Chapter 4

Federal Attention to Pulmonary Toxicants

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INTRODUCTION

Congress has enacted a diverse body of laws to help control human exposure to toxicants. These laws require the Federal Government to regulate the public's exposure to toxic substances and to conduct and sponsor research that will improve identification and regulation of toxicants. This chapter describes regulatory and research programs of the Federal Government specifically related to the control and investigation of airborne pulmonary toxicants. The chapter provides examples of Federal activities but is not an exhaustive listing.

FEDERAL REGULATORY ACTIVITIES

Several Federal laws authorize administrative agencies to regulate substances to prevent adverse health effects, including respiratory effects. This section focuses on the laws and regulations used to control human exposures to pulmonary toxicants. The Environmental Protection Agency (EPA) and the Occupational Safety and Health Administration (OSHA), part of the Department of Labor (DOL), implement most of the statutes designed to limit human exposures to environmental and occupational pollutants. The Mine Safety and Health Administration (MSHA), also part of DOL, regulates pollution in the mining industry. The Consumer Product Safety Commission (CPSC) and the Food and Drug Administration (FDA) also have some authority over pulmonary toxicants.

Environmental Protection Agency

EPA administers a variety of laws that require protection of human health and the environment, including the Clean Air Act (CAA; 42 U.S.C. 7401 et seq.), the Resource Conservation and Recovery Act (RCRA; 42 U.S.C. 6901 et seq.), the Toxic Substances Control Act (TSCA; 15 U.S.C. 2601 et seq.), and the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA; 7 U.S.C. 136 et seq.). These statutes authorize EPA to control human exposure to substances that cause adverse human health effects, and the agency has, in fact, regulated some substances on the basis of pulmonary toxicity.

Clean Air Act

The CAA requires EPA to identify airborne substances that may "cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare" and to set national ambient air quality standards (NAAQS) for those 'criteria" pollutants. NAAQS, which apply only to outdoor concentrations of pollutants, have been set for sulfur oxides, particulate matter, carbon monoxide, ozone, nitrogen dioxide, and lead. EPA regulated sulfur oxides, particulate matter, ozone, and nitrogen dioxide because of their adverse effects on the pulmonary system (22,23). Table 4-1 presents the (health-based) primary ambient air quality standard for each criteria pollutant and lists adverse effects on the pulmonary system.

The CAA also requires EPA to control "hazardous air pollutants," defined by law as substances for which no ambient air quality standard can be set and that 'may reasonably be anticipated to result in an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness." Between 1970 and 1984, seven substances were placed on the hazardous air pollutants list: asbestos, benzene, beryllium, inorganic arsenic, mercury, radionuclides, and vinyl chloride (3,23). Coke oven emissions were added to this list in 1984 (3). The 1990 amendments to the CAA substantially augmented the list of hazardous air pollutants—bringing it to 189—and required EPA to regulate them at the level possible under maximum achievable control technology (MACT) (23). Table 4-2 lists hazardous air pollutants known to be pulmonary toxicants.

Incentive Programs Under the CAA. Following adoption of the 1990 amendments to the CAA, EPA developed the Early Reduction Program (ERP), which provides incentives for companies to make immediate, major reductions (90 percent for gases and 95 percent

Table 4-1—National Primary Ambient Air Quality Standards

Pollutant	Primary standard	Effects on the lung
Sulfur oxides	80 micrograms/m^3 0.03 ppm annual arithmetic mean 0.14 ppm maximum 24-hour concentration not to be exceeded more than once a year	Can aggravate asthma, decrease lung function via inflammation; tendency develop allergies
Particulate matter	150 micrograms/m^3 24-hour average concentration 50 micrograms/m^3 annual arithmetic mean	Depending on specific particle, causes decreased lung function, bronchitis, and pneumonia; can aggravate asthma; some can cause fibrosis; increase deaths
Carbon monoxide	10 milligrams/m^3 9 ppm for an 8-hour average concentration not to exceed more than once a year 40 milligrams/m^3 35 ppm for a l-hour average concentration not to be exceeded more than once a year	Can cause death or damage to lungcells by passing into the bloodstream inhibiting the ability of red blood cells to carry oxygen to cells of the body
Ozone	235 micrograms/m^3 0.12 ppm	Can irritate and inflame the lungs, cause shortness of breath, increased susceptibility to respiratory infections, accelerated aging of the lungs, and emphysema; fatal at high concentrations (effects have been shown below the current standard
Nitrogen dioxide	100 micrograms/m^3 0.053 ppm annual arithmetic mean concentration	Can cause acute respiratory disease at high concentrations, increased susceptibility to viral infections; can aggravate asthma; can cause inflammation
Lead	1.5 micrograms/m^3 maximum arithmetic mean averaged over a calendar quarter	Lung acts as site of entry for lead which in turn can damage the nervous system, kidneys, and reproductive system

SOURCES: 40 CFR 50, July 1, 1991; U.S. Congress, *United States Code Congressional and Administrative News, 95th Congress, 1st Sess. 1977* (St. Paul, MN: West Publishing Co., 1977), pp. 1187-88; U.S. Congress, *United States Code Congressional and Administrative News, 101st Congress, 2d Sess., 1990* (St. Paul, MN: West Publishing Co., 1990), pp. 3392-94.

for particulate) in their emissions of hazardous air pollutants. Companies that participate in the ERP will be allowed a 6-year compliance extension after emissions standards (anticipated to require reductions in excess of 90 to 95 percent) are developed. EPA monitors company compliance with the ERP and focuses on specific sources, even sources within a plant's boundaries. Participating companies who fail to make the voluntary reductions will not receive the compliance extension (24).

The ERP covers all 189 hazardous air pollutants listed in the CAA, but it identifies 35 substances deemed 'highly toxic pollutants" as its most important targets. Each of these substances is weighted according to its toxicity, and volume and total toxicity must both

be reduced in order to fulfill the requirements of the ERP (24). Table 4-3 lists substances covered by the ERP that are known to be pulmonary toxicants.

EPA also designed the 33/50 Program to encourage companies to make voluntary reductions in pollutant emissions before MACT standards are in place. The 33/50 Program asks companies to voluntarily reduce aggregate releases and off site transfers of 17 high priority toxic substances by a total of 33 percent by 1992 and a total of 50 percent by 1995. This program does not focus on reducing emissions at or within particular plants but concentrates on national goals (25).

Each substance covered by the 33/50 Program:

- appears on the CAA's list of hazardous air pollutants;
- is included in the Toxic Release Inventory (TRI);
- is a multimedia pollutant on the agenda of every department of EPA
- is produced in large quantities and has a high release to production ratio;
- has been shown to be amenable to pollution control; and
- is known to be toxic to both human health and the environment (8).

Table 4-3 lists the chemicals targeted by the 33/50 Program that are known to be pulmonary toxicants. Participants in the 33/50 Program set their own goals for emissions reductions, and EPA has no enforcement mechanism. Compliance is measured through TRI reporting and is not as closely monitored as in the ERP (24).

