Two NIOSH Resources for Implementing Workplace Safety and Health Surveillance

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INTRODUCTION

Health practitioners and researchers alike are concerned with high rates of disease that occur in smaller populations. Some of these diseases may be of occupational origin. The frequency of occupational illnesses and diseases varies depending upon the individual work conditions; yet, their occurrence is sufficient to warrant active surveillance of such workers. Two resources from the National Institute for Occupational Safety and Health (NIOSH) are described herein for the implementation of workplace safety and health surveillance: (1) the Occupational Sentinel Health Events (SHEO) list,[1,2] which provides the involved occupations, industries, and agent(s) for a specific occupational disease or condition; and (2) a table of medical screening and biological monitoring tests that are currently available in the literature for monitoring workers potentially exposed to OSHA-regulated substances.[3]

PROVISION OF OCCUPATIONAL MEDICAL SERVICES

The provision of some aspects of medical care to workers in manufacturing and nonmanufacturing facilities seems to have changed during the 1980s from that noted in the 1970s, according to two observational surveys conducted by NIOSH (TABLE 1).[4] The first NIOSH survey, the National Occupational Hazard Survey (NOHS), was conducted between 1972 and 1974. Because of the continuing need for information on nationwide patterns of occupational exposure to health hazards, NIOSH conducted a second survey, the National Occupational Exposure Survey (NOES), during 1981-1983. The surveyed facilities in both NOHS and NOES were designed to be representative of virtually all the nonagricultural, nonmining, and nongovernmental businesses covered under the Occupational Safety and Health Act of 1970.

TABLE 1 shows that the proportion of the workforce with access to physician services in off-site clinics was 19.6% in the survey conducted between 1972 and 1974. In the second survey (1981-1983), the proportion of the workforce with access to physician services in off-site clinics rose to 57.8%, almost threefold from that used a decade earlier. On-site physician services (employed or contract) remained stable during both surveys—i.e., approximately 20%.[4] Information was not collected on the training of the physicians providing these services.

TABLE 1. Proportion of Workforce With Access to Physician Services from Two Surveys Conducted by the National Institute For Occupational Safety and Health (NIOSH)[a]

Off-Site Physician Services		On-Site Physician Services	
1972-1974	1981-1983	1972-1974	1981-1983
19.6%	57.8%	20.8%	19.1%

[a] Adapted from Ref. 4.

Even though the NIOSH survey data is over 10 years old, it does show that occupational health activities were being conducted by off-site and/or contractual physicians, many of whom may not have been adequately trained in occupational medicine. From the data available to NIOSH, comparative analyses of the data between on-site and off-site practice of medicine showed that use of off-site medical practice apparently resulted in diminished provision of screening tests and medical examinations of workers; this tendency may have been due to the recent decline of the presence of on-site physicians and the subsequent rapid growth of off-site medical practice.[5]

An Occupational Safety and Health Administration (OSHA) survey conducted in 1990-1991 estimated that only 6.3% of United States industries currently had a medical surveillance program at the individual establishment.[6,7]

An increased interest in academic training for occupational medicine has also been shown in the United States. Although there has been a growth in the number of accredited occupational medicine residencies from 10 in 1976 to 39 in 1993 (NIOSH, unpublished), the number of residents now being trained in occupational health is probably still too few to handle the problems of the numerous workers exposed to occupational hazards.

Some problems have been noted in the provision of occupational medical services:[3,5-8]

(1) The off-site, nonoccupational physicians often may have very little formal training in occupational medicine.
(2) Since they are practicing away from their on-site industrial hygienist and occupational nurse colleagues, these physicians may or may not be familiar with the type of work being conducted or the existing work conditions.
(3) They may have very little information on the various hazards that workers are exposed to and may not be aware of the toxicity of all hazards of each exposed worker.
(4) There are so many medical tests recommended in the literature for the various substances that they may not be able to decide which tests are to be performed on a worker at that specific worksite.
(5) Very few industries have an ongoing medical surveillance program.

Occupational Illnesses and Injuries

What is the magnitude of occupational illnesses, injuries, and deaths occurring in the United States?

According to estimates obtained by the National Traumatic Occupational Fatality (NTOF) surveillance system administered by NIOSH, 63,589 workers died from injuries sustained while working (1980-1989); 62,289 (98%) were workers in the civilian labor force. The average annual occupational fatality rate for the United States workforce was 7.0 per 100,000 workers.[9]

In 1992, the Bureau of Labor Statistics (BLS) implemented a new plan to conduct a systematic, verifiable count of all fatal occupational injuries and to obtain descriptive data on the circumstances surrounding these events.[10] Statistics reported to the National Safety Council (NSC)[10,11] for occupational injuries, illnesses, and deaths for the years 1992 through 1995 are presented in TABLE 2. From 1992 to 1993, the number of occupational illnesses seems to have increased almost 5% (from 457,000 to 482,000).[10] The data for 1994 show 514,700 illnesses, an increase of over 1 percent from 1993.[11] The occupationally related illnesses for 1995, however, decreased to 494,800 illnesses.

The number of disabling injuries has steadily risen from 3.2 million in 1993 to 3.6 million in 1995. There is an upward trend in the total number of occupationally related deaths (including suicides and homicides) from 6,217 in 1992 to 6,588 in 1994;[10,11] however, for 1995, the estimated number of all deaths including homicide and suicide was 5,300.[11]

TABLE 2. Number of Occupationally Related Illnesses and Deaths from the Bureau of Labor Statistics, 1992-1995[a]

	1992	1993	1994	1995
Illnesses	457,000	482,000	514,700	494,800[b]
Disabling injuries	3.3 million	3.2 million	3.5 million	3.6 million
Deaths (total)	6,217	6,271	6,588	5,300
Homicides, suicides	1,252	1,297	1,281	1,239[b]

[a] Adapted from Refs. 10 and 11.
[b] Not yet published.

CONTROL OF OCCUPATIONAL DISEASE

The successful control of occupational disease depends upon two factors: the recognition and diagnosis of cases by physicians and the implementation of epidemiologic surveillance, prevention, and control programs. Unfortunately, these factors have historically received inadequate attention.

Recognition and Diagnosis of Occupational Diseases

An instructive example of how occupationally related illnesses can be underdiagnosed can be found in a letter written to the editor of the New England Journal of

Medicine in 1980.[12] Sixty-seven physicians, more than half of whom were board-certified pathologists, were interested enough to take a one-week postgraduate course on pathology of the lung. A microscopic section was shown to demonstrate a straightforward example of asbestosis. Fewer than 10 percent (6 of 67) of the physicians suspected and diagnosed asbestosis. On the other hand, 75–80 percent of them diagnosed successfully "mystery" cases of non-occupationally related disease.[12]

Further documentation of the isolation of occupational disease was published in an editorial in the *Annals of Internal Medicine* by L. Rosenstock.[13] The systematic estimates of the magnitude of occupationally related illnesses and injuries available during the 1970s and 1980s are believed by many to be gross underestimates of the extent of the occupational health problems in the United States, due, perhaps, to various factors: (1) failure to identify diseases as occupational; (2) if an occupational cause is suspected, failure to report it; (3) the link between work and ill-health is often obscured by the long lag time from exposure to a subsequent illness; (4) the multiple and often poorly characterized hazardous exposures in the workplace; and (5) the multifactorial causation of many illnesses.[13]

