1×10^{-5} (i.e., within an acceptable risk range). Given the multiple uncertainties in the assumptions for the calculation, the calculated maximum expected health risk is highly uncertain. We can compare predicted concentrations shown in Table 12 with those measured in typical polluted urban air in U.S. cities shown in Table 14. For conditions typical of a windy island, all concentrations are for short exposures less than that found in the polluted U.S. cities. Under inversion conditions, the concentrations of methylene chloride, chloroform, and carbon tetrachloride are much higher than found in U.S. cities under polluted conditions. Table 14 also shows the International Agency for Research on Cancer (IARC) classifications of carcinogenicity for these substances. Before burning chlorinated organic wastes in a specific cement kiln, trial burns are suggested to determine emission rates and downwind concentrations for specific candidate hazardous wastes, and to make calculations of health risks under different conditions. For example, in some locations of specific cement kilns, it may be desirable to

209

Table 14. POHC concentrations in typical polluted U.S. cities
(classification of carcinogenicity and POHC concentrations)

POHCs	IARC Classification (1979-82)	Weight of Evidence for Carcinogenicity	Typical Concentration in polluted U.S. Cities* (ppb)
Methylene Chloride	3	Inadequate human and animal	0.5 - 4.0
Chloroform	2B	Sufficient animal; inadequate human	0.1 - 0.2
Carbon Tetrachloride	2B	Sufficient animal; inadequate human	0.1 - 0.3
Benzene	1A	Sufficient human	1.0 - 6.0

*Source: Shah and Heyerdahl (1988).

avoid burns of some hazardous wastes during some conditions such as atmospheric inversions. In some cases, it may be desirable to change stack heights.

7. CEMENT KILNS IN SELECTED ASIA-PACIFIC COUNTRIES

In June 1988, at the outset of the study of this topic, Consortium members were requested to provide information on cement kilns in their country. Specifically, they were requested to provide an inventory of cement kilns listing plant capacity, type of process, approximate age of plant, current ownership, location, population density, and type of surrounding land use, together with any notes on operating experience for those plants that might be pertinent in considering these plants as candidates for hazardous waste disposal.

Table 15 presents 1988 data provided by Consortium members in Malaysia, Korea, and New Zealand. These data give some insight into the potential for using cement kilns for disposal of hazardous waste in those countries. Hopefully, in subsequent phases of this study, similar data will be available from Consortium members in other Asia-Pacific countries. Even though recent experience in the United States indicates hazardous wastes can best be introduced as only a small percentage of input feedstock, a review of Table 15 indicates that cement plants in those three countries have a substantial potential for disposing of large quantities of hazardous wastes. If site-specific studies confirm the potential for safe and economical disposal, it will be possible to avoid major capital expenditures for new hazardous waste disposal facilities to the extent that certain cement kilns can be used for that disposal function.

It is of some interest to review the 1988 data in Table 15 in the light of some 1984 data in Table 16 from global statistics. As of 1984, the Asian region alone accounted for about 38 percent of world cement production; China accounted for about 35 percent of Asia's production, followed by Japan (22 percent), India (8 percent), and the Republic of Korea (6 percent).

The 1988 data compared with the 1984 data gives some measure of significant growth trends in the cement industry in New Zealand, Malaysia, and Korea. This growth probably also represents increasing opportunities for prudent and economical hazardous waste disposal through use of cement kilns in those countries.

Table 15. Profile of cement plants in selected Asia-Pacific countries (as of 1988)

Country	Name and location of cement plant	Production capacity (tonne/yr)	Type of process	Age of plant (yrs)	Pattern of ownership	Type of surrounding land-use
Malaysia	Associated Pan Malaysian Cement, Rawang, Selangor	1,000,000	Wet	35	Private limited	Residential-cum-urban area
	Perak-Hanjong Simen, Padang, Padang Perak	1,000,000	Dry	2	Private limited	Residential areas, fruit orchards, paddy fields, and rubber estates
	Cement Industries of Malaysia Bernad, Perlis	1,000,000	Dry	13	Public limited	Residential areas and rubber estates
	Tasek Cement Bernad, Jopn Perak	1,000,000	Semi-dry and dry	26	Public limited	Industrial
	Kedah Cement Bdn, Lanekawi, Kedah	600,000	Dry	4	Government-owned	Rubber and coconut estates, paddy fields, fruit orchards, and residential areas
	Associated Pan Malaysian Cement, Chermor, Perak	403,700	Wet	24	Private limited	Rubber estates and residential areas
	Malaysia Industrial Mining Corporation, Batu Cava, Belangor	60,000	Dry	29	Public limited	Residential areas and limestone hills
	Rook Chemical Industries, Lahat, Perak	12,000	Dry	13	Private limited	Rubber estates
Korea	Dongyang Cement, Sanchuck	5,164,750	Dry with suspension preheat	46	NA	Urban; population density of 905/sq km
	Seangyong Yanghon Cement, Dornghan	10,385,710	Dry with suspension preheat	20	NA	Urban; population density of 509/sq km
	Seangyong Yanghon Cement, Yeonghul	2,346,950	Dry with suspension preheat	14	NA	Rural; population density of 74/sq km
	Seangyong Yanghon, Munkyung	317,550	Wet	31	NA	Urban; population density of 1209/sq km

212

Country	Name and location of cement plant	Production capacity (tonnes/yr)	Type of process	Age of plant (yrs)	Pattern of ownership	Type of surrounding land-use
	Hanil Cement, Danyang	3,222,950	Dry with suspension preheat	24	NA	Rural; population 30/sq km
	Hyundai Cement, Danyang	3,212,000	Dry with suspension preheat	24	NA	Rural; population 30/sq km
	Asea Cement, Jeocun	2,387,100	Semi-dry and dry	22	NA	Rural; population 62/sq km
	Sungshin Yanghoe Cement, Danyang	3,639,050	Dry with suspension preheat	19	NA	Rural; population 30/sq km
	Goryu Cement, Jangsung	730,000	Dry with suspension preheat	15	NA	Rural; population 159/sq km
	Halla Cement, Okgye	1,314,000	Dry with suspension preheat	3	NA	Rural; population 89/sq km
	Union Ltd, Chungjoo	109,500	Dry with suspension preheat	7	NA	Rural; population 169/sq km
New Zealand	Golden Bay Cement Co., Portland near Whangarei	500,000	Dry with suspension preheat	6	NA	Rural; nearest village has 80 houses and 2 km distance
	Milburn New Zealand, Ltd., Cape Foulwind near Westport	420,000	Wet	32	NA	Rural
	Milburn New Zealand, Ltd., Burnside, Green Island	125,000	Wet	62	NA	Rural; nearest house is about 0.5 to 1 km away

Table 16. Cement production in selected countries

	Million metric tonnes (1984)
World	913.37
Africa	37.53
N. America	106.59
USA	70.54
S. America	39.54
Europe	246.55
Asia	353.16
China	123.02
Hong Kong	1.85
India	29.43
Indonesia	6.61
Japan	78.86
Korea, Republic	20.41
Malaysia	3.47
Philippines	3.66
Singapore	2.51
Thailand	8.27
USSR	129.87
Oceania	5.64
Australia	4.65
Fiji	0.10
New Caledonia	0.06
New Zealand	0.82

Source: United Nations (1987).

8. FINDINGS

1. Disposal of selected hazardous wastes is currently being safely conducted at more than 20 cement plants in the United States, with specific and significant economies being achieved. Other plants are in various stages of planning to use combustible hazardous waste as fuel.
2. Although data on cement-kiln disposal for a complete spectrum of hazardous waste types were not available during this initial phase of study, there is substantial information on cement-kiln disposal of solvent-derived fuels (SDFs). SDF constitutes a large fraction of hazardous wastes in many regions. Since many SDFs have high heat value and can be used as a partial substitute energy source for cement kilns, there is substantial economic motivation for developing countries to concentrate on SDFs in their initial trial programs for disposal of hazardous wastes in cement kilns. Bouse and Kamas (1987) provide information concerning disposal of SDF in cement kilns.
3. The Introduction listed many promising characteristics of the cement manufacturing process that can lead to opportunities for environmentally sound and economically attractive disposal of hazardous wastes. However, evaluation of this technology to date indicates that the following constraints must be recognized:
 - Waste type characteristics: Cement kilns are limited in the types of waste they can accept. Solid hazardous wastes, for example, do not appear to be economically attractive at present. Wastes with low heating value (e.g., under 8,000 Btu/lb) may be marginally attractive. Chlorine content of waste fuels must generally be kept under 0.5 percent of clinker weight. Water content of the waste fuel must not be excessive.

- Permits and regulations: To date, at least in the United States, the permitting process (including test burns) is usually time-consuming, complex, and expensive. This discourages some plant owners/managers from adopting this technology. Moreover, regulatory requirements for continuing monitoring and recordkeeping increase costs.
- Liability and insurance: Processing hazardous wastes often introduces additional liability and insurance costs.
- Waste fuel supply: There must be a reliable and continuing supply of waste fuel available within a reasonable distance at a reasonable price (or fee) to justify the investment necessary for burning the waste fuel.
- Public and employee acceptance: Due to a desire to avoid public opposition, some cement plants have not burned well-known hazardous wastes such as PCBs on a continuing basis, despite the fact that test burns have demonstrated the ability of cement kilns to destroy these substances (Lauber 1987).