Resource Conservation and Recovery Act

RCRA attempts to safeguard public health and the environment by controlling waste disposal. It requires EPA to identify and list hazardous wastes, defined as solid wastes, which due to potency, volume, or physical, chemical, or infectious qualities may:

- cause or considerably add to deaths or serious irreversible or incapacitating reversible illness, or
- create significant present or potential dangers to human and environmental health if improperly handled.

Several chemicals regulated under RCRA have adverse effects on the pulmonary system; see table 4-4.

Toxic Substances Control Act

TSCA calls on EPA to regulate chemicals in premarketing and post-marketing phases to avoid unreasonable risk of injury to public health and the environment. TSCA requires the manufacturer to provide EPA with a pre-manufacturing notice (PMN), including test results on the chemical, at least 90 days before manufacturing begins. If EPA does not request further data within the 90-day period, the manufacturer is free to begin production (2). If EPA finds that the chemical may pose an unreasonable risk to human health or the environment, or that insufficient data exist to make a determination about risk, or that the chemical will be produced in substantial quantities, EPA may require additional testing. This testing is conducted by the chemical manufacturer or processor.

Many of the regulations issued under TSCA (40 CFR 790 et seq.) provide guidelines for testing chemicals. Guidelines exist for testing acute, sub-chronic, and chronic inhalation toxicity. Acute inhalation toxicity testing provides information on health hazards likely to result from short-term exposure to a substance. Acute inhalation tests involve a single, 4- to 24-hour exposure to a particular substance followed by a 14-day observation period. The sub-chronic inhalation tests assess the effects of toxicants from repeated daily exposures to a substance for approximately 10 percent of the animal's lifespan. These tests involve repeated daily exposures for at least 90 days. Chronic toxicity inhalation testing is designed to determine the health effects that are cumulative or have along latency period. These tests involve repeated daily exposures to a substance for at least 12 months.

If tests show that a chemical poses an unreasonable risk to human health or the environment, EPA can limit or prohibit its use, manufacture, and distribution. EPA has taken action under TSCA due to the possibility that certain chemicals pose pulmonary health threats. For example, EPA has required manufacturers to report health and safety study data on 26 diisocyanates because of concern that acute and chronic exposures could cause respiratory tract effects and nose irritation (5). EPA has also required significant new use evaluations for substituted oxirane, substituted al-

Table 4-2-Hazardous Air Pollutants Regulated Under the CAA **Due to Non-Cancer Health Effects on the Pulmonary System**

Chemical	Pulmonary health effect
Acetaldehyde	Respiratory tract irritation
Acrolein	Respiratory tract irritation
Acrylic acid	Lung injury, and possibly death
Allyl chloride	Pulmonary irritation and histologic lesions of the lung
Asbestos	Asbestosis
Benzene	Pulmonary edema and hemorrhage; tightness in chest, breathlessness; unconsciousness may occur and death may follow due to respiratory paralysis in cases of extreme exposure
Benzylchloride	Lung damage and pulmonary edema
Beryllium compounds	Non-malignant respiratory disease and berylliosis
Caprolactam	Upper respiratory tract irritation and congestion
Catechol	Acute respiratory toxicity and upper respiratory tract irritation
Chlorine	Necrosis of tracheal and bronchial epithelium, bronchitis, bronchopneumonia and fatal pulmonary edema
2-Chloroacetophenone	Difficulty in breathing
Chloroprene	Lung irritation
Chromium	Pulmonary disease (unspecified)
Cresol (o-, m-,& p-)	Obliterative bronchiolitis, ademonatosis, and hypersentivity reactions, chronic interstitial pneumonitis and occasional fatalities
Diazomethane	Chest pain, respiratory irritation, damages to mucous membranes
Dichloroethyl ether	Respiratory system irritation and pulmonary damage
1,3-Dichloropropene	Respiratory irritation
Dimethyl sulfate	Lung edema
2,4-Dinitrophenol	Respiratory collapse
l,4-Dioxane (l,4-Diethleneoxide)	Lung edema; can cause death
l,2-Epoxybutane	Lung irritation, edema, and pneumonitis
Epichlorohydrin	Lung edema, dyspnea, bronchitis, and throat irritation
Ethyl acrylate	Respiratory irritation, pneumonia and pulmonary edema
Ethyl benzene	Lung congestion
Ethylene glycol	Throat and respiratory irritation
Ethylene imine(Aziridine)	Lung edema and secondary bronchial pneumonia
Ethylene oxide	Respiratory irritation and lung injury (unspecified)
Formaldehyde	Difficulty breathing, severe respiratory tract injury leading to pulmonary edema, pneumonitis, and bronchial irritation which may lead to death
Hexachlorobutadiene	Pulmonary irritation
Hexachlorocyclopentadiene	Pulmonary irritation, bronchitis, and bronchiolitis
Hexamethylene-1,6-diisocyanate	Pulmonary edema, chronic bronchitis, chronic asthma; pulmonary edema; may be fatal

Table 4-Z-Hazardous Air Pollutants Regulated Under the CAA Due to Non-Cancer Health Effects on the Pulmonary System (Cent'd)

Chemical	Pulmonary health effect
Hydrochloric acid	Pulmonary edema
Hydrogen fluoride	Respiratory tract irritation and lung damage
Hydrogen sulfide	Pulmonary edema
Maleic anhydride	Chronic bronchitis
Methyl bromide	Bronchopneumonia
Methyl ethyl ketone	Upper respiratory tract irritation
Methyl iodide (Iodomethane)	Lung irritation
Methyl isocyanate	Pulmonary edema and lung injury
Methyl methacrylate	Fatal pulmonary edema
Methylene diphenyl diisocyanate (MDI)	Restricted pulmonary function
Napthalene	Lung damage
2-Nitropropane	Pulmonary edema
p-Phenylenediamine	Allergic asthma and inflammation of larynx and pharynx
Phosgene	Extreme lung damage;severe pulmonary edema after a latent period of exposure; bleeding and painful breathing; death
Phosphine	Pulmonary edema and acute dyspnea
Phthalic anhydride	Respiratory irritation and pulmonary sensitization
Propionaldehyde	Fatal pulmonary edema
Propoxur (Baygon)	Severe bronchoconstriction and paralysis of respiratory muscles
Propylene oxide	Pulmonary irritation
l,2-Propylenimine (2-Methyl aziridine)	Diphtheria-like mutations of trachea and bronchi; bronchitis, lung edema, secondary bronchial pneumonia
Styrene	Abnormal pulmonary function, upper respiratory tract irritation, wheezing, chest tightness, and shortness of breath
Tetrachloroethylene (Perchloroethylene)	Acute pulmonary edema
2,4-Toluene diisocyanate	Pulmonary sensitization and long-term decline in lung function
Toxaphene (Chlorinated camphene)	Lung inflammation
1,2,4-Trichlorobenzene	Lung and upper respiratory tract irritation
Trichloroethylene	Lung adenomas
Triethylamine	Vapors cause severe coughing, difficulty breathing, and chest pain; pulmonary edema
2,2,4-Trimethylpentane	Pulmonary lesions
Vinyl acetate	Upper respiratory tract imitation

SOURCES: 42 U.S.C. 7412; Tim Simpson, U.S. Environmental Protection Agency, Research Triangle Park, NC, personal communication, August 1991; 54 *Federal Register 2329-2984* (Jan. 19, 1989).