Prevention and Control of Occupational Disease

The control of occupational disease has its genesis in methodologies used in the health-care field that were found to be successful. As an example, the approach of identifying and counting the number of preventable tragedies in the health-care field was successfully used in the 1930s, when every maternal death occurring in New York City was vigorously pursued; pertinent facts were collected and later evaluated by a group of obstetricians. The evolution and implementation of this process was followed by a rapid drop in maternal mortality in New York City.[14]

The above principles were applied to infant deaths in 1967 and 1968 in Massachusetts. Such evaluations demonstrated that about one-third of infant deaths in the state of Massachusetts were preventable by medical means.[15]

Based on the experience with the identification and prevention of maternal and infant mortality, the late Dr. Rutstein coined the term *Sentinel Health Event* for diseases and disabilities that were preventable. Thus, "The occurrence of an unnecessary disease, disability, or untimely death is a *Sentinel Health Event* (SHE) that justifies carefully controlled scientific research for remediable underlying causes."[16]

The occurrence of a SHE serves as a warning signal that the quality of preventive and/or therapeutic medical care may need to be improved. Thus, according to Rutstein, the SHEs serve as negative indexes of the quality of medical care where unnecessary disease or untimely death occurs. For example, a case of polio is a SHE. The occurrence of this preventable disease signals a breakdown in immunization programs.[16]

Occupational Sentinel Health Event

The Sentinel Health Event (SHE) approach was subsequently modified and successfully applied to the field of occupational disease.[1] Thus, an occupational sentinel

health event (SHEO) is a preventable disease, a preventable disability, or a preventable untimely death that is occupationally related.

The occurrence of a SHEO indicates that (1) epidemiologic studies or industrial hygiene studies should be conducted; (2) control technology should be implemented to prevent that disease, disability, or death; and (3) appropriate medical care should be provided.[1]

Two broad categories of SHEOs have been recognized. The first group includes diseases or conditions that, by their inherent nature, are occupationally related. Such conditions include the pneumoconioses; it is unlikely that these diseases would occur in the absence of an occupational exposure to the inciting agent. The second set of conditions include such diseases as lung cancer, leukemia, peripheral neuropathy, leptospirosis, and ornithosis, which may or may not be occupationally related. For the latter set of conditions, further information on the industry and occupation is required to establish a causal link between disease condition and occupation.[1,2]

The occupational health literature was surveyed, and a list of SHEOs was assembled, each of which met three criteria of scientific proof: documentation of associated agent or agents, of involved industries, and of involved occupations. In addition, the disease or condition must be codable within the framework of the Ninth Revision of the International Classification of Diseases Adapted for Use in the United States, 1975—i.e., ICD-9.[1,2]

The first list of 50 work-related conditions was published in 1983.[1] Most of the reports included in the list were epidemiologic studies; few of them were case reports. An updated list of SHEOs was published in 1991.[2] (This is included below as APPENDIX 1.) For the updated SHEO list, additional criteria were used, since many studies were found to be equivocal.

First, the report had to be a sound epidemiologic study with appropriate controls, end point, and specifics concerning occupation, industry, and agent.[2] Second, in the case of lung cancer, the study must have been controlled for smoking history. A few epidemiologic studies were noted in which lung cancer was the end point but there was no mention of smoking characteristics as a confounding factor; such studies were not included in the SHEO list. Third, for death certificate studies, confirmatory studies must have been done using more rigorous methodologies—e.g., case control study or a retrospective mortality study, etc.[2]

The updated SHEO list contained 64 diseases or conditions and over 140 agents. Of the 14 new conditions included in the list, 7 belonged to the infectious disease group. These were "Fish fancier's finger," "Herpetic whitlow," "HIV infection," "Rocky Mountain spotted fever," "Leptospirosis," "Histoplasmosis," and "Sporotrichosis." None of these conditions was solely related to occupation. Details of the occupations/industries dealing with the new infectious disease conditions are presented in TABLE 3.[2]

METHODS OF SURVEILLANCE OF OCCUPATIONAL DISEASES

Two approaches are useful in the surveillance of occupational disease conditions: medical screening and biological monitoring. Medical screening is the search for early signs or symptoms of disease *before* the patient is symptomatic. Biological

TABLE 3. Occupations, Industries, and Agents Noted for Seven New Infectious Diseases in the Occupational Sentinel Health Event (SHEO) Update[a]

ICD-9	Condition	Industry/Process/Occupation	Agent
031.1	Fish-fancier's finger	Aquarium worker/cleaner, owner/breeder	*Mycobacterium marinum*
		Longshoreman	*Mycobacterium marinum*
054.6	Herpetic whitlow	Surgical resident, student nurse, nurse, dental assistant, physician, orthopedic scrub nurse, psychiatric nurse	Herpes simplex virus
042	Human immunodeficiency virus	Health care worker	Human immunodeficiency virus
082.0	Rocky Mountain spotted fever	Laboratory technician, tick breeder, virologist, microbiologist, physician	*Rickettsia rickettsii*
100.8	Leptospirosis	Farmer/laborer	*Leptospira*
115	Histoplasmosis	Bridge maintenance worker	*Histoplasma capsulatam*
117.1	Sporotrichosis	Nurseryman, forester, florist, equipment operator	*Sporothrix schenkii*

[a] Adapted from Ref. 2.

monitoring is the testing of a specimen from the patient for the presence of a hazardous intoxicant or its metabolite.[3]

A simple guide containing specific medical tests for medical screening and biological monitoring of specific substances would be helpful to both the occupational health professional and the general practitioner. Hence, to provide the practicing physician with a roadmap to the literature of the available recommendations for medical screening and biological monitoring, a literature search was conducted to obtain information on medical tests that were available for these substances. The medical tests recommended by the federal government (NIOSH/OSHA) and other researchers for substances regulated by OSHA in 1989 and revised in 1993 were summarized, in tabular format. There are so many agents being used in the workplace, and a start had to be made somewhere; hence, for this report, medical tests available for screening workers exposed to the substances regulated by OSHA were chosen.[3]

The criteria for an effective screening test are: safety, reliability, validity, positive results in presymptomatic period, and positive predictive value.[17]

The medical tests recommended for substances regulated by OSHA (and for which permissible exposure limits had been specified) were tabulated.[3] (This is included below as APPENDIX 2.) Included in the table were the name of the substance, the Chemical Abstracts Service Registry (CAS) number, and recommendations for specific medical tests made by NIOSH/OSHA[18,19] and by other data sources.[20–28] A glossary was also provided in the table to define the terms or abbreviations used in the table. The intent of this table was not to provide an evaluation of the recommendations or a validation of the medical tests for use in surveillance, but to provide a source for the medical tests described in the literature for the specific regulated agent. The efficacy of these tests for screening workers exposed to the specific substances was not evaluated.[3] This table is now available from NIOSH as a poster.

When a worker is exposed to a specific substance—e.g., trichloroethylene—the occupational health professional needs to know the specific medical test or tests to detect this agent or its effects on the worker. Most often, only the agent under question gets screened for, in this case, trichloroethylene. There are agents whose metabolites are also toxic. In such cases the worker should be screened not only for the specific agent but also for its metabolites. In the case of trichloroethylene, the metabolites are trichloroacetic acid and trichloroethanol, both of which are toxic. Hence, the worker should be screened for trichloroethylene as well as the two metabolites that are also toxic. The media that are to be used are urine, blood, and exhaled air.[3]

Medical tests recommended by NIOSH/OSHA and other researchers for acetone, benzene, and carbon tetrachloride are presented in TABLE 4.

