underestimation of the severity of the impairment until relatively late in the disease. For patients with a history of asbestos exposure, conventional computed tomography (CT) is more sensitive for the detection of pleural thickening, and high-resolution CT (HRCT) improves the detection of asbestosis.

Other procedures that may be of use in identifying the role of environmental exposures in causing lung disease include skin prick testing or specific IgE antibody titers for evidence of immediate hypersensitivity to agents capable of inducing occupational asthma (flour antigens in bakers), specific IgG precipitating antibody titers for agents capable of causing hypersensitivity pneumonitis (pigeon antigen in bird handlers), and assays for specific cell-mediated immune responses (beryllium lymphocyte proliferation testing in nuclear workers or tuberculin skin testing in health care workers). Sometimes a bronchoscopy to obtain transbronchial biopsies of lung tissue may be required for histologic diagnosis (chronic beryllium disease). Rarely, video-assisted thoracoscopic surgery to obtain a larger sample of lung tissue may be required to determine the specific diagnosis of environmentally induced lung disease (hypersensitivity pneumonitis or giant cell interstitial pneumonitis due to cobalt exposure).

DETERMINANTS OF INHALATIONAL EXPOSURE

The chemical and physical characteristics of inhaled agents affect both the dose and the site of deposition in the respiratory tract. Water-soluble gases such as ammonia and sulfur dioxide are absorbed in the lining fluid of the upper and proximal airways and thus tend to produce irritative and bronchoconstrictive responses. In contrast, nitrogen dioxide and phosgene, which are less soluble, may penetrate to the bronchioles and alveoli in sufficient quantities to produce acute chemical pneumonitis.

Particle size of air contaminants must also be considered. Because of their settling velocities in air, particles >10–15 μm in diameter do not penetrate beyond the nose and throat. Particles <10 μm in size are deposited below the larynx. These particles are divided into three size fractions on the basis of their size characteristics and sources. Particles ~2.5–10 μm (coarse-mode fraction) contain crustal elements such as silica, aluminum, and iron. These particles mostly deposit relatively high in the tracheobronchial tree. Although the total mass of an ambient sample is dominated by these larger respirable particles, the number of particles, and therefore the surface area on which potential toxic agents can deposit and be carried to the lower airways, is dominated by particles <2.5 μm (fine-mode fraction). These fine particles are created primarily by the burning of fossil fuels or high-temperature industrial processes resulting in condensation products from gases, fumes, or vapors. The smallest particles, those <0.1 μm in size, represent the ultrafine fraction and make up the largest number of particles; they tend to remain in the airstream and deposit in the lung only on a random basis as they come into contact with the alveolar walls. If they do deposit, however, particles of this size range may penetrate into the circulation and be carried to extrapulmonary sites. New technologies create particles of this size ("nanoparticles") for use in many commercial applications. Besides the size characteristics of particles and the solubility of gases, the actual chemical composition, mechanical properties, and immunogenicity or infectivity of inhaled material determine in large part the nature of the diseases found among exposed persons.

OCCUPATIONAL EXPOSURES AND PULMONARY DISEASE

Table 311-1 provides broad categories of exposure in the workplace and diseases associated with chronic exposure in those industries.

ASBESTOS-RELATED DISEASES

Asbestos is a generic term for several different mineral silicates, including chrysolite, amosite, anthophyllite, and crocidolite. In addition to workers involved in the production of asbestos products (mining, milling, and manufacturing), many workers in the shipbuilding and construction trades, including pipe fitters and boilermakers, were occupationally exposed because asbestos was widely used during the twentieth century for its thermal and electrical insulation properties. Asbestos also was used in the manufacture of fire-resistant textiles, in cement and floor tiles, and in friction materials such as brake and clutch linings.

TABLE 311-1 CATEGORIES OF OCCUPATIONAL EXPOSURE AND ASSOCIATED RESPIRATORY CONDITIONS

Occupational Exposures	Nature of Respiratory Responses	Comment
Inorganic Dusts		
Asbestos: mining, processing, construction, ship repair	Fibrosis (asbestosis), pleural disease, cancer, mesothelioma	Virtually all new mining and construction with asbestos done in developing countries
Silica: mining, stone cutting, sandblasting, quarrying	Fibrosis (silicosis), progressive massive fibrosis (PMF), cancer, tuberculosis, chronic obstructive pulmonary disease (COPD)	Improved protection in United States; persistent risk in developing countries
Coal dust: mining	Fibrosis (coal worker's pneumoconiosis), PMF, COPD	Risk persists in certain areas of United States, increasing in countries where new mines open
Beryllium: processing alloys for high-tech industries	Acute pneumonitis (rare), chronic granulomatous disease, lung cancer (highly suspect)	Risk in high-tech industries persists
Other metals: aluminum, chromium, cobalt, nickel, titanium, tungsten carbide, or "hard metal" (contains cobalt)	Wide variety of conditions from acute pneumonitis to lung cancer and asthma	New diseases appear with new process development
Organic Dusts		
Cotton dust: milling, processing	Byssinosis (an asthma-like syndrome), chronic bronchitis, COPD	Increasing risk in developing countries with drop in United States as jobs shift overseas
Grain dust: elevator agents, dock workers, milling, bakers	Asthma, chronic bronchitis, COPD	Risk shifting more to migrant labor pool
Other agricultural dusts: fungal spores, vegetable products, insect fragments, animal dander, bird and rodent feces, endotoxins, microorganisms, pollens	Hypersensitivity pneumonitis (farmer's lung), asthma, chronic bronchitis	Important in migrant labor pool but also resulting from in-home exposures
Toxic chemicals: wide variety of industries; see Table 311-2	Asthma, chronic bronchitis, COPD, hypersensitivity pneumonitis, pneumoconiosis, and cancer	Reduced risk with recognized hazards; increasing risk for developing countries where controlled labor practices are less stringent
Other respiratory environmental agents: uranium and radon daughters, secondhand tobacco smoke, polycyclic aromatic hydrocarbons (PAHs), biomass smoke, diesel exhaust, welding fumes, wood finishing	Occupational exposures estimated to contribute to up to 10% of all lung cancers; chronic bronchitis, COPD, and fibrosis	In-home exposures important; in developing countries, biomass smoke is a major risk factor for COPD among women