Table 4-3—Pulmonary Toxicants Controlled Under EPA's Early Reduction and 33/50 Programs

Early Reduction Program	Effect
Asbestos	Asbestosis
Acrolein	Respiratory irritation
Acrylic acid	Lung injury and possible death
Benzene	Pulmonary edema and hemmorhage; tightness of chest, breathlessness; unconsciousness may occur and death may follow due to paralysis in cases of extreme exposure
Beryllium compounds	Non-malignant respiratory disease and berylliosis
Chloroprene	Lung irritation
Chromium compounds	Pulmonary disease and other toxic effects
Dichloroethyl ether	Respiratory system irritation and damage
Methyl isocyanate	Pulmonary edema
Methylene diphenyl diisocyanate (MDI)	Restricted pulmonary function
Phosgene	Extreme lung damage; severe pulmonary edema after a latent period of exposure; bleeding and painful breathing; death
2,4 Toluene diisocyanate	Pulmonary sensitization and long-term decline in lung function
33/50 Program	**Effect**
Benzene	Pulmonary edema and hemmorhage; tightness of chest, breathlessness and unconsciousness may occur and death may follow due to respiratory paralysis in cases of extreme exposure
Chromium & chromium compounds	Pulmonary disease and other toxic effects
Methyl ethyl ketone	Upper respiratory tract irritation
Nickel & nickel compounds	Pulmonary irritation, pulmonary damage, hyperplasia, and interstitial fibrotic lesions
Tetrachloroethylene	Acute pulmonary edema
Trichloroethylene	Lung adenomas

SOURCES: U.S. Environmental Protection Agency, Office of Air and Radiation, "Early Reduction Program," unpublished memo, Washington, DC, July 1991; U.S. Environmental Protection Agency, "EPA's 33/50 Program: A Progress Report," unpublished memo, Washington, DC, July 1991; Tim Simpson, U.S. Environmental Protection Agency, Research Triangle Park, NC, personal communication, August 1991; 54 *Federal Register 2329-2984* (Jan. 19, 1989).

kyl halides, and perhalo alkoxy ether due to the threat of pulmonary edema. EPA imposed the same requirement on silane because data showed that it causes irreversible lung toxicity (6).

Federal Insecticide, Fungicide, and Rodenticide Act

FIFRA was enacted to help avoid unreasonable adverse effects on the environment, including humans, due to exposure to pesticides. It requires those who sell or distribute pesticides to register the product with EPA. A product maybe classified and registered for general or restricted use, or both. If a pesticide is classified for restricted use because it poses an inhalation toxicity hazard to the applicator or other persons, then the product may only be applied by or used under the direct supervision of a certified applicator. Substances that pose inhalation hazards are substances that are dangerous to some organ and that enter the body through the lung. Not all inhalable toxicants af-

Table 4-4-Regulated Levels of Pulmonary Toxicants Under RCRA

Contaminant	Pulmonary effect	Regulatory level (mg/L)
Arsenic	Respiratory irritation and inflammation	5.0
Benzene	Pulmonary edema and hemmorhage; tightness of chest, breathlessness and unconsciousness may occur and death may follow due to respiratory paralysis in cases of extreme exposure	0.5
Chromium	Pulmonary disease and other toxic effects	5.0
Cresol (o-, m- & p-)	Obliterative broncholitis, adenomatosis, and hypersensitivity reactions; chronic interstitial pneumonitis and occasional fatalities	200.0
Methyl ethyl ketone	Upper respiratory tract irritation	200.0
Tetrachloroethylene	Acute pulmonary edema	0.7
Toxaphene	Lung inflammation	0.5

SOURCES: 40 CFR261.24, July 1, 1991; Tim Simpson, U.S. Environmental Protection Agency, Research Triangle Park, NC, personal communication, August 1991; 54 *Federal Register 2329-2984* (Jan. 19, 1989).

Table 4-5—Pulmonary Toxicants Regulated Under FIFRA

Active ingredient in pesticide	Criteria influencing restriction
Acrolein	Respiratory tract irritant
Allyl alcohol	Upper respiratory tract irritant
Hydrocyanic acid	Upper respiratory tract irritant
Methyl bromide	Lung irritant; causes pulmonary edema
Methyl parathion	Excessive exposure may cause bronchoconstriction
Paraquat (dichloride) and paraquat bis(methyl sulfate)	Pulmonary irritant; can cause pulmonary edema, intra-alveolar hemmorhage, and death

SOURCES: 40 CFR 152.175, July 1, 1991; 54 *Federal Register 2329-2984* (Jan. 19, 1989).

feet the lung; table 4-5 lists active pesticide ingredients regulated under FIFRA that are pulmonary toxicants.

Department of Labor

Two entities within DOL regulate human exposure to airborne toxicants. OSHA administers the Occupational Safety and Health Act (OSH Act; 29 U.S.C. 651 et seq.). MSHA administers the Federal Mine Safety and Health Act (FMSHA; 30 U.S.C. 801), which operates similarly to the OSH Act but is restricted to the mining industry.

Occupational Safety and Health Administration

OSHA's task is to develop regulations for the use of toxic substances in the workplace. OSHA can require specific handling procedures, training for workers, recordkeeping, and testing of hazardous materials. It can also establish or modify permissible exposure limits (PELs) for toxic substances. Many substances are regulated by OSHA because of their detrimental effects on the pulmonary system. Table 4-6 lists air contaminants regulated by OSHA because of pulmonary toxicity.