Regarding medical tests for acetone, for example, though there is a NIOSH recommended exposure level and an OSHA permissible exposure level for acetone, this chemical was not yet included in the *Occupational Health Guidelines for Chemical Hazards* (1981-1989);[18,18a] however, in the *Occupational Diseases* book published by NIOSH, preplacement examinations were recommended for acetone to evaluate the worker's skin and respiratory conditions.[19]

In addition to NIOSH's recommendations, four other sources have recommended sampling for acetone in whole blood;[20,21] in expired air;[21,22] by urinalysis (in general);[20] by urinalysis at the end of work shift;[21] and by urinalysis during exposure.[23]

TABLE 4. Medical Tests Recommended for Acetone, Benzene, and Carbon Tetrachloride by NIOSH/OSHA and Other Researchers[a]

Name of Substance	CAS Number	Recommendations by	
		NIOSH/OSHA	Other Researchers
Acetone	00067-64-1	Pulmonary function tests	Whole blood, expired air, urinalysis at end of exposure, urinalysis during exposure
Benzene	00071-43-2	Complete blood count, pulmonary function tests	Urinalysis, urinalysis at end of shift, expired air, expired air prior to next shift, whole blood
Carbon tetrachloride	00056-23-5	Liver function tests, urinalysis	Liver function tests, kidney function tests, urinalysis, urinalysis (24 h), whole blood, expired air

[a] Adapted from Ref. 3.

Taking another example, benzene exposure has been associated with leukemia. Thus, preplacement and periodic examinations should include the effects of benzene on the blood and bone marrow and a history of exposure to other myelotoxic agents or drugs or of other diseases of the blood.[18] According to the *Occupational Diseases* book, preplacement laboratory examinations should include (1) a complete blood count—i.e., hematocrit, hemoglobin, mean corpuscular volume, white blood count, differential count, and platelet estimation; (2) reticulocyte count; (3) serum bilirubin; and (4) urinary phenol.[19]

Eight other data sources have recommended sampling by using one or more of the following media for benzene exposure: urinalysis;[20–22,24–26] urinalysis at end of shift;[27] expired air;[20–22,26] expired air prior to next shift—i.e., pre- and postshift;[27] and whole blood.[20,21,23,26]

A discussion is presented herewith regarding recommendations for urinalysis. If the substance under question or its metabolite has a half-life of less than five hours, the term "end of shift" is used. That means sampling can be done during the last two hours of exposure of that day's shift. For the term "end of workweek," the sampling should be done after four to five consecutive days of exposure since the half-life of the substance is greater than five hours. If "end of shift at end of workweek" is specifically mentioned, the sampling should be done during the last hour of the fifth day; in other words, the exposure of the fifth day also needs to be taken into consideration before sampling is done.

Taking the medical tests for carbon tetrachloride as another example, the *NIOSH/OSHA Occupational Health Guidelines* recommended that the examination of liver and kidneys should be stressed.[18] For preplacement examination, liver function tests and urinalysis should be conducted, and these tests should be repeated on an annual basis.[18]

Other than NIOSH/OSHA, one data source recommended liver function tests, kidney function tests, and urinalysis for the monitoring of carbon tetrachloride.[28] Another data source recommended 24-hour urinalysis,[23] two sources recommended whole blood sampling,[21,23] and three sources recommended the sampling of carbon tetrachloride in expired air.[21–23]

CONCLUSIONS

The occurrence of occupational illnesses and diseases warrants the implementation of active safety and health surveillance in the workplace. To assist the occupational health provider in this effort, two NIOSH resources, (1) a list of SHEOs from the published literature, and (2) recommended medical screening and biological monitoring methods for OSHA regulated substances, have been described in this report.

It is advisable that a list of SHEOs be developed in each workplace by occupation, process, or work unit. When the process is changed, the agents used may also change, and hence, a new list of SHEOs will have to be developed.

Also, specific medical tests should be performed by the occupational health professional on each worker depending upon the particular agent and the extent of exposure of the worker to that agent. To effectively and appropriately utilize these

techniques, the occupational health professional delivering occupational medical services must:

(1) understand the role of medical screening and biological monitoring in the full spectrum of approaches to occupational disease prevention;
(2) be knowledgeable of the chemical, physical, and biological hazards (including toxicity) to which the workers are exposed; and
(3) have access to scientific and regulatory literature.

The occupational health program should not be cast in stone for a particular industry or occupational group. With newer processes and agents entering the industrial environment, there will be a continual change in the nature of work, and occupational diseases will also change. For example, if another agent, say X, is substituted for carbon tetrachloride, the required medical screening and biological monitoring would be different if X does not cause liver or kidney dysfunction. Thus, the toxicity of the new agent X is to be first determined, and appropriate medical tests should be performed. Preventive measures should be taken to control the worker's exposure to agent X in order to prevent occupational diseases due to exposure of the worker to agent X.

Thus, from the perspective of a health care provider, appropriate questions regarding work history should be asked. To cite an example, Ramazzini (1713) would ask the worker what kind of work he performed. Specifically, the question asked was, "What trade are you of?"[29] Hence, the specific industry (4-digit Standard Industrial Classification [SIC] code), the specific occupation (3-digit occupation code), the various agents used, the duration of exposure, whether part-time or full-time exposure to the agent, etc. are all important parameters that a health provider should ascertain before a diagnosis of the illness is made.

SUMMARY

To improve safety and health in the workplace, appropriate occupational health programs should be implemented utilizing expertise from multiple disciplines. In other words, the occupational health program should be a *team effort.* Expertise from all aspects of occupational health should be utilized, from the industrial hygienist, to the safety officer, to the occupational health nurse, and the practicing physician—all should be involved in the program to maintain a safe and healthy workplace.

Two NIOSH resources have been described to assist the occupational health professional in the improvement of safety and health in the workplace. First, the SHEO approach, where a separate SHEO list is to be developed for each workplace. This may be a problem when the physician is an outside contractor, but with the help of the team approach, a list of SHEOs can be developed. Second, medical screening and biological monitoring is often required. While we realize that medical screening and biological monitoring is part of the complete occupational health program, the table of medical tests that we have prepared[3] may give some leads into the type(s) of medical tests to be conducted on the individual worker at a particular worksite.