Some cement plants, particularly those near residential neighborhoods because of inadequate attention to fugitive dust problems, have in past decades been considered as undesirable neighbors, regardless of what fuels the cement plants were using, or might use in the future. As a consequence, the public may often view new proposals concerning any changes whatsoever in cement operations with suspicion.

4. Despite the preceding constraints, it is considered that this technology in many instances can provide mutual benefits to both industry, which generates such wastes, and to society and governments that want to dispose of hazardous wastes properly. A thoughtful, well-designed community education program and appropriate risk assessment are necessary.
-

5. The applicability of this disposal technology at specific cement plants may be dependent on:

- Land use and population factors near the plant;
- Chemical and economic characteristics of a specific waste proposed for disposal;
- Unique operating characteristics of a plant;
- Local topography and meteorology at a plant site (which, for example, might be related to stack height); and
- Unique regulatory and permitting requirements.

Accordingly, some form of risk assessment for each specific waste at each specific site appears to be a prudent step to take before making any commitment to this technology. Section 6 presents the concepts of such risk assessment. If an initial risk assessment indicates a potentially unacceptable risk to human health or ecosystems, an adjustment of stack height, or added scrubbers, or reduction in firing rate (reduction in percentage of hazardous waste in feedstock) may be adequate mitigating actions to reduce risk to an acceptable level. Other risk management measures such as avoiding hazardous waste burns during atmospheric inversions may be available.

Even in a case where costs of dealing with concerns about health and the environment exceed energy savings, the cement-kiln disposal option might be the most prudent if other disposal options are still more expensive.

9. RECOMMENDATIONS

1. Consortium members interested in application of this disposal technology should first survey the types and quantities of combustible hazardous wastes and the cement kilns and lime kilns in their geographic area.
2. For those who wish to pursue the cement kiln option further in their own country, it is suggested that brief preliminary risk assessments (including consideration of risk perception) be prepared for any candidate cement plant site.
3. For the most likely sites, it is recommended that trial burns be carried out. Appendix B of this study gives some guidelines for trial burns. These trial burns can help prepare a more quantitative risk assessment and establish operating conditions/limitations to assure that risks can be maintained at an acceptable level.
4. This study contains information on test burns and permitting procedures primarily in the context of environmental regulations in the United States. It is important that Consortium members in other countries make their evaluations of potential application of this technology using existing and planned environmental regulations in their own country.

APPENDICES

Hazardous Waste Incineration: The Cement Kiln Option

Legislative Commission on Toxic Substances and Hazardous Wastes

Senator John B. Daly, Chairman
Senator John R. Dunne
Senator Hugh T. Farley
Senator William T. Stachowski

John H. Stuart
Executive Director

Assemblyman Eric N. Vitaliano, Vice-Chairman
Assemblyman Richard Miller
Assemblyman Francis J. Pordum

Principal Author:
Andrew Beers

Albany, New York

December 1987

TABLE OF CONTENTS

I. INTRODUCTION	1
II. OVERVIEW OF CEMENT AND LIGHTWEIGHT AGGREGATE KILN TECHNOLOGIES	
A. Cement Kiln Technology	3
B. Lightweight Aggregate Kiln Technology	6
III. THE TECHNOLOGY FOR BURNING HAZARDOUS WASTE FUELS IN CEMENT AND LIGHTWEIGHT AGGREGATE KILNS	
A. The Advantages of Cement and Lightweight Aggregate Kilns as a Hazardous Waste Disposal Option	9
B. Technological Limitations	11
C. Plant Modifications Required to Burn Hazardous Wastes	12
D. Economics of Burning Hazardous Wastes	14
E. Community Impacts of a Waste Fuels Project ...	17
IV. ENVIRONMENTAL CONCERNS RELATED TO THE BURNING OF HAZARDOUS WASTES IN CEMENT KILNS	
A. Emissions of Toxic Air Pollutants	19
B. Transportation Risks	22
C. Waste Storage and Handling Risks	23
D. Disposal of Cement Kiln Dust	24
E. Summary of Risks Posed by Incineration of Hazardous Wastes	25
V. THE PERMITTING PROCESS	
A. The SEQRA Process	27
B. Required Air Pollution Control Permits	28
C. Required RCRA Permits	29
D. Required Siting Certificate	33
E. Opportunities for Public Participation in the Permitting Process	34
F. Positive and Negative Impacts of the Permitting Process	35

I. INTRODUCTION

New York State's industries generate greater than 172,000 tons of liquid organic hazardous wastes and 187,000 tons of waste oils each year.¹ In July, 1987, the Legislature enacted legislation (Chapter 618, Laws of 1987) mandating that New York's primary longterm strategy for dealing with these wastes should be to encourage industries to substantially reduce their generation of hazardous waste through source reduction and on-site recycling. However, even under a scenario of maximum waste reduction, considerable quantities of hazardous wastes and waste oils will continue to be generated for the foreseeable future. Due to technical and economic limitations, many of these wastes cannot be recycled. Therefore, there is a strong need to develop innovative, advanced-technology options for treating and destroying hazardous wastes in New York State.

Incineration is one of the most promising options currently available for destroying organic hazardous wastes. The U.S. Environmental Protection Agency (EPA) has determined that:

Incineration . . . is a valuable and environmentally sound treatment option of liquid hazardous wastes. . . . Risk assessments conducted by EPA indicate that properly designed and operated incinerators which meet the regulatory requirements for destruction and removal efficiency pose minimal risks to human health and the environment.²

Hazardous waste incinerators have the potential to destroy virtually all types of organic hazardous wastes, reducing complex organic compounds to several relatively harmless substances, primarily carbon dioxide, water, ash and trace amounts of other substances, including sulfur dioxide, nitrogen oxides and hydrogen chloride.

At present, commercial hazardous waste incineration capacity is extremely limited in New York State.⁴ However, two types of existing industrial furnaces -- cement and lightweight aggregate kilns -- currently operating in New York have the potential to successfully destroy large quantities of organic liquid wastes and waste oils. Tests conducted at a number of facilities in the United States, Canada and Europe have demonstrated that cement kilns can safely destroy almost all types of organic wastes, while providing the added benefit of recovering substantial amounts of energy that would otherwise be discarded. Lightweight aggregate kilns can also be an effective

II. OVERVIEW OF CEMENT AND LIGHTWEIGHT AGGREGATE KILN TECHNOLOGIES

A. CEMENT KILN TECHNOLOGY

Cement manufacturing is one of the largest mineral commodity industries in the United States, with an estimated production capacity of greater than 86 million tons annually.⁵ The principal chemical elements required for the production of cement are calcium, silicon, aluminum and iron.⁶ Calcium is provided by a calcareous material, typically limestone, that usually is mined close to the plant site. Silicon and aluminum are provided by an appropriate mixture of clay, shale, slate and/or sand. Iron is provided by iron ore or steel mill scale.

Cement is produced in a horizontal rotary kiln lined with temperature-resistant refractory brick. These kilns are quite large, ranging in size up to 760 feet in length and 25 feet in diameter. The kiln is inclined at a slight angle (3 to 6 degrees) to facilitate the movement of materials down the kiln. Heat is applied at the lower end of the kiln by a powerful coal, gas or oil flame. The cement feed material is introduced at the elevated end of the kiln. As the cement kiln rotates, typically at speeds of 50 to 70 revolutions per hour, the feed material slowly moves downward towards the firing end of the kiln. Feed material residence times in the cement kiln typically range from two to four hours.

Several distinct thermal zones exist within an operating cement kiln. The specific physical and chemical reactions that lead to the formation of cement occur in these thermal zones. The elevated end of the kiln at which feed material is introduced is known as the drying and preheating zone. In this zone, all water is evaporated out of the feed product, and the temperature of the feed is raised to approximately 1480 degrees Fahrenheit.

The preheating zone is followed by the calcining zone of the kiln. Calcination is the process through which carbon dioxide is driven off from the limestone materials in the feed, leaving free lime and magnesia. Feed material temperatures in the calcining zone of the kiln reach 2190 degrees Fahrenheit.

Once calcination is complete, the feed material enters the sintering zone of the kiln, commonly referred to as the burning zone. In this zone, the chemical reactions leading to the formation of cement take place at temperatures exceeding 2550 degrees Fahrenheit. The feed material, which at this point is in a semi-liquid state, forms into small

It is important to note that the feed material must reach a minimum temperature of 2550 degrees Fahrenheit in order for clinker to form; cement cannot be produced at temperatures below 2550 degrees. To raise the temperature of the feed this high, combustion gas temperatures in the kiln generally must exceed 3000 degrees Fahrenheit. It is not unusual to experience combustion gas temperatures of 3200 to 3500 Fahrenheit in the burning zone. Further, combustion gas residence time in the burning zone of the cement kiln ranges from two to five seconds, depending on the size and configuration of the kiln.¹⁰

Cement kilns operate in a counter current fashion. Combustion gases and waste dust travel in the opposite direction of the feed material, exiting at the elevated end of the kiln. Exhaust gases consist primarily of carbon dioxide, water, fly ash, sulfur and nitrogen oxides from the combustion of coal, and small particles of feed and clinker material, referred to as kiln dust. These materials are transported out of the elevated end of the kiln by a powerful induced draft fan to required air pollution control equipment. Almost all cement kilns utilize either a baghouse filter or an electrostatic precipitator system, often preceded by a centrifugal cyclone, to remove pollutants from the kiln exhaust gases.¹¹ Cement kiln dust collected by pollution control equipment is either returned to the kiln as feed material or disposed of on-site in a landfill. After passing through the pollution control system, the remaining combustion gases, primarily carbon dioxide and water, are discharged through a stack to the atmosphere.