Table 4-6-Air Contaminants Regulated by OSHA Because of Pulmonary Effects

Substance	Effects
Acetyladehyde	Respiratory tract irritation
Acetic acid	Bronchial constriction, respiratory tract irritation, bronchitis, and pharyngitis
Acetic anhydride	Nose and throat irritation; bronchial and lung irritation
Acetone	Pharyngial and lung irritation; inflammation of respiratory tract; irritation and infections of respiratory tract
Acetylsalicyclic acid	Respiratory tract irritation
Acrolein	Respiratory irritation
Acrylic acid	Lung injury and possible death
Allyl alcohol	Upper respiratory tract irritation
Allyl chloride	Histologic lesions of the lung and pulmonary irritation
Allyl glycidyl ether	Respiratory irritation
Allyl propyl disulfide	Upper respiratory tract irritation
Aluminum	Pulmonary fibrosis and respiratory irritation
Ammonia	Upper respiratory tract irritation
Ammonium chloride fume	Respiratory tract irritation
Arsenic	Respiratory irritation and inflammation
Asbestos	Causes asbestosis
Barium sulfate..	Upper respiratory tract imitation and pneumoconiosis
Benzene	Pulmonary edema and hemorrhage; tightness of chest, breathlessness; unconsciousness may occur and death may follow due to respiratory paralysis in cases of extreme exposure
Benzyl chloride	Shown to cause lung damage and pulmonary edema in animals
Beryllium & beryllium compounds	Non-malignant respiratory disease and berylliosis
Bismuth telluride	Granulomatous lesions in lungs
Berates	Upper respiratory tract irritation
Boron oxide...	Upper respiratory tract imitation
Boron tribromide	Pneumonia and pneumonitis
Bromine	Respiratory tract irritation and lung edema
2-Butoxyethanol	Toxic lung changes
n-Butyl acetate	Respiratory imitation
n-Butyl lactate	Upper respiratory tract imitation
o-sec-Butylphenol	Respiratory tract irritation
Calcium hydroxide	Severe caustic irritation to upper respiratory tract
Calcium oxide	Inflammation of respiratory tract and pneumonia
Camphor	Inflammation of upper respiratory tract;dyspnea
Caprolactam	Congestion and irritation of upper respiratory tract
Captofol (Difolatan)	Respiratory sensitization
Carbonyl fluoride	Respiratory tract irritation
Catechol	Acute respiratory toxicity and upper respiratory tract irritation
Cesium hydroxide	Respiratory tract irritation
Chlorine	Necrosis of tracheal and bronchial epithelium, bronchitis, broncho pneumonia and fatal pulmonary edema
Chlorine dioxide	Respiratory irritation and bronchitis
a-Chloroacetophenone	Difficulty in breathing
Chloroacetyl chloride	Respiratory irritation, cough, dyspnea, and pulmonary edema

Table 4-6-Air Contaminants Regulated by OSHA Because of Pulmonary Effects (Cent'd)

Substance	Effects
o-Chlorobenzylidene malononitrile	Upper respiratory tract incitation and dyspnea
Chromium metal	Pulmonary disease (unspecified)
Coal dust (greater and less than 5 percent quartz)	Pneumoconiosis and fibrosis after long-term exposure
Cobalt (metal, dust, and fume)	Obliterative bronchiolitis adenomatosis, asthma, and chronic interstitial pneumonia
Cobalt carbonyl	Coughing and dyspnea
Cobalt hydrocarbonyl	Lung damage (unspecified)
Cotton dust	Byssinosis
Cresol (all isomers)	Obliterative bronchiolitis; adenomatosis; hypersensitivity reactions; chronic interstitial pneumonitis and occasional fatalities
Cyanogen chloride	Pulmonary edema and upper respiratory tract irritation
Cyclohexanone	Respiratory tract irritation
Cyhexatin	Respiratory irritation
1,2-dibromo-3-chloropropane	Upper respiratory tract irritation
Dibutyl phosphate	Respiratory tract irritation
Dichloroacetylene	Pulmonary edema
Dicholorethyl ether	Lung injury (unspecified)
1,3-dichloropropene	Respiratory irritation
2,2-dichloropropionic acid	Respiratory irritation
Dicyclopentadiene	Respiratory irritation and lung hemorrhage
Diethylamine	Tracheitis, bronchitis, pneumonitis, and pulmonary edema
Diethylene triamine	Respiratory tract sensitization
Diglycidyl ether	Respiratory irritation
Diisobutyl ketone	Upper respiratory tract irritation
Dimethyl sulfate	Lung edema
Dioxane	Pulmonary edema; can cause death through repeated exposures at low concentrations
Divinyl benzene	Respiratory irritation
Emery	Respiratory tract irritation and pneumonconisis
Epichlorohydrin	Lung edema, respiratory tract irritation, dyspnea, and bronchitis
Ethanoamine	Lung damage (unspecified)
Ethyl acrylate	Respiratory irritation, pneumonia and pulmonary edema
Ethyl benzene	Lung congestion
Ethyl bromide	Respiratory tract irritation; lung irritation and congestion
Ethyl silicate	Lung damage (unspecified)
Ethylene chlorohydrin	Respiratory tract and lung irritation
Ethylene glycol	Respiratory tract irritation
Ethylene imine	Lung edema and secondary bronchial pneumonia
Ethylene oxide	Respiratory irritation and lung injury (unspecified)
Ferbam	Upper respiratory tract irritation
Ferrovanadium dust	Chronic bronchitis and chronic lung inflammation
Formaldehyde	Difficulty breathing, severe respiratory tract injury leading to pulmonary edema, pneumonitis, and bronchial irritation which may lead to death depending on concentration of exposure; chronic exposure may lead to development of bronchitis and asthma

Table 4-6-Air Contaminants Regulated by OSHA Because of Pulmonary Effects (Cent'd)

Substance	Effects
Furfural	Respiratory tract irritation
Furfuryl alcohol	Asthma
Gluteraldehyde	Upper respiratory tract irritation
Glycidol	Respiratory tract and lung irritation, pneumonitis and emphysema
Grain dust (oat,wheat,barley)	Chronic bronchitis, asthma, dyspnea, wheezing, and reduced pulmonary function
Graphite	Pneumoconosis and anthracosilicosis
Hexachlorobutadiene	Pulmonary irritation
Hexachlorocyclopentadiene	Pulmonary irritation, bronchitis, and bronchiolitis
Hexalene glycol ”	Respiratory irritation
Hydrogen bromide	Upper respiratory tract irritation
Hydrogen cyanide	Upper respiratory tract irritation and dyspnea
Hydrogen fluoride	Respiratory tract irritation
Hydrogen sulfide	Pulmonary edema; fatal at high concentrations
Hydrogenated terphenyls	Lung damage (unspecified)
Indene	Chemical pneumonitis, pulmonary edema and lung hemorrhage
Indium & Indium compounds	Widespread alveolar edema
Iron oxide	Siderosis
Iron pentacarbonyl	Pulmonary injury and dyspnea
Isoamyl alcohol	Upper respiratory tract irritation
Isophorone diisocyanate	Respiratory tract irritation, decreased pulmonary function, and sensitization
n-Isopropylamine	Respiratory tract irritation
Isopropy glycidyl ether	Upper respiratory tract irritation
Kaolin	Respiratory effects (unspecified)
Ketene	Respiratory tract irritation and pulmonary edema
Limestone	Upper respiratory tract irritation
Magnesium oxide fume	Chronic respiratory disease (unspecified)
Maleic anhydride	Chronic bronchitis
Manganese cyclopentadienyl tricarbonyl	Pulmonary edema
Manganese fume	Pneumonia and lung damage (unspecified)
Manganese tetroxide	Pneumonitis and other respiratory effects
Methyl acetate	Pulmonary irritation
Methyl bromide	Bronchopneumonia, lung irritation, and pulmonary edema
Methyl demeton	Lung congestion
Methyl ethyl ketone	Upper respiratory tract irritation
Methyl ethyl ketone peroxide	Upper respiratory tract irritation and lung damage (unspecified)
Methyl formate	Pulmonary edema, lung inflammation, and dyspnea
Methyl iodide	Lung irritation
Methyl isocyanate	Pulmonary edema and lung irritation
Methyl mercaptan	Pulmonary edema
Methyl methacrylate	Fatal pulmonary edema
Methyl parathion	Bronchioconstriction
Methyl cyclohexanol	Respiratory irritation
Methylene bis(4-cyclohexylisocyanate)	Pulmonary irritation