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APPENDIX 1

Occupationally Related Unnecessary Disease, Disability, and Untimely Death[a,b]

ICD-9	Condition[c]	Industry/Process/Occupation	Agent
011	Pulmonary tuberculosis (O)	Physician, medical personnel, medical laboratory worker	*Mycobacterium tuberculosis*
011, 502	Silicotuberculosis	Quarryman, sandblaster, silica processor, mining, metal foundry, ceramic industry	Silica + *Mycobacterium tuberculosis*
020	Plague (O)	Shepherd, farmer, rancher, hunter, field geologist	*Yersinia pestis*
021	Tularemia (O)	Hunter, fur handler, sheep industry worker, cook, veterinarian, rancher, veterinarian pathologist, laboratory worker, soldier	*Francisella tularensis, Pasteurella tularensis*
022	Anthrax (O)	Shepherd, farmer, butcher, handler of imported hides or fibers, veterinarian, veterinarian pathologist, weaver	*Bacillus anthracis*
023	Brucellosis (O)	Farmer, shepherd, veterinarian, laboratory worker, slaughterhouse worker, field officer	*Brucella abortus, suis*
031.1[d]	Fish-fancier's finger (O)	Aquarium worker/cleaner, breeder/owner, longshoreman	*Mycobacterium marinum*
037	Tetanus (O)	Farmer, rancher	*Clostridium tetani*
042[e]	Human immunodeficiency virus (O)	Health care worker	Human immunodeficiency virus
054.6	Herpetic whitlow (O)	Surgical resident, student nurse, nurse, dental assistant, physician, orthopedic scrub nurse, psychiatric nurse	Herpes simplex virus
056	Rubella (O)	Medical personnel, intensive care personnel	Rubella virus
070.0 .1	Hepatitis A (O)	Day care center staff, orphanage staff, mental retardation institution staff, medical personnel	Hepatitis A virus
070.2 .3	Hepatitis B (O)	Nurse and nurses' aide, anesthesiologist, orphanage and mental institution staff, medical laboratory personnel, general dentist, oral surgeon, physician	Hepatitis B virus

Occupationally Related Unnecessary Disease, Disability, and Untimely Death[a,b] *(Continued)*

ICD-9	Condition[c]	Industry/Process/Occupation	Agent
070. 4	Non-A, non-B Hepatitis (O)	As above for hepatitis A and B	Unknown
071	Rabies (O)	Veterinarian, animal and game warden, laboratory researcher, farmer, rancher, trapper	Rabies virus
073	Ornithosis (O)	Psittacine bird breeder, pet shop staff, poultry producer, veterinarian, zoo employee, duck processing and rearing	*Chlamydia psittaci*
082.0	Rocky Mountain spotted fever (O)	Laboratory technician, tick breeder, virologist, microbiologist, physician	*Rickettsia rickettsii*
100.8	Leptospirosis (O)	Farmer/laborer	*Leptospira*
115	Histoplasmosis (O)	Bridge maintenance worker	*Histoplasma capsulatam*
117.1	Sporotrichosis (O)	Nurseryman, forester, florist, equipment operator	*Sporothrix schenkii*
147	Malignant neoplasm of nasopharynx (O)	Carpenter, cabinet maker, sawmill worker, lumberjack, electrician, fitter	Chlorophenols
155M[f,g]	Hemangiosarcoma of the liver	Vinyl chloride polymerization industry Vintner	Vinyl chloride monomer Arsenical pesticides
158, 163	Mesothelioma (MN of peritoneum and pleura)	Asbestos industries and utilizers	Asbestos
160.0	Malignant neoplasm of nasal cavities (O)	Woodworker, cabinet and furniture maker	Hardwood dusts
		Boot and shoe industry	Unknown
		Radium chemist and processor, dial painter	Radium
		Chromium producer, processor, user	Chromates
		Nickel smelting and refining	Nickel
		Sawmill worker, carpenter	Chlorophenols
161	Malignant neoplasm of larynx (O)	Asbestos industries and utilizers	Asbestos
162	Malignant neoplasm of trachea, bronchus, and lung (O)	Asbestos industry and utilizers	Asbestos
		Topside coke oven workers	Coke oven emissions
		Uranium and fluorspar miner	Radon daughters

		Chromium producer, processor, user	Chromates
		Nickel smelter, processor, user	Nickel
		Smelter	Arsenic, arsenic trioxide
		Mustard gas formulator	Mustard gas
		Ion exchange resin maker, chemist	Bis(chloromethyl)ether, chloromethyl methyl ether
		Iron ore (underground) miner	Radon daugthers
		Plant protection worker/agronomist	Pesticides, herbicides, fungicides, insecticides
		Welder	Unknown
		Copper smelter and roaster worker	Inorganic arsenic, sulfur dioxide, copper, lead, sulfuric acid, arsenic trioxide
		Welder, gas cutter	Asbestos, hexavalent chromium
		Foundry—floor molders and casters	Polyaromatic hydrocarbons
		Dichromate production—floor molder/caster	Unknown
		Chromate production	Chromium dust
		Chromate pigment production worker	Lead chromate, zinc chromate
		Pigment production	Zinc chromate dust
		Steel industry—furnace/foundry worker	Unknown
		Rubber reclaim operations	Unknown
170	Malignant neoplasm of bone (O)	Radium chemist and processor, dial painter	Radium
187.7	Malignant neoplasm of scrotum	Automatic lathe operator, metalworker	Mineral/cutting oils
		Coke oven worker, petroleum refiner, tar distiller	Soots/tar/tar distillates
		Tool setter, fitter, cotton spinner, chimney sweep, machine operator	Mineral oil, pitch, tar
188	Malignant neoplasm of bladder (O)	Rubber and dye worker	Benzidine, alpha- and beta-naphthylamine, magenta, auramine, 4-aminobiphenyl, 4-nitrophenyl
189	Malignant neoplasm of kidney, other, and unspecified urinary organs (O)	Coke oven worker	Coke oven emissions

Occupationally Related Unnecessary Disease, Disability, and Untimely Death[a,b] *(Continued)*

ICD-9	Condition[c]	Industry/Process/Occupation	Agent
204.0	Lymphoid leukemia, acute (O)	Rubber industry	Unknown
		Radiologist	Ionizing radiation
205.0	Myeloid leukemia, acute (O)	Occupations with exposure to benzene	Benzene
		Radiologist	Ionizing radiation
207.0	Erythroleukemia (O)	Occupations with exposure to benzene	Benzene
283.1	Hemolytic anemia, nonautoimmune (O)	Whitewashing and leather industry	Copper sulfate
		Electrolytic processes, arsenical ore smelting	Arsine
		Plastics industry	Trimellitic anhydride
		Dye, celluloid, resin industries	Naphthalene
284.8	Aplastic anemia (O)	Explosives manufacture	Trinitrotoluene
		Occupations with exposure to benzene	Benzene
		Radiologist, radium chemist, dial painter	Ionizing radiation
288.0	Agranulocytosis or neutropenia (O)	Occupations with exposure to benzene	Benzene
		Explosives and pesticide industries	Phosphorus
		Pesticides, pigments, pharmaceuticals	Inorganic arsenic
289.7	Methemoglobinemia (O)	Explosives and dye industries	Aromatic amino and nitro compounds. (e.g., aniline, trinitrotoluene, nitroglycerin)
		Rubber worker	Aniline, o-toluidine, nitrobenzene
323.7	Toxic encephalitis (O)	Battery, smelter, and foundry workers	Lead
		Electrolytic chlorine production, battery maker, fungicide formulator	Inorganic and organic mercury
332.1	Parkinson's disease (secondary) (O)	Manganese processing, battery maker, welder	Manganese
		Internal combustion engine industries	Carbon monoxide
334.3	Cerebellar ataxia (O)	Chemical industry using toluene	Toluene
		Electrolytic chlorine production, battery maker, fungicide formulator	Organic mercury