There are four types of cement kilns in use in the United States: wet process, dry process, preheater and precalciner kilns. In the most common type, the wet process kiln, the feed material is introduced into the kiln as a slurry mixture containing 30 to 40 percent water. The wet process, which is a relatively old technology, has the advantages of uniform feed blending and lower emissions of kiln dust. However, because all water must be evaporated out of the slurry mixture before the reactions that create cement may take place, wet process kilns require greater energy input than other types of cement kilns.

Cement production is presently shifting toward the use of dry process kilns, which can accept feed material in a dry powder form. Additionally, preheater and precalciner units may be added to dry process kilns to further increase energy efficiency. These units preheat the dry feed material prior to its introduction into the main kiln chamber. The amount of energy required to produce cement by the wet, dry and preheater processes is 5.8, 4.6 and 3 million Btus per ton, respectively.¹²

physical strength. The cooled material is then sized for use in concrete production.

Lightweight aggregate kilns operate in a counter current fashion, similar to cement kilns. Feed materials slowly progress down a slight incline, while combustion gases and kiln dust travel in the opposite direction, exiting to pollution control equipment at the elevated end of the kiln. Most aggregate kilns utilize either a scrubber system or an electrostatic precipitator to remove kiln dust and air pollutants from exhaust gases.

The manufacture of quality lightweight aggregate requires that the temperatures within the kiln be controlled within a narrow range. In order to produce aggregate, the temperature of the feed material must reach at least 1900 degrees Fahrenheit. Combustion gas temperatures of between 2050 and 2300 degrees Fahrenheit are necessary to assure that the feed material attains this temperature.¹⁴ Further, combustion gas residence times in aggregate kilns generally exceed two seconds.

There are presently two lightweight aggregate plants in operation in New York State: Norlite, located in Cohoes, which operates two kilns fueled by a combination of chemical wastes, waste oils, fuel oil, natural gas and coal; and Northeast Solite, located in Mount Marion, which operates three kilns, each of which is fired exclusively with coal. Annual production of lightweight aggregate at both of these facilities varies substantially in response to demand on the part of the construction industry.

A comparison of the combustion temperatures, gas residence times and size of cement kilns, lightweight aggregate kilns and standard hazardous waste incinerators is presented in Table 2.

III. THE TECHNOLOGY FOR BURNING OF HAZARDOUS WASTES FUELS IN CEMENT AND LIGHTWEIGHT AGGREGATE KILNS

A recent national survey identified 17 cement kilns and 18 lightweight aggregate kilns that are presently burning liquid organic hazardous wastes, primarily industrial solvents and waste oils.¹⁶ In 1986, these 35 kilns incinerated a total of 86 million gallons of hazardous wastes. Several of these facilities, primarily lightweight aggregate operations, utilize waste fuels to provide one hundred percent of their energy needs during normal kiln operation. However, most of these facilities burn hazardous wastes as a supplemental fuel, replacing between 25 and 50 percent of the energy that would otherwise be supplied by coal or another primary fuel. This section provides a description of the technical aspects of burning hazardous wastes in cement and lightweight aggregate kilns.

A. THE ADVANTAGES OF CEMENT AND LIGHTWEIGHT AGGREGATE KILNS AS A HAZARDOUS WASTE DISPOSAL OPTION

Cement Kilns

In comparison to other types of hazardous waste incinerators, cement kilns possess several characteristics which make them an efficient technology for destroying organic wastes. These characteristics include:

- combustion gas temperatures and residence times in cement kilns exceed those generally experienced in commercial hazardous waste incinerators (Table 2). These high combustion temperatures and long residence times, along with the strong turbulence encountered in cement kilns, virtually assure the complete¹⁷ destruction of even the most stable organic compounds;
- due to the large size and amount of heated material in cement kilns, these kilns exhibit high thermal stability. In other words, temperatures within the kiln change very slowly. Thus, even if a cement kiln is forced into an emergency shutdown resulting from a loss of primary fuel or severe upset, all hazardous waste in the kiln should be completely destroyed, provided that automatic cutoffs prevent further injection of wastes;¹⁸
- cement kilns operate under alkaline conditions. Therefore, virtually all of the chlorine entering the kiln is neutralized to form calcium chloride, sodium chloride and potassium chloride, relatively non-toxic

- while combustion gas temperatures in lightweight aggregate kilns are equivalent to those encountered in commercial hazardous waste incinerators, they are significantly less than those experienced in cement kilns (Table 2). Similarly, although aggregate kilns exhibit relatively high thermal stability, they are smaller than cement kilns, and therefore, may experience more rapid changes in temperature; and

- unlike cement, which is produced from limestone, lightweight aggregate is produced from slate or shale. Therefore, the alkaline conditions encountered in cement kilns do not exist in aggregate kilns. Accordingly, aggregate kilns burning chlorinated wastes must utilize additional air pollution control equipment, such as a scrubber system, to control emissions of hydrogen chloride, a highly acidic compound. Some concerns have also been voiced that, because of the absence of an alkaline environment, aggregate kilns burning highly chlorinated wastes may be more prone to emitting dioxins than are cement kilns.²⁴ These concerns, however, have not been documented in the literature describing trial burns conducted to date (information on emissions of toxic pollutants from cement and aggregate kilns is presented in section IV).

B. TECHNOLOGICAL LIMITATIONS

The primary drawback of cement and lightweight aggregate kilns as a hazardous waste disposal option is that they are limited in the types of wastes they can accept. In order to assure complete combustion, hazardous wastes must be injected into the firing end of the kiln. At present, only pumpable liquid hazardous wastes containing minimal amounts of water can be incinerated in these kilns. Although solid materials could theoretically be disposed of in cement kilns, major plant modifications, including²⁵ the use of combustion gas afterburners, would be required. To date, the viability of burning solid hazardous wastes and contaminated soils in cement kilns has not been demonstrated.

Because metals are not destroyed in the incineration process, wastes containing significant quantities of metallic constituents, including lead, arsenic, mercury, cadmium and chromium, are poor candidates for incineration in cement and lightweight aggregate kilns. Therefore, regulatory agencies typically set maximum acceptable concentrations (usually in the parts per million range) for metallic constituents in waste fuels. In addition, chlorine tends to accumulate in kilns in the form of alkali chlorides, which may adversely effect the production process and lead to

prior to accepting that shipment to determine its heating value and to certify that the waste meets parameters specified in the facility's operating permit. These specifications are designed to prevent violent reactions or explosions resulting from the mixture of incompatible wastes, to assure that wastes do not contain unacceptable concentrations of halogens or metals, to assure that unauthorized wastes, such as PCBs or excess concentrations of metals, are not injected into the kiln, and to protect cement product quality and process equipment.

The major plant modification required to burn hazardous wastes is the construction of waste receiving, storage and handling areas. A typical waste storage area consists of a tanker truck unloading area, four or more 30,000 gallon waste storage tanks, one or more 30,000 gallon blending tanks, and associated piping, valves and equipment to pump wastes to and from the various tanks.²⁹ The design and operation of hazardous waste handling areas are strictly regulated under the Resource Conservation and Recovery Act (RCRA), and are specified in the plant's RCRA treatment, storage and disposal facility (TSDF) permit. Storage and handling requirements, which are similar to those placed on industries that routinely handle flammable or hazardous materials, include:

- waste fuel storage tanks must meet design and installation requirements that minimize the likelihood of leakage or tank rupture. In addition, tank storage areas generally are constructed with secondary containment systems with capacity exceeding 110 percent of the largest storage tank;
- when handling ignitable or reactive wastes, a facility must utilize special precautions to prevent accidental explosions or releases. For example, nitrogen usually is pumped into storage tanks during unloading of organic solvents and waste oils;
- storage tanks must be equipped with vapor control systems, and must utilize automated pressure, vapor release and tank overflow monitors. In addition, facilities utilizing underground storage tanks generally are required to install leak detection and groundwater monitoring systems;
- procedures must be established which minimize or eliminate the risk of spills during the transfer of hazardous wastes. For example, transportation tanker unloading areas are usually constructed with secondary spill containment exceeding 110 percent of tanker capacity;
- pumps, valves and piping must meet design standards

contracting with commercial facilities for disposal of these wastes.