Table 4-6-Air Contaminants Regulated by OSHA Because of Pulmonary Effects (Cent'd)

Substance	Effects
Mica	Symptoms resembling those of silicosis and pneumoconiosis
Morpholine	Thickened alveoli, emphysema, and respiratory irritation
Nickel (soluble compounds)	Pulmonary irritation, interstitial fibrotic lesions, hyperplasia
Nitric acid	Chronic bronchitis and pneumonitis
Nitrogen dioxide	Chronic bronchitis, emphysema, and decreased lung capacity
2-Nitropropane	Pulmonary edema from severe exposure
Oil mist(mineral)	Respiratory tract irritation
Osmium tetroxide	Respiratory irritation
Oxalic acid	Respiratory tract irritation
Oxygen difluoride	Pulmonary edema and hemorrhage
Ozone	Significant reduction in pulmonary vital capacity and pulmonary congestion
Paraquat	Pulmonary irritation, pulmonary edema, and intra-alveolar hemorrhage
Particulates (not otherwise regulated)	Upper respiratory tract irritation
Perchloryl fluoride	Alveolar hemorrhage, emphysema, and alveolar edema
Phenol	Guinea pigs died after inhalation exposure; no human inhalation data
Phenyl glycidyl ether	Respiratory tract irritation
p-Phenylenediamine	Allergic asthma and inflammation of the larynx and pharynx from industrial exposure
Phenylhydrazine	Lung adenomas
Phenyl mercaptan	Lung toxicity
Phosgene	Extreme lung damage; severe pulmonary edema after latent period of exposure; bleeding and painful breathing; causes death
Phosphine	Pulmonary edema and acute dyspnea; at concentrations of 400 t0 600 pm death may occur 30 minutes to 1 hour after exposure
Phosphoric acid	Respiratory irritation
Phosphorous oxychloride	Respiratory tract irritation and pulmonary edema
Phosphorous pentasulfide	Respiratory irritation
Phosphorous trichloride	Bronchitis and pneumonia
Phthalic anhydride	Respiratory irritation and pulmonary sensitization
Picric acid	Edema, papules, vesicles, and desquamations of the nose
Piperazine dihydrochloride	Pulmonary sensitization
Portland cement	Respiratory irritation
Potassium hydroxide	Respiratory irritation
Propionic acid	Respiratory tract irritation
n-Propyl acetate	Respiratory irritation
Propylene oxide	Respiratory irritation
Rhodium compounds	Respiratory sensitization
Rosin core solder pyrolysis products	Upper respiratory tract irritation
Rouge	Upper respiratory tract irritation
Silica	Silicosis
Silicon	Pulmonary lesions
Silicon carbide	Aggravates pulmonary tuberculosis
Silicon tetrahydride	Upper respiratory tract irritation
Soapstone	Pneumoconiosis

Table 4-6-Air Contaminants Regulated by OSHA Because of Pulmonary Effects (Cent'd)

Substance	Effects
Sodium azide	Bronchitis
Sodium bisulfite	Respiratory irritation
Sodium hydroxide	Upper respiratory tract irritation and pneumonitis
Stoddard solvent	Lung congestion and emphysema
Styrene	Upper respiratory tract imitation and abnormal pulmonary function
Subtilisins	Bronchoconstrictions and respiratory tract irritation
Sulfur dioxide	Accelerated loss of pulmonary function, bronchoconstriction, and dyspnea
Sulfur monochloride	Lung irritation
Sulfur pentafluoride	Lung congestion, lesions, and pulmonary edema
Sulfur tetrafluoride	Emphysema, pulmonary edema, and difficulty breathing
Sulfuryl fluoride	Pulmonary edema
Talc	Pneumoconiosis, pleural thickening and calcification,reduced pulmonary function, and fibrotic changes in lung tissue
Tantalum	Lung lesions, bronchitis, hyperemia, and interstitial pneumonitis
Terphenyls	Respiratory tract irritation
Tetrachloroethylene	Long-term decline in lung function and pulmonary edema
Tetrasodium pyrophosphate	Respiratory tract irritation
Tin oxide	Stannosis and reduced pulmonary capacity
Toluene-2,4-diisocyanate	Pulmonary sensitization and long term decline in lung function
Toxaphene	Lung inflammation
Tributyl phosphate	Lung toxicity
1,2,4-Trichlorobenzene	Upper respiratory tract irritation
1,2,3-Trichloropropane	Upper respiratory tract irritation
Triethylamine	Pulmonary irritation
Trimellitic anhydride	Intra-alveolar hemorrhage
Trimethyl phosphite	Lung irritation
Trimethylamine.	Upper respiratory tract irritation
Trimethylbenzene	Asthmatic bronchitis
Tungsten &tungsten compounds (insoluble)	Proliferation of intra-alveolar septa, pulmonary fibrosis, and dyspnea
Vanadium dust	Bronchial irritation and tracheobronchitis
Vanadium fume	Bronchitis, emphysema, tracheitis, pulmonary edema, and bronchial pneumonia
Vinyl acetate	Upper respiratory tract irritation
VM&P Naphtha	Upper respiratory tract irritation
Welding fumes	Damage to small airways causing interstial pneumonia; respiratory irritation
Wood dust	Allergic respiratory effects, decrease in pulmonary function
Zinc chloride fume	Damage to respiratory tract, severe pneumonitis, and advanced pulmonary fibrosis
Zinc oxide fume	Shortness of breath and pneumonia
Zinc oxide dust	Respiratory effects (unspecified)
Zinc stearate	Pulmonary fibrosis
Zirconium compounds	Granulomas in the lung

SOURCES: 29 CFR 1910.1000, July 1, 1991; 29 CFR 1910.1001, July 1, 1991; 29 CFR 1910.1018, July 1, 1991; 29 CFR 1910.1028, July 1, 1991; 29 CFR 1910.1044, July 1, 1991; 29 CFR 1910.1043, July 1, 1991; 29 CFR 1910.1044, July 1, 1991; 29 CFR 1910.1047, July 1, 1991; 29 CFR 1910.1048, July 1, 1991; 53 *Federal Register* 21062 (June 7, 1988); 54 *Federal Register* 2329-2984 (Jan. 19, 1989).