354M[h]	Carpal tunnel syndrome (O)	Meat packer, deboner	Cumulative trauma
354.0	Mononeuritis of upper limb and mono-	Dental technician	Methyl methacrylate monomer
.2	neuritis multiplex (O)	Poultry processing—turkey	Cumulative trauma
.3		Meat packer, deboner	Cumulative trauma
357.7	Inflammatory and toxic neuropathy (O)	Pesticide industry, pigments, pharmaceuticals formulator	Arsenic/arsenic compounds
		Furniture refinisher, degreasing operations	Hexane
		Plastic-coated fabric worker	Methyl n-butyl ketone
		Explosives industry	Trinitrotoluene
		Rayon manufacturing	Carbon disulfide
		Plastics, hydraulics, coke industries	Tri-o-cresyl phosphate
		Battery, smelter, and foundry workers	Inorganic lead
		Dentist, chloralkali workers	Inorganic mercury
		Chloralkali plants, fungicide maker, battery maker	Organic mercury
		Plastics industry, paper manufacturing	Acrylamide
		Ethylene oxide sterilizer operator	Ethylene oxide
366.4	Cataract (O)	Microwave and radar technicians	Microwaves
		Explosives industries, trinitrotoluene worker	Trinitrotoluene
		Radiologist	Ionizing radiation
		Blacksmith, glass blower, baker	Infrared radiation
		Moth repellant formulator, fumigator	Naphthalene
		Explosives, dye, herbicide, and pesticide industries	Dinitrophenol, dinitro-o-cresol
		Ethylene oxide sterilizer operator, microbiology supervisory, inspector	Ethylene oxide
388.1	Noise effects on inner ear (O)	Occupations with exposure to excessive noise	Excessive noise
443.0	Raynaud's phenomenon (secondary) (O)	Lumberjack, chain sawyer, grinder, chipper, rock driller, stone cutter, jackhammer operator, riveter	Whole body or segmental vibration
		Vinyl chloride polymerization industry	Vinyl chloride
493.0,	Extrinsic asthma (O)	Jewelry, alloy, and catalyst makers	Platinum
507.8		Polyurethane, adhesive, paint workers	Isocyanates

Occupationally Related Unnecessary Disease, Disability, and Untimely Death[a,b] *(Continued)*

ICD-9	Condition[c]	Industry/Process/Occupation	Agent
		Alloy, catalyst, refinery workers	Chromium, cobalt
		Solderer	Aluminum soldering flux
		Plastic, dye, insecticide makers	Phthalic anhydride
		Foam worker, latex maker, biologist	Formaldehyde
		Printing industry	Gum arabic
		Nickel plater	Nickel sulfate
		Baker	Flour
		Plastics industry, organic chemicals manufacture	Trimellitic anhydride
		Woodworker, furniture maker	Red cedar (plicatic acid) and other wood dusts
		Detergent formulator	*Bacillus*-derived exoenzymes
		Crab processing worker	Unknown
		Hospital and geriatric department nurses	Psyllium dust
		Laxative manufacture and packing	Psyllium dust
		Prawn processing worker	Unknown
		Snow crab processing worker	Unknown
495.4	Maltworker's lung	Maltworker	*Aspergillus clavatus*
495.5	Mushroom worker's lung	Mushroom farm/spawning shed, farmer	Pasteurized compost
495.8	Grainhandler's lung	Grain handler	*Erwinia herbicola (Enterobacter agglomerans)*
	Sequoiosis	Red cedar mill worker, woodworker, sawmill, joinery	Redwood sawdust, *Thuja plicata*
495.9	Unspecified allergic alveolitis	Cinnamon processing worker	Cinnamon dust, cinnamaldehyde
		Distillery, vegetable compost plant worker	*Aspergillus fumigatus*
		Sawmill worker	Unknown
		Paper manufacture/wood room	*Alternaria,* wood dust

		Snow crab processing worker	Unknown
500	Coalworker's pneumoconiosis	Coal miner	Coal dust
501	Asbestosis	Asbestos industries and utilizers	Asbestos
502M[i]	Silicosis	Quarryman, sandblaster, silica processor, mining, metal, and ceramic industries	Silica
		Cryolite refining	Cryolite (Na_3AlF_6), quartz dust
	Talcosis	Talc processor, soapstone mining/milling, polishing, cosmetics industry	Talc
503M[j]	Chronic beryllium disease of the lung	Beryllium alloy worker, ceramic and cathode ray tube makers, nuclear reactor worker	Beryllium
504	Byssinosis	Cotton industry worker	Cotton, flax, hemp, and cotton-synthetic dusts
506.0, 506.1	Acute bronchitis, pneumonitis, and pulmonary edema due to fumes and vapors (O)	Refrigeration, fertilizer, oil refining industries	Ammonia
		Alkali and bleach industries	Chlorine
		Silo filler, arc welder, nitric acid industry	Nitrogen oxides
		Paper and refrigeration industries, oil refining	Sulfur dioxide
		Cadmium smelters, processors	Cadmium
		Plastics industry	Trimellitic anhydride
		Boilermaker	Vanadium pentoxide
		Organic chemicals manufacture	Trimellitic anhydride
570, 573.3	Toxic hepatitis (O)	Solvent utilizer, dry cleaner, plastics industry	Carbon tetrachloride, chloroform, tetrachloroethane, trichloroethylene, tetrachloroethylene
		Explosives and dye industries	Phosphorus, trinitrotoluene
		Fire and waterproofing additive formulator	Chloronaphthalenes
		Plastics formulator	Methylenedianiline
		Fumigator, gasoline and fire extinguisher formulators	Methyl bromide
			Ethylene dibromide
		Disinfectant, fumigant, synthetic resin formulators	Cresol
584, 585	Acute or chronic renal failure (O)	Battery maker, plumber, solderer	Inorganic lead
		Electrolytic processes, arsenical ore smelting	Arsine

Occupationally Related Unnecessary Disease, Disability, and Untimely Death[a,b] *(Continued)*

ICD-9	Condition[c]	Industry/Process/Occupation	Agent
		Battery maker, jeweler, dentist	Inorganic mercury
		Fluorocarbon formulator, fire extinguisher maker	Carbon tetrachloride
		Antifreeze manufacture	Ethylene glycol
		Chromate pigment production worker	Inorganic lead
606	Infertility, male (O)	Kepone formulator	Kepone
		DBCP producer, formulator, and applicator	Dibromochloropropane
692	Contact and allergic dermatitis (O)	Leather tanning, poultry dressing plants, fish packing, adhesives and sealants industry, boat building and repair	Irritants (e.g., cutting oils, phenol, solvents, acids, alkalis, detergents); allergens (e.g., nickel, chromates, formaldehyde, dyes, rubber products)
733.9M[k]	Skeletal fluorosis (O)	Cryolite worker (grinding room), cryolite refining worker	Cryolite (Na_3AlF_6)

[a] Modified from TABLE I of R. J. Mullan & L. I. Murthy, 1991, Occupational Sentinel Health Events: An Up-Dated List for Physician Recognition and Public Health Surveillance, Am. J. Ind. Med. **19:** 775-799.

[b] External causes of injury and poisoning (occupational), including accidents, are classified in the ICD-9 Manual under the E codes.

[c] (O) indicates that condition is specifically occupation related.

[d] Original ICD rubric = Cutaneous Diseases Due to Other Mycobacteria.

[e] From the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM).

[f] M = Modified ICD rubric.

[g] Original ICD rubric = Malignant Neoplasm of Liver and Intrahepatic Bile Ducts.

[h] Original ICD rubric = Mononeuritis of Upper Limb and Mononeuritis Multiplex.

[i] Original ICD rubric = Pneumoconiosis Due to Other Silica or Silicates.