Although DEC, in conjunction with the State Energy Office, is mandated by state law to monitor the generation and disposal of waste oils in New York State, this information has not been collected since 1981. Data gathered at that time indicated that 46.8 million gallons (approximately 187,000 tons) of waste oil was generated during 1981. Of that amount, it was estimated that 35 million gallons was potentially available as waste fuel. The majority of waste oil collected in New York is burned in industrial or residential boilers without reprocessing to remove hazardous constituents, a practice that may present unacceptable environmental risks.³²

The above data indicates that a minimum of 90 million gallons of liquid organic wastes are generated annually in New York State, and that the actual amount may be much greater. For comparison, the largest cement kiln waste fuel project proposed to date in New York State would have a maximum annual disposal capacity of 20 million gallons. However, it is not clear what percentage of the 90 million gallons are available for use as waste fuels. Depending on market factors, a portion of this waste stream may be recovered and recycled by solvent and waste oil refiners. For example, commercial solvent recovery firms in New York reprocessed an estimated 3 million gallons of industrial solvents in 1984.³³ Other organic wastes may not meet permit requirements governing total halogens content, concentrations of metallic constituents, or minimum Btu content for waste fuels. Therefore, it is not currently possible to precisely quantify the availability of waste fuels in New York State. However, the fact that three facilities located in New York are pressing forward with proposals to burn hazardous wastes suggests that these facilities believe that they will not encounter problems securing adequate supplies of waste fuels.

Income and Cost Projections

At present, cement and lightweight aggregate facilities are charging industrial generators between ten and thirty cents per gallon to accept organic solvents and waste oils. However, it is difficult to project how the fees that firms are able to charge to accept waste fuels will fluctuate in the future. For example, RCRA contains provisions that will prohibit the land disposal of most liquid organic wastes over the next several years. These prohibitions could raise the price that facilities are able to charge for accepting hazardous wastes. In contrast, the proposed waste fuel projects at Lehigh Cement Company and Blue Circle Atlantic would raise commercial hazardous waste incineration capacity

of \$9 per ton (3 1/2 cents per gallon) under the New York State Superfund program. And third, a commercial hazardous waste disposal facility may be subject to a local gross receipts assessment of up to five percent (information on the gross receipts assessment is presented below).

Once a firm has estimated the annual costs and savings of constructing and operating a waste fuels project, the company is then able to calculate the return on investment it can expect from utilizing this technology. The fact that three of the six cement and lightweight aggregate companies operating in New York State are actively seeking permits to burn hazardous wastes indicates that, despite the high initial investment required, the economic return from a waste fuels program is favorable.

K. COMMUNITY IMPACTS OF A WASTE FUELS PROJECT

A waste fuels project clearly has the potential to impact on residents living in the vicinity of the facility. The host community must bear the risks associated with the transport, storage and incineration of hazardous wastes. Although the public health and environmental risks associated with the burning of liquid organic wastes are extremely small, they cannot be completely eliminated. Furthermore, even though these risks appear to be negligible, they may be perceived by persons living near the facility to be unacceptable. Such perceived risks, whether based on available technical and scientific evidence or not, impose real burdens on individuals forced to bear them. In addition, many citizens fear that the siting of a commercial hazardous waste facility in their community may result in a decrease in local property values, as well as in a tarnishing of the community's image.

However, in contrast to these potentially negative impacts, a waste fuels project may provide several mitigating benefits to the community in which it is located. First, the cement and lightweight aggregate industries are highly competitive. By reducing a facility's energy costs and by providing a new source of revenue, the burning of waste fuels may significantly increase a cement plant's economic viability, thus enhancing its competitiveness. This increased profitability may translate to the creation or retention of jobs in the community, a strengthening of the local tax base and other indirect economic benefits to the community.

Second, New York State enacted a law in 1986 which allows the city or town in which a commercial hazardous waste facility is located to impose an assessment of up to five percent on the gross receipts of the waste management activities of the facility.³⁷ This gross receipts

IV. ENVIRONMENTAL CONCERNS RELATED TO THE BURNING OF HAZARDOUS WASTES IN CEMENT KILNS

The environmental and public health concerns stemming from the use of hazardous wastes and waste oils as supplemental fuels in cement and lightweight aggregate production can be grouped into four general areas: emissions of toxic pollutants; risks associated with the transportation of wastes; risks associated with the on-site storage and handling of wastes; and, releases of toxic constituents from cement kiln dust disposal sites.

A. EMISSIONS OF TOXIC AIR POLLUTANTS

A number of test burns have been conducted at cement facilities to determine the impact of burning organic hazardous wastes on emissions of a number of air pollutants, including: organic constituents and products of incomplete combustion, lead and other metals, hydrogen chloride, particulates, and sulfur and nitrogen oxides.

Destruction of organic wastes. Trial burns conducted at over a dozen cement plants over the past nine years in the United States, Canada and Europe have demonstrated that these facilities have the capability to destroy greater than 99.99 percent of even the most difficult-to-incinerate organic substances.³⁹ Although exceptions to the 99.99 percent destruction and removal efficiency (DRE) were noted during some of the trial burns at two of these facilities, the majority of these tests demonstrated DREs approaching 99.999 percent. Those tests at which the 99.99 percent DRE were not obtained appear to have resulted from a failure to properly atomize wastes or other operating errors.

It is conceivable that very small amounts of hazardous waste burned in an incinerator achieving a DRE of 99.99 percent will escape destruction, and thus, may be emitted to the atmosphere. However, the concentration of unburned waste in exhaust gases from a properly operating incinerator can be expected, at most, to range from 5 to 50 parts per billion.⁴⁰ These emission levels of unburned waste are considerably below DEC's regulatory air emission standards for the classes of solvents and organic chemicals that the cement facilities located in New York State are proposing to incinerate.⁴¹

In comparison to cement kilns, relatively few trial burns investigating destruction and removal efficiencies for hazardous wastes have been conducted at lightweight aggregate facilities. Because aggregate kilns burn at lower

temperatures or combustion efficiency drops below optimal levels.

Formation of Dioxins and Furans. Two types of highly toxic PICs, dioxins (TCDDs) and furans (TCDFs), have received special attention because they have been identified in air emissions from a number of solid waste incinerators. However, a survey of test results from trial burns conducted at cement kilns and other industrial hazardous waste incinerators indicates that emissions of dioxins and furans from these facilities are not significant.⁵² The dioxin isomer of greatest concern (2,3,7,8-TCDD) has not been detected in emissions from any of seventeen hazardous waste incinerators where tests for these substances have been conducted. Although other isomers of dioxins and furans have been identified in stack gases at several of these facilities, including during a trial burn conducted in 1985 at the Lehigh Cement facility in Cementon, New York, emissions from hazardous waste incinerators appear to be approximately three orders of magnitude⁵³ less than those reported for municipal incinerators.

To date, no data has been published characterizing emissions of dioxins and furans from lightweight aggregate kilns. Lightweight aggregate kilns lack the caustic conditions encountered in cement kilns. Therefore, the chlorine contained in halogenated solvents burned in aggregate kilns combines with hydrogen to form hydrogen chloride, a highly acidic compound, rather than reacting with calcium to form non-toxic compounds, as is the case in cement kilns. Some experts have theorized that this availability of chlorine molecules increases the likelihood that lightweight aggregate kilns may emit trace amounts of dioxins and furans,⁵⁴ although evidence supporting this theory has not been collected.

Metals Emissions. Because waste oils and many hazardous wastes typically contain metallic constituents, most notably lead, concerns have been raised over emissions of metals in cement kiln exhaust gases. The data on metal emissions from hazardous waste incinerators is less well developed than the data characterizing destruction and removal efficiencies for organic substances.⁵⁵ However, evidence published to date indicates that the burning of waste fuel in cement and lightweight aggregate kilns results either in no increase or in only a slight increase in air emissions of lead and other metals.⁵⁶ Studies have shown that greater than 99 percent of the lead contained in waste fuels is either incorporated in an inert form in the clinker product or is adsorbed onto kiln dust particles that are removed by air pollution control devices.⁵⁷ For comparison, a recent survey of trial burns in which wastes containing lead were incinerated in cement kilns concluded that lead emissions from six of the seven facilities tested were less

eliminate these risks, hazardous waste transporters operating in New York State must conform with a series of regulatory requirements promulgated by the Department of Environmental Conservation designed to minimize the likelihood of accidental releases of hazardous materials. These regulations, established pursuant to the federal Resource Conservation and Recovery Act (RCRA), require transporters to obtain a permit from DEC, submit to inspections, obtain insurance for hazardous waste spills, and comply with various recordkeeping and manifest requirements designed to track the disposition of hazardous wastes.⁶³ Design specifications for waste tanker trucks are similar to those for vehicles transporting petroleum products or hazardous chemicals. These products, which present transportation risks that are similar to hazardous wastes, are routinely transported around the state.