Mine Safety and Health Administration

MSHA develops regulations to protect the health and safety of miners. It administers FMSHA, which is clearly concerned about pulmonary toxicants. FMSHA uses the framework for health guidelines presented in the Federal Coal Mine Health and Safety Act of 1%9, which was primarily concerned with black lung disease, a form of pneumoconiosis common to coal miners (21,22). The statute and regulations require air sampling, medical examinations for miners, and dust control measures. A stated purpose of the health standards was to ensure that mines are "sufficiently free of respirable dust concentrations . . . to permit each miner the opportunity to work underground during the period of his entire adult working life without incurring any disability from pneumoconiosis or any other occupation-related disease during or at the end of such period."

Other Federal Regulatory Activities

EPA and DOL exercise the main regulatory authority over airborne pulmonary toxicants. Other agencies also administer laws that can be used to control these substances, however. CPSC enforces the Consumer Product Safety Act (CPSA; 15 U.S.C. 2051 et seq.) and the Federal Hazardous Substances Act (FHSA; 15 U.S.C. 1261 et seq.). The FDA regulates chemicals found in foods, drugs and cosmetics under the Federal Food, Drug, and Cosmetic Act (FDCA; 21 U.S.C. 301 et seq.).

Consumer Product Safety Commission

The CPSC conducts research on injuries and diseases caused by consumer products and disperses information. The commission is also charged with the duty of generating consumer product safety standards and monitoring compliance.

Consumer Product Safety Act—CSPA is intended to protect the American public from undue risk of injury from consumer products and to help consumers judge the comparative safety of articles available in the marketplace. CPSA gives CPSC the authority to ban or recall hazardous products. Few regulations issued under CPSA (16 CFR 1000 et seq.) deal specifically with health hazards to the pulmonary system posed by unsafe consumer products. However, several products containing asbestos are mentioned specifically as banned materials. Consumer patching compounds containing respirable free-form asbestos are prohibited on the American market. Also, artificial emberizing materials (e.g., artificial fireplace logs) containing respirable free-form asbestos are forbidden. The regulations for these products specify the reason for the ban as the unreasonable risk of lung cancer, noncancerous lung diseases and injury due to inhaling asbestos fibers.

Federal Hazardous Substances Act. FHSA is intended to protect the public from health problems by requiring that hazardous substances be labeled to warn individuals of associated health risks. Regulations issued under FHSA control a number of pulmonary toxicants, including formaldehyde, which is a strong sensitizer (a substance that causes normal living tissue, through an allergic or photodynamic process, to become severely hypersensitive on re-exposure to the substance).

The regulations also control "hazardous substances," which are defined as materials that have the potential to cause substantial personal injury or substantial illness as a result of any customary or reasonably foreseeable use or handling. Benzene, products containing 5 percent or more by weight of benzene, and products containing 10 percent or more by weight of toluene, xylene, turpentine, or petroleum distillates (e.g., kerosene, naphtha, and gasoline) are listed as hazardous substances. Such products must be clearly labeled with several words and symbols including "danger" and "harmful or fatal if swallowed" since these materials may be aspirated into the lungs causing chemical pneumonitis, pneumonia, and pulmonary edema.

Food and Drug Administration

FDA regulates chemicals found in foods, drugs, and cosmetics, primarily through FDCA. Some of FDA's actions under this statute have been taken to protect pulmonary health. For example, sulfites are subject to a number of FDA regulatory requirements because they have been found to cause severe, and potentially lethal, asthma attacks in sensitive individuals. Sulfites are no longer considered safe for use in meats, fruits and vegetables to be served or sold raw or presented to consumers as fresh (21 CFR 182). The presence of sulfites in food must be declared when these chemicals

are present at levels above 10 parts per million. However, FDA has not regulated airborne substances because of pulmonary toxicity.

FEDERAL **RESEARCH ACTIVITIES**

Knowledge of the pulmonary system and the mechanisms and causes of pulmonary disease helps Federal agencies create effective regulations. Federal research in these areas is conducted mainly under the direction of EPA the Department of Health and Human Services (DHHS), and the Department of Energy (DOE). EPA's Health Effects Research Laboratory (HERL) conducts research in pulmonary toxicology and epidemiology. DHHS conducts noncancer pulmonary research through several agencies, including the National Institutes of Health (NIH), the Centers for Disease Control (CDC), and the FDA. The Office of Health and Environmental Research, part of the Office of Energy Research, handles DOE's research in pulmonary toxicology.

Environmental Protection Agency

Two divisions within HERL conduct research on pulmonary toxicants. The Environmental Toxicology Division, through its Pulmonary Toxicology Branch, primarily tests the effects of air pollutants on animals to develop a basis for regulations under the CAA. In addition, it conducts pulmonary research with volatile organic compounds, sulfuric acid, and nitric acid. The Clinical Research Branch of the Human Studies Division conducts research on the effects on humans from exposures to ozone and other criteria pollutants regulated under CAA. The Epidemiology Branch of the Human Studies Division also carries out epidemiologic studies on the criteria pollutants.

HERL, located in Research Triangle Park, NC, collaborates with the University of North Carolina Center for Environmental Medicine and Lung Biology (CEMLB), which provides important support for the clinical and epidemiologic studies. HERL also works with the Duke University Center for Extrapolation Modeling, which works to confirm that animal models used in the Toxicology Division accurately predict responses in humans, and develops generic models to be used in risk assessment programs.

HERL's work in pulmonary toxicology takes several forms. The laboratory studies extrapolation techniques-applying knowledge gained from animal test results to human risk. HERL also performs acute exposure studies and attempts to apply those results to chronic exposure scenarios. HERL is engaged in the effort to define adversity of response, i.e., deciding at what point a response, which may be a normal compensatory activity of the body, can be considered "adverse." HERL also focuses on susceptible populations, such as asthmatics, to determine why some persons exhibit more detrimental effects from air pollution than others.

Current funding for the Pulmonary Toxicology Branch is approximately $2.6 million. The Clinical Research Branch is funded at a level of about $4.1 million, and the Epidemiology Branch receives approximately $2.4 million (4,15).

Department of Health and Human Services

The National Institute of Environmental Health Sciences (NIEHS), part of the NIH, had a budget of approximately $5,230,000 for intramural noncancer pulmonary research in fiscal year 1991. NIEHS also made over $15 million in extamural grants to various universities and institutions in fiscal year 1991 for study of pulmonary toxicants. An additional $3,190,000 was spent on extramural contracts. The studies funded employ a wide range of techniques, including microbiology, whole animal studies, human clinical studies, and epidemiology. Substances researched include those affecting small sub-groups of the population, as well as those affecting the general population. The following projects provide examples of the extramural research funded by NIEHS.