[j] Original ICD rubric = Pneumoconiosis Due to Other Inorganic Dust.

[k] Original ICD rubric = Other Disorders of Bone and Cartilage.

APPENDIX 2

Specific Medical Tests Published in the Literature for OSHA-Regulated Substances[a]

NOTES TO APPENDIX 2:

- Efficacy of medical tests has not been evaluated.
- NIOSH references include diagnostic, screening, and other tests.
- OSHA-mandated medical tests are shown in **BOLD**, underlined, and are listed separately.
- Only OSHA-regulated substances with published medical tests are included.
- Abbreviations and references are at end of APPENDIX 2.

Name of Substance	CAS Number	Specific Medical Tests (References in Superscript)
Acetaldehyde	00075-07-0	BL[3] ExA[3,4] U[3]
Acetone	00067-64-1	BL[3,5] BL(DE)[15] ExA[3,4] ExA(DE)[15] PFT[2] U[5] U(DE)[15] U(EOS)[3,18]
Acetonitrile	00075-05-8	BLC[2,3,16] BLP[2,3] ExA[4] U[3] Ua[2]
Acetylaminofluorene, 2-	00053-96-3	**RIC**[1] U[2]
Acetylene tetrabromide	00079-27-6	ExA[4] LFT[2,7]
Acrolein	00107-02-8	CXr[2,7] ExA[4] PFT[2,7]
Acrylamide	00079-06-1	NCS[15]
Acrylonitrile	00107-13-1	**CXr**[1] **FOB**[1] BLC[3] BLP[3] BLS[15] ExA[4] PFT[2] U[3,15]
Aldrin	00309-00-2	BLP[3] CBC[2] LFT[2] ReC[2] Ua[7]
Allyl chloride	00107-05-1	CBC[2] CXr[2,7] ExA[4] LFT[2] PFT[2,7] Ua[2]
Aluminum metal	07429-90-5	BLS[9] CXr[7] U[5,9,10,17]
Aminodiphenyl, 4-	00092-67-1	**RIC**[1] U[2]
Ammonia	07664-41-7	CXr[2,7] ExA[4] PFT[2,7]
Aniline	00062-53-3	BL[5,7] BL(COHb)[4] BL(DE)[11] BL(Hgb)[7] BL(MHgb)[2-5,8,11,15,16] BL(MHgb EOS)[15] CBC[2] ReC[2] U[3-6,12] U(EOS)[2,11,15,18] U(EWW)[18] Ua[2] Ua(Cyt Hmt)[2,16]
Anisidine (o-,p-isomers)	Varies	BL(Hgb)[7] BL(MHgb)[2,7,8,11] CBC[2] ReC[2] Ua[2]
Antimony and compounds	Varies	BL[9,17] BT[9] Cxr[7] PFT[2,7] U[3-5,9,13]
Arsenic, inorganic and compounds	Varies	**CXr**[1] **SpC**[1] BT[6] CXr[7] NCS[14] PFT[2,7] U[3-5,9,10,12-14] U(EWW)[11,15,16,18]

Specific Medical Tests Published in the Literature for OSHA-Regulated Substances (Continued)

Name of Substance	CAS Number	Specific Medical Tests (References in Superscript)
Arsine	07784-42-1	BL[7,13] BLP(Hgb)[16] LFT[7] PFT[2] ReC[16] U[9,10] U(EWW)[11] Ua[7] Ua(Hgb)[16] WBC[16]
Asbestos	Varies	**CXr**[1] **PFT**[1] CXr[2] PFT[2]
Azinphos-methyl (Guthion®)	00086-50-0	BF[2] BLS[9] CH[7] CH(BLS RBC)[2] CH(RBC)[11]
Barium and compounds	Varies	CXr[2] Ecg[2] PFT[2] U[9,17]
Benzene	00071-43-2	**CBC**[1] BL[3,5,12] BL(PNS)[15] ExA[3-5,12] ExA(EWW)[18] ExA(PNS)[11,15] ExA(PTS)[18] PFT[2] U[3-5,9,10,12] U(EOS)[11,15,18] U(PPS)[17] U(EWW)[18]
Benzidine	00092-87-5	**RIC**[1] PFT[2] U[2,3,17] Ua(Cyt[6M] Hmt[EM])[2] Ua(EM)[2]
Benzyl chloride	00100-44-7	CXr[2] ExA[4] PFT[2]
Beryllium and compounds	Varies	BT[9] CXr[2,7,16] PFT[2,7] U[3,4,10] WBC(LTT)[2]
Bis(chloromethyl) ether	00542-88-1	**RIC**[1] PFT[2] SpC[15]
Boron trifluoride	07637-07-2	CXr[2,7] PFT[2,7] U(PPS)[2]
Bromine	07726-95-6	CXr[2,7] PFT[2,7]
Butoxyethanol, 2-	00111-76-2	CBC[2,7] RBC(Frg)[2]
Butyl alcohol, n-	00071-36-3	BL[3] ExA[4]
Butyl chromate, tert-	00189-85-1	CXr[2] U[2]
Butyl glycidyl ether, n- (BGE)	02426-08-6	ExA[4] PFT[2]
Butyl mercaptan, n-	00109-79-5	ExA[4] PFT[2]
Butyltoluene, p-tert-	00098-51-1	CBC[2] Ecg[2] ExA[4]
Cadmium dust and fume	Varies	**U**[1] **BL**[1] BL[3-5,9,11,13,15,17,18] BT[9] CXr[2,4,7] LFT[2] PFT[2,7] U[3-5,7,9,11,13-15,18] Ua[7] Ua(Cyt)[2]
Camphor, synthetic	00076-22-2	BLP[3] U[3]
Carbaryl (Sevin®)	00063-25-2	BL(EOS)[15] BLS[9] CH[7] CH(PPS)[2,3] U[3-5,7] U(EOS)[15] Ua[2]
Carbon black	01333-86-4	PFT[2]
Carbon disulfide	00075-15-0	BL[3] Ecg[2,7] ExA[4] LFT[2,7] Oph[2,7] U[3-5] U(EOS)[3,11,15,18] U(EWW)[18] Ua[2,7]
Carbon monoxide	00630-08-0	BL[5] BL(COhb)[2-5,7,8,12] BL(COHb EOS)[11,18] BL(COHb EWW)[18] BL(EOS)[15] CBC[2] ExA[3-5] ExA(EOS)[11,18] ExA(EWW)[18]