From a statewide perspective, the risks associated with the transport of hazardous wastes and waste oils to cement and lightweight aggregate facilities are no different than the risks currently being incurred by the shipment of these wastes to other types of existing commercial hazardous waste disposal facilities. As long as hazardous wastes continue to be generated, these risks cannot be avoided. However, steps can be taken, through the strict enforcement of RCRA transporter regulations and the development of thorough emergency contingency plans, to minimize the risk of accidents during the transport of waste fuels.⁶⁴

C. WASTE STORAGE AND HANDLING RISKS

The risks of explosion or tank failure leading to the release of toxic materials from storage areas are similar to those encountered by industries that routinely use or generate flammable or hazardous materials, including petroleum products and organic chemicals. Technologies and practices that have been developed by these industries can be readily utilized by cement facilities to minimize the risk of catastrophic accidents during hazardous waste storage and handling. A study conducted for the U.S. Environmental Protection Agency has concluded that the use of these storage and handling techniques at cement facilities reduces the risk_{of} major releases of hazardous wastes to negligible levels.⁶⁵

Although catastrophic accidents are highly unlikely at waste storage areas, it is virtually impossible to completely prevent small spills of hazardous wastes during unloading and pumping of waste fuels.⁶⁶ These spills may be caused by equipment failures, maintenance operations, or operator error. However, facilities managing hazardous wastes are required by RCRA to develop waste handling procedures that

E. SUMMARY OF RISKS POSED BY INCINERATION OF HAZARDOUS WASTES IN CEMENT AND LIGHTWEIGHT AGGREGATE KILNS

The U.S. Environmental Protection Agency has conducted a risk assessment of the potential health effects of toxic organic and metals emissions based on trial burns conducted at nine hazardous waste incineration facilities.⁷² This risk assessment conservatively estimated that the increased cancer risk for an individual exposed to incinerator emissions over a seventy year period ranges from one in 100,000 to one in 100,000,000. Because this is a worst case estimate, it likely overstates the actual risk of cancer resulting from emissions from hazardous waste incinerators. Although EPA's risk estimate was based on data from a relatively small number of facilities, other available risk assessments corroborate EPA's assertion that emissions from properly operated hazardous waste incinerators do not pose a significant threat to public health or the environment.

Hazardous wastes will continue to be generated in New York State for the foreseeable future. Therefore, New York State must develop technologies for treating or destroying these wastes in an environmentally sound manner. No technology for managing hazardous wastes can be risk-free. Cement and lightweight aggregate kilns are no exception to this rule. However, the risks stemming from the use of this technology either appear to be extremely small (as is the case with emissions of toxic pollutants or the potential for hazardous releases from storage and handling areas) or will be incurred by New York State regardless of the disposal technology utilized (as is the case with transportation risks). Furthermore, as discussed in the next section, any facility proposing to burn hazardous wastes must comply with a rigorous set of environmental standards and regulations and must complete a lengthy permitting process designed to identify and mitigate any potential risks associated with the project.

IV. THE PERMITTING PROCESS

Any cement or lightweight aggregate facility proposing to burn hazardous wastes must complete a complex and lengthy permitting process. As a part of this regulatory review process, the facility must:

- comply with the New York State Environmental Quality Review Act, which will likely require the preparation of an Environmental Impact Statement and the holding of public hearings;
- obtain several state air pollution control permits;
- obtain a state hazardous waste treatment, storage and disposal permit pursuant to the federal Resource Conservation and Recovery Act; and
- comply with New York's hazardous waste facility siting requirements.

Because waste oils presently are not regulated as a hazardous waste in New York, a facility intending to burn waste oils, but not hazardous wastes, needs only to obtain the necessary air permits.

A. THE SEQRA PROCESS

An application for permits to burn hazardous wastes or waste oils as a supplemental fuel in a cement or lightweight aggregate kiln will be evaluated by the Department of Environmental Conservation (DEC) pursuant to the State Environmental Quality Review Act (SEQRA).⁷⁴ Initially, this review serves to determine whether construction and operation of the project will present a significant environmental impact. DEC has indicated that it will make a determination that a proposal to burn hazardous wastes or waste oils in a cement or lightweight aggregate kiln presents a significant environmental impact, and therefore is subject to the full SEQRA review process.

Under SEQRA, any project deemed by DEC to have a significant environmental impact must undergo a detailed environmental analysis through the preparation of an environmental impact statement (EIS). The EIS must address a number of factors, including: a description of the environmental setting and the important environmental impacts of the proposed action; a description of mitigation measures that will be used to minimize identified adverse environmental impacts; and a description and evaluation of any

is required to demonstrate compliance with a set of DEC guidelines which are designed to control hazardous air emissions. These guidelines, contained in "New York State Air Guide-17: Trade and Use of Waste Fuels and Energy Recovery", require the demonstration of an acceptable combustion efficiency and the completion of an ambient air quality impact analysis prior to the burning of Waste Fuel B. Waste fuels containing greater than 5000 ppm organic chlorine or greater than 50 ppm PCBs are also subject to the full range of requirements in New York's hazardous waste regulations, including the completion of a trial burn.

Due to the promulgation of federal waste fuel regulations in November, 1985, the above program for regulating the burning of waste fuels in New York State will likely be revised this year.⁷⁶ For example, the federal regulations for waste fuels lower the maximum lead content for Waste Fuel A to 100 ppm, and raise the acceptable total halogens content of Waste Fuel A to 4000 ppm.

Finally, emissions of toxic compounds from the facility, including fugitive emissions from hazardous waste storage tanks, are regulated under a separate regulatory document, "Air Guide-1: Guidelines for the Control of Hazardous Ambient Air Contaminants." Tanks used to store hazardous waste fuels prior to incineration in a cement or lightweight aggregate kiln are required to utilize Best Available Control Technology (BACT) to insure that air emissions of toxic chemicals meet regulatory requirements. To meet these requirements, storage tanks generally are vented through a carbon filter or directly to the kiln.

C. REQUIRED RCRA PERMITS

In New York State, the Department of Environmental Conservation has received authority from EPA to administer the Resource Conservation and Recovery Act (RCRA), the primary federal statute regulating the handling and disposal of hazardous wastes. Cement and lightweight aggregate kilns proposing to burn hazardous wastes (excludes waste oils) in New York State must comply with two types of RCRA requirements -- general regulations that apply to all hazardous waste treatment, storage and disposal facilities (TSDFs), and special regulations that apply only to hazardous waste incinerators and energy recovery facilities.

New York State's RCRA regulations impose the following general requirements on hazardous waste TSDFs:

- general facility standards: the facility must comply with general facility requirements covering such areas as waste analysis, plant security, inspection

- the exhaust gas must be analyzed for emissions of each POHC and for emissions of oxygen and HCl;
- the destruction and removal efficiency (DRE) must be computed for each POHC;
- the emission of particulates and carbon monoxide must be quantified; and
- fugitive emissions from the incinerator must be identified.

DEC may then issue a final RCRA permit for the facility provided that the trial burn results indicate a DRE of at least 99.99 percent for each specified POHC, and provided that the facility's application also satisfies all general RCRA requirements placed on TSDFs.

Because no real-time monitoring method is currently available for determining the waste destruction performance of hazardous waste incinerators, the final permit will specify a number of operating requirements designed to assure that the 99.99 percent DREs are maintained during normal operation. These operating conditions, which are set on a case-by-case basis, set specifications for:

- combustion temperature: temperatures within the kiln must meet minimum levels. These temperatures are continuously monitored by thermocouples in various parts of the kiln;
- carbon monoxide: the concentration of carbon monoxide in the exhaust gas is closely monitored because it provides an accurate indicator of combustion efficiency within the kiln. In a properly operating incinerator, the oxidation of carbon and hydrogen molecules in organic wastes results in the formation of carbon dioxide and water. The presence of carbon monoxide in the flue gas, which is relatively easy to monitor on a continuous basis, indicates that conditions for complete combustion of wastes are not being met within the kiln;
- waste composition and maximum feed rate: parameters are set for minimum Btu content and maximum allowable concentrations of halogens, PCBs and metallic constituents in the waste feed;
- combustion gas velocity: gas velocity in the kiln is measured to assure that hazardous wastes remain in the burning zone of the kiln for a minimum of two seconds;
- fugitive emissions: because the use of a powerful induced draft fan located at the elevated end of the

storage tanks, materials used to clean up small spills and contaminated protective clothing. These wastes are subject to a series of storage, labeling and reporting requirements. Because these materials can not be injected into the kiln, they must be transported off-site to a permitted TSD facility for disposal. For example, Norlite Corporation, which currently burns 4 to 8 million gallons of waste fuels annually, generates approximately 40 tons of hazardous wastes each year.

D. REQUIRED SITING CERTIFICATE

In addition to meeting applicable air and hazardous waste regulatory standards, a cement or lightweight aggregate facility that commenced burning hazardous waste after February, 1982 is subject to the requirements of New York State's hazardous waste facility siting statute. This statute requires the owner of a new industrial hazardous waste management facility to obtain a certificate of environmental safety and public necessity from a state siting board prior to construction and operation of the facility.

Upon receipt of a completed siting application, the Governor is required to constitute an eight member siting board to review and rule on the proposed hazardous waste management facility. The siting board is comprised of the Commissioners of Transportation, Environmental Conservation, Health and Commerce, the Secretary of State, and three ad hoc members appointed by the Governor, two of whom must be local representatives from the county in which the proposed facility is located. At the same time that the siting board members are appointed, DEC is required to appoint a hearing officer to oversee the consideration of the necessary state environmental permits. A joint adjudicatory hearing is then held by the siting board and the DEC hearing officer to evaluate the applications for a siting certificate and the air and RCRA permits. After the completion of the hearing and a public comment period, the board renders a decision on the siting application based on the environmental impact statement, the hearing record and any other relevant materials.