- Scientists at the University of Iowa Department of Medicine received approximately $77,000 to study the effects of silica on the epithelial cells of the lungs in order to better understand how silicosis can be prevented.
- Researchers at the Medical College of Wisconsin received over $77,000 to study growth factor secretion in dust-induced lung disease in rats. This study was undertaken in order to clarify how alveolar

macrophages react to dust, eventually leading to pneumonconiosis.

.The National Jewish Center for Immunology and Respiratory Medicine received nearly $76,000 to study the immunologic and toxic mechanisms of beryllium disease in mice and humans in order to better understand the pathology of chronic beryllium disease in humans.

.Scientists at the University of California at Davis received $530,000 to study the effects of ozone on the lungs of rats, mice, hamsters, and monkeys as a basis to predict the effects of ozone in ambient air on humans.

. Researchers at the University of Rochester School of Medicine received $175,000 to conduct clinical inhalation studies on healthy humans and those with chronic pulmonary disease to investigate the respiratory effects of particulate and oxidant air pollutants (26).

.Scientists at the University of Iowa Pulmonary Disease Division received close to $53,000 to conduct epidemiologic studies of vegetable dust-induced airway disease in humans. The purpose of this study is to evaluate the feasibility of using the current threshold safety limit in the handling of cereal grain (oats, wheat, rye and barley) to protect the health of noncereal grain and vegetable (corn and soybean) handlers.

.Harvard University received $864,000 to conduct an epidemiologic study of the effects of acid aerosols, ozone, and particulate matter on the respiratory health of children in 24 cities in North America.

Using a model of asbestosis in laboratory animals, NIEHS intramural scientists have found that as macrophages engulf asbestos particles, growth factors are secreted that induce an increase in the number of fibroblasts. The fibrotic condition that results disrupts gas exchange. Current studies focus on stopping the release of the growth factors or preventing their biological activity. In fiscal year 1991, this project received funding of nearly $821,000 (19).

Other NIEHS intramural scientists are studying the regulation of the pulmonary surfactant system and its modification by toxic agents such as silica dusts. These studies are focused on identifying cellular factors released by inflammatory cells in response to a toxic agent that regulates surfactant production in alveolar Type II cells. This project received almost $575,000 in fiscal year 1991 (19).

NIEHS also contracts for a variety of inhalation toxicology studies on drugs, naturally occurring agents, and industrial compounds. For example, the IIT Research Institute in Chicago, IL, was awarded over $495,000 to investigate the toxicity of isobutyl nitrite (IBN). IBN is a component of some room deodorizers and is sold illicitly in ampules known as "Poppers." In the prechronic study, the lungs, bone-marrow, spleen, and nasal-cavity were identified as target organs for toxicity (19).

The National Heart, Lung, and Blood Institute (NHLBI), also part of NIH, conducts noncancer pulmonary research through its Division of Lung Diseases. This program includes studies on environmental lung disease caused by air pollutants and occupational lung disease. Approximately half of this research is carried out on animals and the other half is done on human subjects.

Extramural grants from NHLBI support research on pulmonary toxicology at a number of universities. Examples of environmental research include:

- Researchers at Louisiana State University are currently studying the effects of ozone, automobile exhaust, and tobacco smoke on the lung. This project is funded at approximately $127,000 per year.
- Scientists at the State University of New York at Stony Brook are studying ozone and respiratory mucus permeability, and receive about $79,000 for this project.
- Researchers at Pennsylvania State University are conducting tests on oxidant stress in the respiratory system at a funding level of approximately $185,000 per year.
- Two groups of scientists at the University of California at Irvine are conducting human research on inhaled particle deposition and animal research on the effects of air pollution. They receive approximately $325,000 per year for these studies.
- Researchers at the University of Maryland received approximately $100,000 to study the effect of environmental tobacco smoke on human lungs.
- Scientists at the University of California at Berkeley receive approximately $240,000 to conduct a human study of the physical and chemical proper-

ties of smoke and of the deposition of smoke particles in the lung.

- Researchers at Harvard University are conducting human and animal studies of inhaled retention of particulate matter, for which they receive approximately $134,000 per year.
- Scientists at the University of California at Santa Barbara received funding of about $190,000 for a study of the mechanisms of human response to ozone.

A number of research projects supported by NHLBI relate to occupational exposure to pulmonary toxicants. For example:

- Specialized Centers of Research (SCOR) investigators at the University of Iowa are studying the epidemiology and pulmonary responses to organic dust exposures in farm workers, for which they have received $127,000.
- The Iowa investigators and investigators at the University of New Mexico, are studying mechanisms of hypersensitivity pneumonitis, also known as farmer's lung, for which they have received over $135,000.
- A group of SCOR researchers at Tulane University received approximately $933,000 for a study of the respiratory effects of exposure to irritant gases and vapors in a population of 25,000 workers in the chemical manufacturing industry.
- At the University of Vermont, SCOR scientists received over $230,000 for an assessment of the mechanisms involved in injury and inflammation in occupationally related fibrotic lung disease associated with exposure to asbestos.
- Researchers at the State University of New York at Buffalo received $354,054 for a study of the pathogenesis of disease associated with exposures in the textile industry.

For fiscal years 1992 and 1993, the Division of Lung Diseases is developing two special initiatives. One is related to the mechanisms of ozone-induced lung injury and a second is on basic mechanisms of asbestos and nonasbestos fiber-related lung disease (13,14). NHLBI conducts basic research not specifically linked to any particular legislation or regulations. For fiscal year 1991, the total budget for lung research was $205,255,000; of that, $26,980,000 was dedicated to research on asthma, and approximately $22,619,000 was used to study chronic bronchitis and emphysema (12).

The National Institute for Occupational Safety and Health (NIOSH), part of the CDC, studies the pulmonary system through its Division of Respiratory Disease Studies (DRDS) at the Appalachian Laboratories for Occupational Health and Safety at Morgantown, WV. In addition, an extramural grant program is directed through NIOSH's administrative offices in Atlanta, GA. The overall budget for NIOSH in fiscal year 1992 is $103,450,000 with $13,400,000 designated for the study of occupational respiratory diseases. This is an increase from the approximately $7,687,112 allocated to intramural research and $3,1%,218 spent on extramural research in the area of occupational lung disease in fiscal year 1991 (7,16).

NIOSH conducts research stimulated by the advice of DOL and investigator initiated research. Additionally, the Mine Health Research Advisory Committee suggests areas of study where gaps exist in the knowledge base. Other research suggestions come from NIOSH's Board of Scientific Counselors. NIOSH has specific authority from the OSH Act and FMSHA to conduct research and to make recommendations for health and safety standard regulations (27).