Carbon tetrachloride	00056-23-5	BL[3,6] ExA[3,4] KFT[7] LFT[2,7] Ua[2,7]
Chlordane	00057-74-9	BL[3,15] BLS[9] BT[3] Ua[2,7]
Chlorinated diphenyl oxide	55720-99-5	LFT[2]
Chlorine	07782-50-5	CXr[2,7] ExA[8] PFT[2,7]
Chlorine dioxide	10049-04-4	CXr[2,7] PFT[2,7]
Chlorine trifluoride	07790-91-2	CXr[2,7] PFT[2,7]
Chlorobenzene	00108-90-7	U(EOS)[18] U(EWW)[18]
Chloroform (trichloromethane)	00067-66-3	ExA[3,4] LFT[2,7] Ua[2,7]
Chloromethyl methyl ether	00107-30-2	**RIC**[1] PFT[2] SpC[15]
Chloropicrin	00076-06-2	CXr[2,7] ExA[4] PFT[2,7]
Chloroprene, beta-	00126-99-8	CXr[2,7] PFT[2]
Chromic acid and chromates	Varies	BL[17] CBC[2] CXr[2,7] LFT[2] PFT[2,7] U[7] Ua[2]
Chromium, metal and compounds	Varies	BL[9,12] BT[9] CXr[2,7,9] PFT[2] U[4,5,9,11–13,17] U(EOS)[3,15,18] U(ESW)[11] U(EWW)[15,18]
Coal dust	68131-74-8	CXr[7] PFT[7]
Coal tar pitch volatiles	65996-93-2	CBC[2] CXr[2,7] PFT[2,7] PpT[2] SpC[2,7] Ua[2] Ua(Cyt Hmt)[2]
Cobalt metal, dust, and fume	07440-48-4	BL[9,13,17] BL(EOS)[18] BL(EWW)[18] BT[9] CXr[2,7] PFT[2,7] U[4,5,9,13] U(EOS)[3,18] U(EWW)[18]
Coke oven emissions	—	**CXr**[1] **PFT**[1] **SpC**[1] **Ua**[1] **Ua(Cyt Hmt)**[1]
Copper dust and mist	07440-50-8	BL[4,9,17] BLS[3] BT[9] U[9,17] U(24H)[3]
Cotton dust	—	**PFT**[1] CXr[2] PFT(PPS)[2]
Cresol, p-isomer	00106-44-5	LFT[2] PFT[2] U[3,9] U(PPS)[17]
Cumene	00098-82-8	U(L2H)[3,5]
Cyanide	00057-12-5	BL[3,5] BLC[16] BLP[3] CXr[2] PFT[2] U[3,5,15]
Cyclohexane	00110-82-7	BL[3,5] BL(DE)[15] ExA[3–5] ExA(DE)[15] U[5,10] U(EOS)[3] U(L4H)[15]
Cyclohexanone	00108-94-1	ExA[4] PFT[2] U[5]
Demeton (Systox®)	08065-48-3	CH[10] CH(BL BLP RBC)[5,16] CH(BLS RBC)[2] CH(RBC)[7,11]
Diacetone alcohol	00123-42-2	ExA[4] PFT[2]
Diazomethane	00334-88-3	CXr[2,7] PFT[2,7]
Diborane	19287-45-7	CXr[2,7] PFT[2,7]
Dibromo-3-chloropropane, 1,2- (DBCP)	00096-12-8	**BLS (FSH LH SCt TE)**[1] **GUT**[1] PFT[2]
Dibutyl phosphate	00107-66-4	Ecg[7] SpC[7] WBC[7]

Specific Medical Tests Published in the Literature for OSHA-Regulated Substances (Continued)

Name of Substance	CAS Number	Specific Medical Tests (References in Superscript)
Dichlorodiphenyltrichloroethane (DDT)	00050-29-3	AdT[3] BL[12] BLS[3,9] BT[3] U[3,4]
Dichlorophenoxyacetic acid,2,4- (2,4-D)	00094-75-7	BLP[3] U[3,4] U(24H)[12]
Dichlorobenzene, p-	00106-46-7	BL(MHgb)[6] ExA[4] LFT[2,7] U[2-5]
Dichlorobenzidine, 3,3′-	00091-94-1	**RIC**[1] PFT[2]
Dichloro-5,5-dimethyl hydantoin, 1,3-	00118-52-5	Ecg[7] SpC[7] WBC[7]
Dichloroethyl ether	00111-44-4	CXr[2,7] ExA[4] PFT[2,7]
Dichlorvos (DDVP)	00062-73-7	BLS[9] CH[3,10] CH(BLP RBC)[16] CH(BLS RBC)[2] CH(RBC)[7,11] U[3]
Dieldrin	00060-57-1	BL[3,5,15] BLS[9] BT[3]
Diglycidyl ether (DGE)	02238-07-5	CBC[7] CXr[7] PFT[2,7]
Diisobutyl ketone	00108-83-8	PFT[2]
Dimethyl acetamide	00127-19-5	LFT[2,7] U(EOS)[18] U(EWW)[18]
Dimethyl sulfate	00077-78-1	CXr[2,7] LFT[2,7] PFT[2,7] Ua[2,7]
Dimethylaminoazobenzene, 4-	00060-11-7	**RIC**[1]
Dimethylaniline (N,N-dimethylaniline)	00121-69-7	BL(MHgb)[2,7,8,11,16] CBC[2,7] U(Cyt Hmt)[16]
Dimethyl-1,2-dibromo-2,2-dichloroethyl phosphate (Naled)	00300-76-5	BLS[9] CH(BLP RBC)[16] CH(BLS RBC)[2] CH(RBC)[7,11]
Dimethylformamide (DMF)	00068-12-2	BL[5] ExA[4,5] LFT[2,7] U[5,10,12] U(24H)[3] U(EOS)[11,15,18] U(EWW)[18]
Dimethylhydrazine, 1,1-	00057-14-7	CBC[7] LFT[7] PFT[2]
Dinitrobenzene, (all isomers)	Varies	BL(EOS)[15] BL(MHgb)[2,7,8,11,16] CBC[2,7] LFT[2,7] U(Cyt Hmt)[16]
Dinitro-o-cresol	00534-52-1	BLW[3,5]
Dinitrotoluene, 2,4-	00121-14-2	BL(MHgb)[2,7,8,11] CBC[2,7] LFT[2,7]
Dioxane (diethylene dioxide)	00123-91-1	BL(DE)[15] BLP[3] BUN[7] CXr[2] ExA[4] KFT[7] LFT[2,7] PFT[2] U(EOS)[3,15] Ua[2]
Endrin	00072-20-8	BL[5] BL(EOS)[15] BLP[3] BLS[9] U[3,5] U(EOS)[15]
Epichlorohydrin	00106-89-8	CXr[2,7] ExA[4] LFT[2] PFT[2,7] Ua[2]
EPN	02104-64-5	BLS[9] CH(BLS RBC)[2] CH(RBC)[7,11] U[10]
Ethyl alcohol (ethanol)	00064-17-5	BL[3,17] BLS[9] ExA[3,4] U(EOS)[3]