The siting board is required by law to deny the hazardous waste facility siting certificate if one or more of three conditions are violated:

- residential areas or contiguous populations will be endangered;
- the proposed facility does not conform with a series of technical criteria contained in the siting regulations. These criteria require the board to consider such factors as: proximity to residential areas, airports,

local community prior to submitting its permit applications to DEC. Blue Circle also intends to hold smaller-scale meetings with local government and citizen representatives as the permitting process moves forward.

F. POSITIVE AND NEGATIVE IMPACTS OF THE PERMITTING PROCESS

The current permitting process for cement and light-weight aggregate facilities proposing to burn chemical wastes poses several obstacles to the adoption of this technology. Primarily, the process is time consuming. DEC generally requires several rounds of permit application modifications before a permit is deemed complete. In addition, the permit review process itself, which includes technical evaluation of the project, preparation of an EIS, convening of a siting board and scheduling of public hearings, is inherently time consuming. The entire process, from the initial preparation of draft applications to the issuance of final RCRA and air permits by DEC, generally requires a minimum of 30 to 36 months.

In addition, the permitting process is expensive. A RCRA incinerator permit application typically is a six inch thick document containing up to 1,000 pages of detailed information. Total costs for obtaining a RCRA permit, including engineering consultants, public relations efforts⁸⁶ and legal fees, generally range from \$200,000 to \$500,000.⁸⁷ The cost of a trial burn alone typically exceeds \$100,000.

However, the current RCRA permitting process has one major benefit -- it assures that any proposal to incinerate hazardous wastes at a cement or lightweight aggregate facility will undergo an exhaustive technical and public review. This process serves to identify and address all potential hazards associated with such projects. In order to survive this review, a facility must incorporate a wide range of engineering and operational safeguards to protect public health and the environment.

Furthermore, the fact that three cement and lightweight aggregate facilities located in New York State are pressing forward with RCRA permit applications to burn hazardous wastes suggests that the negative impacts of the current siting process (time, expense, uncertain results) are not significant enough to discourage firms from utilizing this technology. These three facilities are reasonably confident that they will receive their RCRA permits. Therefore, while it may be desirable for DEC to expedite the evaluation of these permit applications, the basic permitting process appears to be a workable format for reviewing proposals to burn hazardous wastes.

VI. DESCRIPTION OF EXISTING AND PROPOSED WASTE FUEL PROJECTS IN NEW YORK STATE

Currently, one lightweight aggregate plant located in New York State is burning hazardous wastes, and two cement facilities are in the process of submitting permit applications to implement this technology. In addition, a second lightweight aggregate manufacturer burned waste oils in the past, but is no longer doing so. This section provides a brief description of the operation and permitting status of these four facilities.

It should be noted that Norlite, Lehigh Cement and Blue Circle Atlantic all plan at present to burn only high-Btu organic solvents and waste oils. Although there are currently no technical barriers preventing these facilities from incinerating other hazardous wastes, such as pesticides and organic chemical products, none of these facilities has proposed accepting such wastes.

A. Norlite

Norlite, a producer of lightweight aggregate, has been burning hazardous wastes at its Cohoes, New York facility since 1979.⁸⁸ This facility receives between 4 and 8 million gallons of waste fuels annually, of which approximately 90 percent consists of a variety of halogenated and non-halogenated organic solvents. The remaining 10 percent consists of waste oils. When sufficient supplies of solvents are available, Norlite utilizes waste fuels to provide all of its energy needs for its two kilns. Wastes are stored at the site in six 24,000 gallon underground storage tanks.

Norlite received air and hazardous waste permits to burn waste fuels from DEC in 1983. At that time, however, facilities burning hazardous wastes for energy recovery were exempt from most RCRA regulations. In 1985, New York State eliminated the energy recovery exemption from the RCRA program. Accordingly, Norlite has submitted an application to DEC for a Part 370 RCRA permit to store and incinerate hazardous wastes. As a part of the permit review process, Norlite anticipates conducting a trial burn in the spring of 1988. Because Norlite began burning hazardous wastes prior to 1979, the facility is not subject to the requirements of New York's hazardous waste facility siting statute, and thus is not subject to review by a state siting board. However, Norlite is subject to full regulatory review under RCRA. Until this permit review is completed, Norlite will continue

C. Blue Circle Atlantic Cement Company

In August, 1987, Blue Circle Atlantic submitted a part 370 RCRA permit application to DEC to burn approximately 20 million gallons of chemical solvents and waste oils annually at its Ravena, New York facility, and is considering applying for a separate permit to burn waste oils as well. Under this proposal, hazardous wastes would be utilized to replace up to 35 percent of their energy requirements presently supplied by coal. Blue Circle Atlantic would operate this project in conjunction with Systec Corporation, a consulting firm that would provide engineering and laboratory services and would act as a fuel broker. This is a new proposal; Blue Circle Atlantic has not burned waste fuels in the past. Therefore, this project will require approval from a State siting board prior to receiving its RCRA permit.

Blue Circle Atlantic has obtained a major demonstration grant from the New York State Energy Research and Development Authority (NYSERDA) to finance a significant portion of the design, permitting, construction and public relations costs of implementing its waste fuel proposal. Assuming this waste fuels project comes to fruition, the NYSERDA grant will provide Blue Circle Atlantic up to \$450,000, or roughly thirty percent of the total costs of the project.

D. Northeast Solite

Northeast Solite, located in Mount Marion, New York currently operates three lightweight aggregate kilns. From 1976 to 1982, Solite burned varying amounts of organic industrial solvents in its facility. During this period, Solite experienced several serious problems associated with the operation of its waste fuels program. Groundwater monitoring wells installed at the site revealed chemical contaminants in water flowing beneath the facility. These contaminants were believed to have originated from leaking storage tanks and/or on-site spills of hazardous wastes. Solite officials contend that the contamination problem disappeared with the cessation of waste burning. However, the facility is currently addressing further ground water contamination problems stemming from settling lagoons that accept wastewater from the facility's air pollution scrubber system.

In addition, it was discovered in 1982 that Solite had unknowingly accepted and incinerated waste oils containing PCBs, in violation of its permit requirements. This discovery prompted DEC to obtain a summary abatement order in October of 1982 prohibiting further waste burning activities at the site.

VII. FINDINGS AND RECOMMENDATIONS

A. SUMMARY OF FINDINGS

1. New York State's long-term hazardous waste management strategy should be to encourage industries to reduce their generation of hazardous waste through source reduction and recycling practices. However, even under a scenario of maximum waste reduction, significant quantities of organic hazardous wastes and waste oils will continue to be generated. At present, high temperature incineration is the preferred technology for managing these wastes. Properly designed hazardous wastes incinerators have the capability to destroy virtually one hundred percent of all types of liquid organic wastes. Unfortunately, however, commercial hazardous waste incineration capacity is extremely limited in New York State.
2. Cement and lightweight aggregate kilns have several characteristics which make them a desirable technology for incinerating hazardous wastes. Combustion gas temperatures and gas residence times in these kilns equal or exceed those generally encountered in other types of commercial hazardous waste incinerators. Data collected during trial burns conducted at a number of cement and lightweight aggregate facilities have demonstrated that these kilns have a destruction and removal efficiency (DRE) of greater than 99.99 percent for liquid organic hazardous wastes. Furthermore, energy recovered through the burning of organic solvents and waste oils can yield substantial energy savings for New York State.
3. Nationwide, 17 cement and 18 lightweight aggregate kilns are burning ignitable hazardous wastes as supplemental fuels. In New York State, one lightweight aggregate manufacturer is currently burning hazardous wastes, and two cement plants are pursuing proposals to implement this technology. As proposed, these three facilities could manage a total of 38 million gallons of liquid hazardous wastes annually.
4. A number of studies have been conducted to characterize air emissions from cement and lightweight aggregate kilns burning hazardous wastes. Air pollutants that have been monitored include: unburned wastes, products of incomplete combustion, dioxins and furans, metals, hydrogen chloride, particulates, and sulfur dioxide. The data collected to date strongly indicate that cement and lightweight aggregate kilns have the ability

regarding the use of these facilities for managing hazardous wastes:

1. The Department of Environmental Conservation must ensure that the two cement and one lightweight aggregate facilities proposing to implement waste fuel projects comply with all relevant environmental standards governing hazardous waste incinerators. At the same time, however, DEC should commit the necessary resources and regulatory personnel to allow for the prompt consideration of permit applications for these facilities. Given the present shortage of commercial hazardous waste incineration capacity in New York State, it is important that the permit review process for these facilities be completed in a timely manner.
2. The Department of Environmental Conservation and cement and lightweight aggregate facilities burning hazardous wastes must jointly assure that waste handling and incineration practices specified in these facilities' RCRA permits are strictly adhered to. Each shipment of hazardous wastes must be carefully analyzed prior to being accepted to prevent unauthorized wastes from being burned. Safety procedures must be faithfully carried out. Storage tanks, piping, monitoring equipment and automatic waste fuel cut-offs must be periodically tested and inspected. These activities are crucial for protecting public health and the environment and for building public confidence in this technology.
3. Although virtually all available evidence indicates that air emissions from properly operated cement and lightweight aggregate facilities burning hazardous wastes do not present environmental or public health risks, it appears that additional testing for several types of air pollutants is warranted. Specifically, additional testing appears necessary to better characterize air emissions of PICs during periods of kiln upset and emissions of metals resulting from the burning of waste oils. Therefore, DEC should consider studying emissions of these compounds during trial burns conducted at facilities proposing to incinerate hazardous wastes and waste oils.
4. In July, 1987, New York State enacted legislation requiring DEC to prepare a statewide hazardous waste facility siting plan (Chapter 618, Laws of 1987). This plan is to include an analysis of the sources, composition and quantity of hazardous wastes generated in the State. The siting plan also is to include a determination of the number, size, type and location of hazardous waste management facilities that will be needed for the proper long-term management of hazardous

GLOSSARY

alkaline	a highly basic environment (exhibiting a pH of greater than 7)
Btu	British Thermal Unit. The quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit
clinker	small nodules, consisting of dicalcium and tricalcium silicate, tricalcium aluminate and tetracalcium aluminoferrite, which are the product of cement kilns. Clinker is ground into a powder along with gypsum to make cement
DEC	N.Y.S Department of Environmental Conservation
dioxins (TCDDs)	a class of 75 chlorinated organic compounds. The term "dioxin" often used to refer to the most toxic of the dioxin isomers -- 2,3,7,8-TCDD
Destruction and Removal Efficiency (DRE)	a measurement (usually expressed in percent) of the ability of an incinerator to destroy hazardous wastes
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
furans (TCDFs)	a class of organic compounds similar in structure to dioxins (see above)
halogen	any of five elements (chlorine, fluorine, bromine, iodine and astatine) which may be combined with numerous types of organic molecules to form a wide variety of highly useful (but difficult to incinerate and often toxic) chemical compounds
lightweight aggregate	a low-weight construction material used in place of sand and gravel or stone in the production of concrete

ENDNOTES

1. Environmental Resources Management, New York State Hazardous Waste Facilities Needs Assessment, Appendix A (Albany: NYSDEC, 1985) pp. 4.2, 5.12.
2. United States Environmental Protection Agency, Assessment of Incineration as a Treatment Method for Liquid Organic Hazardous Wastes (Washington: USEPA, 1985) p. 1.
3. Joe Retzer and Mathew Perl, Assessment of Incineration a Treatment Method for Liquid Organic Hazardous Wastes. Background Report 1: Description of Incineration Technology (Washington: USEPA, 1985) p. 2.
4. New York State Hazardous Waste Treatment Facilities Task Force, Final Report (Albany: NYSDEC, 1985) p. 7.
5. Engineering-Science, Background Information Document for the Development of Regulations to Control the Burning of Hazardous Wastes in Boilers and Industrial Furnaces, Volume I draft manuscript (Washington: USEPA, 1987) p. 3.1.
6. Joseph E. Duckett and David Weiss, "RDF as a Kiln Fuel, in Proceedings of the 1980 National Waste Processing Conference, 9th Biennial (New York: American Society of Mechanical Engineers, 1980) p. 388.
7. Kurt E. Peray, The Rotary Cement Kiln, 2nd Edition, (New York: Chemical Publishing Co., Inc., 1986). The following section describing cement kilns is taken from this work.
8. Ibid., p. 24.
9. Gerhard Stohrer, "Burning Hazardous Wastes in Cement Kilns: Report on a Workshop Held at Clean Sites on April 30, 1986" (Alexandria, VA: Clean Sites, Inc., 1986) p. 24.
10. Engineering-Science, p. 4.13.
11. Ibid., pp. 3.2, 3.10.
12. Marvin Branscome, Summary Report on Hazardous Waste Combustion in Calcining Kilns, draft manuscript (Cincinnati: USEPA, 1985) p. 9.
13. Engineering Science, p. 3.17.
14. F.D. Hall, W.F. Kemner, G. Annamraju, R. Krishnan, M. Taft-Frank and D. Albrinck, Evaluation of the Feasibility of

30. See New York State Department of Environmental Conservation, Permit Applicant's Guidance Manual for the General Facility Standards of 6 NYCRR 373-1 and 373-2 (Albany: NYSDEC August 1986).

31. Environmental Resources Management, Appendix A, pp. 4.2-5.12.

32. Barbara Cardone, Used -- But Useful: A Review of the Used Oil Management Program in New York State (Albany: N.Y.S. Legislative Commission on Toxic Substances and Hazardous Wastes, 1986) p. 11.

33. Environmental Resources Management, Appendix A, p. 4.8.

34. Valentino and Gunnar, p. 31.

35. Donald Henz, "Co-Firing Hazardous Waste Fuels in Industrial Processes -- The Business Decision," presented at the 79th Annual Meeting of the Air Pollution Control Association (Minneapolis: June 22-27, 1986) p. 14.

36. New York State's regulatory fee system is specified in N.Y.S. ECL-72-0402. The Superfund fee schedule is specified in N.Y.S. ECL-27-0923.

37. N.Y.S. ECL-27-0925.

38. N.Y.S. ECL-27-1113.

39. For a survey of trial burns conducted in the United States and Canada, see Mournighan, p. 8 and Engineering-Science, p. 4.20. For Europe, see Knut Trovaay, "Hazardous Waste Incineration in a Cement Kiln," World Cement (March, 1983) pp. 59-62. See also William Viken and Per Waage, "Treatment of Hazardous Waste in Cement Kilns Within a Decentralized Scheme: the Norwegian Experience," UNEP Industry and Environment, Special Issue (1983) p. 75.

40. Paul F. Fennelly, "The Role of Incineration in Chemical Waste Management (Washington: American Institute of Chemical Engineers, 1986). Data collected during trial burns indicates that actual emissions of unburned wastes are less than 1 ppb (see J. Chadbourne and Arthur Helmstetter, "Burning Hazardous Waste In Cement Kilns," presented at the 1st International Hazardous Waste Conference (Toronto: October 19-21, 1982) p. 8.).

41. Air pollutant emission standards set by NYSDEC range from 1 to 500 ppm for most organic solvents (see N.Y.S. Department of Environmental Conservation, "Air Guide-1: Guidelines for the Control of Hazardous Ambient Air Contaminants," (Albany: NYSDEC).).

65. Ibid., p. 32.
66. Ibid., p. 32.
67. 6 NYCRR Part 371.1(e)(2).
68. Peters et al., p. 67.
69. Stohrer, p. 26.
70. Mix and Murphy, p. 66.
71. Hazelwood et al., p. 42.
72. Oppelt, p. 579.
73. Ibid., p. 581.
74. See 6 NYCRR Part 617.
75. The air emission permitting requirements described in this section are found at 6 NYCRR Part 201 and 6 NYCRR Part 225-2.
76. New York State Department of Environmental Conservation "Federal Waste Oils Regulations of November 29, 1985", Memorandum 86-Air-20 (Albany: 1986).
77. See 6 NYCRR Subpart 373-2.
78. See 6 NYCRR Subpart 373-2.15.
79. 6 NYCRR Subpart 373-15(f).
80. Lehigh Cement Company, "Part 373 Permit Application to Operate Alternative Fuel Project" (Cementon, NY: December, 1986) pp. D.16-D.17.
81. Kun-chieh Lee, "Potential Problems with the Current RCRA Incineration Permit Process," Journal of the Air Pollution Control Association 35 (October, 1985) p. 1077.
82. Retzer, p. 24.
83. Lee, p. 1077.
84. Norlite Corporation, "6 NYCRR 373 Renewal Permit Application" (Cohoes, NY: March 1986).
85. New York State's hazardous waste facility siting requirements are found at N.Y.S. ECL-27-1101 et seq. and 6 NYCRR Part 361.
86. Fennelly, no page number.

**DRAFT STRATEGY
FOR COMBUSTION OF HAZARDOUS WASTE**

**U.S. ENVIRONMENTAL PROTECTION AGENCY
MAY 1993**

catalyst for discussion with and input from all interested parties on how best to integrate source reduction and waste combustion and on ways by which we can better assure the public of safe operation of hazardous waste combustion facilities.

This draft combustion strategy consists of a discussion of the goals and objectives for this project and a series of short and longer-term actions that can be taken to achieve our goals. These actions are intended as the starting point for discussions with the public and industry. The list of actions in this document are presented for debate and additional ideas. However, while that discussion is taking place, EPA intends to aggressively pursue several of the interim activities.

II. EPA'S STRATEGIC GOALS

A. Background for the Goals

Combustion is currently a large component of hazardous waste management in the United States. It has become a large component as the nation moved away from land disposal in the 1980's and into treatment to reduce the volume and toxicity of hazardous waste. As this shift occurred in the 1980's, citizens in areas where incinerators or boilers and industrial furnaces (BIFs) are located have increasingly challenged the need for these hazardous waste combustion facilities. Citizens evidence concern that waste combustion is too frequently used where source reduction may be the preferred alternative. Citizens also raise concerns regarding facility siting and potential health risks posed by waste management facilities.