DRDS conducts epidemiologic research on pulmonary diseases related to the mining, milling, agricultural, construction, and other industries. Among the research programs in this area are a medical surveillance program for living coal miners (the National Coal Worker's X-ray Surveillance Program), and an autopsy program (the National Coal Workers' Autopsy Study) required by FMSHA. An ongoing surveillance program examines whether current coal mine dust standards protect miners' health. This study has continued for more than 20 years and is conducted through voluntary x-rays and an organized epidemiologic investigation. DRDS also conducts epidemiologic studies of occupational asthma and pulmonary disease caused by exposure to cotton dust. The agency monitors trends in the incidence of all occupational lung diseases. Clinical studies are conducted to determine the effects of occupational exposure to specific substances and to better understand human response mechanisms (28).

DRDS also conducts research in such areas as physiology, pathology, and microbiology to better understand the dangers of substances and the mechanisms of disease. Scientists choose animal models suitable for the study of particular agents and develop new laboratory techniques.

Extramural research is conducted through such programs as the NIOSH Centers for Agricultural Research, Education, and Disease and Injury Prevention Program. This program funds centers at the University of California at Davis, the University of Iowa at Iowa City, the National Farm Medicine Center in Marshfield, WI, and the Colorado State University at Fort Collins. Most of the program's pulmonary studies are conducted at the University of Iowa center, which conducts research in such areas as grain dust exposures and respiratory diseases in dairy farmers (7).

Unlike other Federal research agencies, NIOSH responds to requests from workers and their representatives to investigate the causes of accidents and illnesses in the workplace. In fiscal year 1992, NIOSH issued 40 final reports of respiratory disease health hazard evaluations. Onsite evaluations of possible pulmonary health hazards are performed by DRDS. DRDS medical personnel, industrial hygienists, and epidemiologists analyze the workplace situation and present suggestions for diminishing harmful exposures (28).

The National Center for Toxicological Research (NCTR) in Jefferson, AR, conducts methods development and toxicological research for the FDA. The purposes of the Center are to increase knowledge of human health risks associated with exposure to artificial and natural substances and to elucidate the mechanisms and impact of these risks. Pulmonary toxicity studies conducted at NCTR deal primarily with chronic long-term exposure to carcinogenic or mutagenic compounds. Currently research is focused on compounds of interest to FDA unrelated to pulmonary toxicity (l).

Department of Energy

DOE funds research on pulmonary toxicants conducted by the Inhalation Toxicology Research Institute (ITRI) in Albuquerque, NM. ITRI is owned by DOE and is operated under along-term contract by a private,

Photo Credit: G. Wagner, National Institute for Occupational Safety and Health

nonprofit corporate entity, the Lovelace Biomedical and Environmental Research Institute. ITRI receives approximately 75 percent of its funding from DOE, with the other 25 percent coming from other government agencies, nongovernment associations, and individual companies. Funding by DOE remains constant, while other government agencies and private sources provide funding for particular studies in areas of their interest.

All research at ITRI is lung related, and it ranges from molecular studies focusing on cellular changes caused by inhaled materials to clinical studies of human subjects. Studies are related to two general areas: those which examine the effects of specific substances on the respiratory system and those which explore the structure and function of the respiratory tract and the general behavior of gases, vapors, and particles in the respiratory tract (17).

Research on noncancer pulmonary toxicity is currently being conducted on ozone, nitrogen oxides, sulfur oxides, and the components of engine exhaust. Some studies focus on occupational exposures to pulmonary toxicants, including benzene, butadiene, nickel, and beryllium. Other research examines the effects of exposure to natural fibers, such as asbestos, and synthetic fibers, such as fiberglass. Studies on respiratory system structure and function focus on the uptake, deposition, and excretion of toxicants, and natural defenses of the respiratory system to inhaled materials (17).

ITRI proposes studies it decides need to be conducted, and DOE allocates funds according to its interests and resources. The scientific research budget for ITRI in fiscal year 1992 is approximately $13.5 million. In 1992 ITRI has allocated approximately 54 percent of its budget to cancer research. The other 46 percent is designated for noncancer research. Of the noncancer budget, a little over half is spent on general toxicology, including the study of the mechanisms of diseases, mathematical models of effects, and studies of the metabolism of compounds. Approximately one quarter of the budget is allocated for the study of the nature of airborne materials (vapors, particulate matter and gases). The remaining quarter is designated for dosimetry studies (18).

Cooperative Federal and Private Research

The Health Effects Institute (HEI) supports and evaluates research on the health effects of motor vehicle emissions. Its research program focuses on substances regulated by the NAAQS in the CAA, as well as other pollutants, such as diesel exhaust particles, methanol, and aldehydes (10). Because all research targets emissions, the majority of HEI's research focuses on the lung (20). All research at HEI is extramural, with funding mainly going to universities, but also to research centers (e.g., ITRI and the Los Amigos Research and Education Institute). Both cancer and noncancer research is funded, but no clear breakdown is available because research is pollutant-focused rather than effect-focused (29).

HEI receives one-half of its funding from EPA and the other half from all companies who make or sell automobiles, trucks, or engines in the United States. Currently, EPA and 28 private companies fund HEI. HEI bills the companies separately based proportionally on the number of vehicles or engines they sell that year in the United States. Contributing companies include American, European, and Japanese corporations. The total budget for HEI in fiscal year 1992 is $6 million (9).

A separate nonprofit organization, the Health Effects Research Institute—Asbestos Research (HEI-AR), was established in September 1989 to support scientific studies to evaluate airborne levels of asbestos in buildings, to assess exposure, and to examine asbestos handling and control strategies. HEI-AR is modeled after HEI but is an independent entity.

Beginning in fiscal year 1990 HEI-AR was scheduled to receive $2 million annually for 3 years from EPA. It secures an additional $2 million per year from combined sources in the real estate, insurance, and asbestos manufacturing industries, as well as from public and private organizations interested in asbestos. In 1991, HEI-AR published a report including literature review of current knowledge of asbestos in buildings and identifying areas where more knowledge is needed. It has also begun a program of support and evaluation for scientific asbestos studies (11).

SUMMARY

The Federal Government plays an active role in the protection of pulmonary health through regulations and research. Regulations promulgated under the CAA, RCRA, TSCA, FIFRA, CPSA, and FDCA are designed to protect pulmonary health in the general population. Regulations promulgated under the OSH Act and FMSHA are designed to safeguard workers

and miners respectively from exposure to pulmonary toxicants within the scope of their employment. Federal regulations call for a variety of measures to control the risk of exposure to pulmonary toxicants, including setting exposure levels, banning certain materials which pose an unmanageable risk of pulmonary injury, and requiring safety devices and education in the workplace.

Federal research on pulmonary toxicants is conducted primarily under the auspices of EPA, DHHS, and DOE. Research by these organizations is conducted on an intramural basis and on an extramural basis through grants to universities and other research institutes. An effort has been made to combine public and private funding of pulmonary toxicology research in HEI. Federally funded research includes studies involving human and animal subjects that employ research techniques ranging from cellular studies to epidemiology. Applying the knowledge gained through these studies, Federal agencies have been able to design regulations which should more effectively reduce health risks to the pulmonary system.

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