Hazardous wastes being burned today are generated by major segments of American industry, and represent a spectrum of commonly-encountered wastes, including spent solvents, sludges and distillation bottoms, and off-spec organic chemicals and products. About 5 million tons of these highly organic wastes are being combusted each year -- some 40% in incinerators and 60% in BIFs. Based on our most recent data, it appears that substantial excess capacity exists for combustion of hazardous waste, particularly liquid wastes. It should also be recognized that although some additional wastes are untreated today, these wastes will soon be subject to treatment requirements mandated under the Hazardous and Solid Waste Amendments of 1984 (HSWA). These treatment requirements could use up much of today's surplus capacity over the next several years.

Incinerators and BIFs burning hazardous waste are regulated by EPA and authorized states under the Resource Conservation and Recovery Act (RCRA). EPA's incinerator permit regulations, first promulgated in 1981, control emissions of principal organic hazardous constituents (POHCs), hydrochloric acid (HCl), and

demand for combustion and other waste management facilities.

- o To better address public participation in setting a national source reduction agenda, in evaluating technical combustion issues, and in reaching site-specific decisions during the waste combustion permitting process.
- o To develop and impose implementable and rigorous state-of-the-art safety controls on hazardous waste combustion facilities by using the best available technologies and the most current science.
- o To ensure that combustion facilities do not pose an unacceptable risk, and use the full extent of legal authorities in permitting and enforcement.
- o To continue to advance scientific understanding with regard to waste combustion issues.

These goals address the major issues surrounding hazardous waste combustion today and provide an appropriate framework for a broad assessment of how source reduction and combustion of hazardous waste can be integrated into a national waste management program. This assessment will be comprised of many different activities, many of which will be led by the EPA-State Committee. The Committee and other interested parties are encouraged to examine these goals critically and to consider whether and how they can be improved.

III. THE PROCESS FOR PURSUING A NATIONAL STRATEGY

Under RCRA, EPA and the States are partners and co-regulators of the generation, transportation, treatment, storage, and disposal of hazardous waste. EPA therefore is firmly committed to the view that any evaluation of the role of hazardous waste combustion in our hazardous waste management strategy must be undertaken as a joint federal and state effort. To that end, an EPA-State Committee will be formed under the aegis of the EPA-State Operations Committee. As mentioned earlier, the initial charge to this Committee includes components dealing with aggressive source reduction, improvements to technical and permitting standards, alternative treatment technologies, and a better scientific foundation for decision making.

In each of these areas, this draft strategy lays out a series of short and longer-term actions for public discussion. EPA intends to involve all stakeholders in this dialogue. EPA is providing these ideas as a starting point for discussion on

23

- Perform site-specific risk assessments, including indirect exposure, at incinerator and BIF facilities in the permitting process
- Use omnibus permit authority in new permits at incinerator and BIF facilities as necessary to protect human health to impose upgraded particulate matter standards and if necessary additional metal emission controls, and to impose limits on dioxin/furan emissions
- Establish a priority for reaching final permit decisions for incinerators and BIF facilities
- Enhance public participation in permitting of incinerators and BIFs
- Enhance inspection and enforcement for incinerators and BIFs.

The longer-term actions include:

- o Continued efforts to build an aggressive source reduction program, including exploration of the usefulness and feasibility of setting a national capacity reduction goal for generation of combustible waste
- o Investigation of feasibility and risks associated with alternative waste treatment technologies
- o Upgrades to EPA's rules on emission controls at combustion facilities and on continuous emission monitoring techniques
- o Upgrades to EPA's rules on the permitting and public involvement process for combustion facilities

A. Short Term Actions

1. **Integration of Aggressive Source Reduction and Waste Combustion**
 - o Use of permit priorities to stimulate source reduction

Over the next 18 months, as the national dialogue on source reduction is held, EPA will give low priority to permit-related requests for additional combustion capacity except where that capacity offsets the retirement of existing combustion capacity.

251

- o Target generating industries that produce combustible wastes both for source reduction inspections and for requiring generators to conduct waste minimization audits. 2

EPA will give top priority to ensuring compliance with waste minimization requirements/guidance at those facilities that are driving the demand for waste combustion. In addition, at the same facilities, EPA will to the maximum extent possible include audit requirements in enforcement settlement agreements, permits, and as part of corrective action orders. The audits will allow these companies to investigate the maximum possible use of source reduction to the extent that they are not already doing so in partnership with EPA and the states.

- o Maximum public involvement and information regarding source reduction and its integration with waste combustion

EPA will also establish a program to more effectively provide information to the public on the types of wastes going to combustion units and the sources of those wastes. First, EPA will compile information from the Biennial Report and will collect information from commercial combustion facilities. This information -- such as the specific types and volumes of wastes being sent for combustion as well as the generators of these wastes -- will be compiled in a report and be provided to the public. This information will apprise citizens of those industries that rely on combustion of their wastes and will allow the public to better focus their attention on the appropriate generating facilities.

2. Immediate Actions in Combustion Facility Permitting

The Agency's goal is to continuously improve the regulation of hazardous waste combustion to reflect advances in scientific understanding so that adequate protection of human health and the environment is assured. During the time it takes to propose and finalize updates to national regulations, EPA will use its omnibus authority on a case-by-case basis as necessary to protect human health and the environment to include the appropriate conditions in permits being issued.

At this time, EPA believes that regions and states should use the RCRA omnibus provision and RCRA permit modification regulations to add permit conditions as necessary to protect human health and the environment whenever a combustion facility owner/operator is seeking issuance of a new permit or reissuance of an expiring permit, or, in appropriate circumstances, when

interim measure emission limits of 30 ng/dscm (based on the sum of all tetra through octa dioxin and furan congeners). This standard is the same as the New Source Performance Standard for new municipal waste combustors. Regions and states should supplement this with more stringent emission limits if the site-specific risk assessment warrants.

o **Permit Controls on Incinerators and BIFs**

EPA regions and states should bring incinerators and BIFs under permit controls as soon as possible. This will be implemented through establishment of a schedule for calling in all BIF permits for final determinations. Each region will develop a plan that provides for commercial BIF permits to be called in within the next 12 months and for all other BIF permits to be called in within the succeeding 24 months. Permits represent one of the most effective means by which EPA and the authorized states can develop and enforce conditions on the operation of incinerators and BIFs. At this point, no BIFs have had final permit decisions. Thus, permit determinations should be made as expeditiously as feasible to effectively control those operations that can be operated safely as well as deny permits at those facilities that can not be operated safely.

o **Enhanced Public Participation**

Public participation is one of the major cornerstones of EPA's environmental programs. EPA is committed to meaningful public involvement in its permitting programs. Local citizens must be given the opportunity to assure themselves that facilities in their neighborhoods will be operated safely.

EPA will immediately provide for greater public participation in the permitting of BIFs and incinerators, and will initiate amendments to its rules to reflect new avenues for public participation. Prior to these amendments being finally adopted, EPA will direct all regions and states to provide immediately for additional public participation opportunities during permitting of combustion units - particularly at earlier stages than now provided for under EPA's current permitting regulations. These should include, but are not limited to, public comment on the trial burn plan. EPA will also direct that local citizens be given the opportunity to participate during the risk assessment process at combustion facilities.

o **Enhanced Inspection and Enforcement**

EPA will continue and enhance its current enforcement efforts regarding combustion units through aggressive inspection

259

- o Upgrade EPA's rules to reflect state-of-the-art advancements

EPA will initiate a rulemaking to upgrade our combustion rules. In doing so, EPA will explore the feasibility of a technology-based approach, particularly with respect to setting emission controls on metals, dioxins and furans, acid gases, particulate matter, and products of incomplete combustion. In addition, EPA will continue to refine its risk assessment guidelines to ensure that all risks are effectively addressed by national regulations or site-specific permit conditions.

- o Upgrade EPA's rules on permit process for combustion units

While EPA is directing regions and states to immediately afford greater public participation on a permit-by-permit basis, we will seek to modify our rules to reflect expanded public participation. EPA will initiate a rulemaking to codify our goal of increased public participation at earlier stages in the permitting process for incinerators and BIFs. In particular, EPA will address the trial burn process and the public's role in that process.

EPA also believes there is a need to explore a rulemaking to reform the permit appeal process for combustion units whose permit applications have been denied by the Regional Administrator or State Director. In particular, where the unit has been burning waste under interim status, EPA will seek to establish rules that prevent the continued burning of waste during administrative appeals of a permit denial decision. EPA will also explore additional guidance or a rulemaking to clarify the number of permissible trial burns allowed before permit denial.

- o Use and Feasibility of a Long-Term National Capacity Reduction Goal

EPA will explore the usefulness of developing a long-term reduction goal (e.g., a 25% reduction in combustion capacity over the next 10 years) to reduce combustion capacity beyond that which can be achieved through source reduction efforts. The purpose of such a goal would be to give more concrete national guidance on how best to mesh combustion demand with capacity.

251