Ethyl benzene	00100-41-4	BL[5] ExA[4,5,11] ExA(EWW)[15] ExA(PNS)[15] U[5,9,10] U(EOS)[15,18] U(ESW)[11] U(EWW)[18] U(L2H)[3]
Ethyl ether (ether)	00060-29-7	BL[3] ExA[4]
Ethyl mercaptan	00075-08-1	ExA[4] PFT[2]
Ethylene chlorohydrin	00107-07-3	ExA[4] LFT[2,7] Ua[2,7]
Ethylene dibromide	00106-93-4	BUN[7] CXr[2] Ecg40[2] ExA[4] LFT[2,7] PFT[2]
Ethylene dichloride	00107-06-2	ExA[4] LFT[7] PFT[2]
Ethylene glycol dinitrate	00628-96-6	BL[3,12] BL(DE)[5,15] CBC[7] Ecg[7] ExA(DE)[5] U[3,12]
Ethylene oxide	00075-21-8	**CBC**[1] CBC[7] CXr[7] ExA[4] PFT[2]
Ethyleneimine	00151-56-4	**RIC**[1] CXr[7] ExA[4] PFT[2]
Ferrovanadium dust	12604-58-9	CXr[2] PFT[2]
Fluoride, inorganic	16984-48-8	BLP[3,12] CXr[2,7] PFT[2,7] PXr[2,7] U[2,4,5,9,10,12] U(EOS)[11,15,18] U(EWW)[15,18] U(PNS)[15] U(PPS)[7,17] U(PTS)[11] Ua[2]
Fluorine	07782-41-4	CXr[2,7] PFT[2,7]
Formalydehyde	00050-00-0	**PFT**[1] BL[3,9] CXr[7] PFT[7] PFT(PPS)[2] U[3,9]
Furfural	00098-01-1	U(EOS)[18]
Furfuryl alcohol	00098-00-0	ExA[4] PFT[2]
Graphite, natural	07782-42-5	CXr[2,7] PFT[2,7]
Hexachloronaphthalene (Halowax 1014)	01335-87-1	LFT[2,3,7]
Hexane, n-	00110-54-3	BL[3,5] ExA[3-5,11] ExA(DE)[15] U[3,5,10] U(EOS)[11,15,18] U(EWW)[18]
Hydrazine	00302-01-2	CXr[7] PFT[2,7]
Hydrogen chloride (hydrochloric acid)	07647-01-0	CXr[2,7] PFT[2,7]
Hydrogen cyanide (hydrocyanic acid)	00074-90-8	BL(COHb)[4] Ecg40[2] ExA[4]
Hydrogen fluoride (hydrofluoric acid)	07664-39-3	CXr[2,7] KFT[6] PFT[2,7] PXr[2,7] U[2,10] U(PPS)[7] Ua[2]
Hydrogen sulfide	07783-06-4	BL[3] BL(COHb)[4] BLP[3] CXr[2,7] PFT[2,7]
Hydroquinone	00123-31-9	Oph[7] PFT[2]
Iodine	07553-56-2	CXr[2,7] PFT[2,7]
Iron oxide fume	01309-37-1	BL[9,17] BT[9] CXr[2,7] PFT[2,7] U[9,17]
Isophorone	00078-59-1	CXr[2] PFT[2]
Isopropyl alcohol (isopropanol)	00067-63-0	BL[3] ExA[4] U[3]
Isopropyl glycidyl ether (IGE)	04016-14-2	PFT[2]
Ketene	00463-51-4	CXr[2,7] PFT[2,7]

Specific Medical Tests Published in the Literature for OSHA-Regulated Substances (Continued)

Name of Substance	CAS Number	Specific Medical Tests (References in Superscript)
Lead, inorganic	07439-92-1	**BLL**[1] **BUN**[1] **Hgb**[1] **SCr**[1] **U**[1] **ZPP**[1] BL[3,5,9,11–13,15–17] BLL[2,7,14,16,18] BT[9] CBC[2,7] RBC[2,5] RBC(ZPP)[2] U[3–5,9,11–17] U(EOS)[17] Ua[7] ZPP[2,13] ZPP(1M)[2,11,15,16]
Lindane	00058-89-9	BL[2,3,5,7,12] BLS[3,15] CBC[2,7] U[4]
Lithium hydride	07580-67-8	BL[2,9,17] BLS[3] BT[9] U[3]
Magnesium oxide fume	01309-48-4	BL[17]
Malathion	00121-75-5	BLS[9] CH[3,10] CH(BLS RBC)[2] CH(RBC)[7,11] CXr[2] LFT[2] PFT[2] U[3,4]
Manganese and compounds	Varies	BL[9,13,17] BT[9] CBC[2] CXr[2] Neur[6] PFT[2] U[2–4,9,13,17] Ua[2]
Mercury, inorganic and compounds	Varies	BL[3–5,12,14,16] BL(EOS)[18] BL(ESW)[11] BL(EWW)[18] BT[9] BUN[7] NCS[14,16] TFT[7] U[2–5,7,9,10,12–15] Ua[2,7] U(PTS)[11,18]
Mercury, organo alkyl compounds	Varies	BL[2,3,7,9] Emg[7] U[7,9] Ua[2,7]
Methyl alcohol (methanol)	00067-56-1	BL[16] BLP[16] ExA[4] LFT[2] U[3,5,7,10,16] U(EOS)[11,15,18] U(EWW)[15] U(PNS)[15] U(PWW)[11]
Methyl n-amyl ketone	00110-43-0	PFT[2]
Methyl bromide	00074-83-9	BL[15,16] BLS[3] BUN[7] CXr[2] ExA[4] PFT[2]
Methyl n-butyl ketone (MBK)	00591-78-6	BL[3] Emg[7] ExA[3] PFT[2] U(EWW)[5]
Methyl cellosolve	00109-86-4	CBC[2,7] U[4,9]
Methyl chloride	00074-87-3	BL[3] ExA[3,4]
Methyl chloroform	00071-55-6	BL[3,5,10,12] BL(EOS)[15,18] BL(ESW)[11] BL(EWW)[10,15,18] ExA[3,4,10,12] ExA(16H)[5] ExA(EWW)[10,15,18] ExA(PNS)[15] ExA(PTS)[18] ExA(PWW)[11] LFT[7] U[3,5,12] U(EOS)[15,18] U(ESW)[11] U(EWW)[5,11,15,18]
Methyl ethyl ketone (MEK)	00078-93-3	BL[3,9,10,17] ExA[3,4,10] PFT[2] U[3,5,10] U(EOS)[11,15,16,18]
Methyl hydrazine	00060-34-4	BL(MHgb)[16] PFT[2] U[16] U(Cyt Hmt)[16]
Methyl isobutyl ketone (MIBK)	00108-10-1	ExA[4] PFT[2] U[5] U(EOS)[11,18] U(EWW)[18]
Methyl isocyanate	00624-83-9	CXr[2,7] PFT[2,7]
Methyl mercaptan	00074-93-1	CXr[7] ExA[4] PFT[2,7]
Methyl propyl ketone	00107-87-9	CXr[2] PFT[2]
Methylene bisphenyl isocyanate (MDI)	00101-68-8	CXr[2,7] PFT[2,7]

Methylene chloride	00075-09-2	BL[3,5] BL(COHb)[2-5,16] BL(COHb EOS[15] BL(COHb PNS)[15] BL(EOS)[15] CBC[2,7] ExA[3-5,16] ExA(EOS)[15] LFT[2] U[4,16]
Methylene dianiline, 4,4′-	00101-77-9	**LFT**[1] **U**[1] U[16]
Mica	12001-26-2	CXr[2,7] PFT[2,7]
Molybdenum and compounds	Varies	BL[4,9,17] BT[9] U[4,9,17]
Monomethyl aniline	00100-61-8	BL[7] BL(MHgb)[2,7,8,11,16] CBC[2,7] U[7] U(Cyt Hmt)[16] Ua[7]
Naphthalene	00091-20-3	BL[7] BLP(Hgb)[7] CBC[2,7] LFT[7] RBC(Hem)[2] U[7] Ua[2] WBC[7]
Naphthylamine, alpha-	00134-32-7	**RIC**[1] Ua[7] Cys[7]
Naphthylamine, beta-	00091-59-8	**RIC**[1] Ua[7] Cys[7]
Nickel carbonyl	13463-39-3	BLP[3] CXr[2,7] ExA[3,9] PFT[2,7] SpC[2] U[3,7,12,16,17] Ua[2]
Nickel, metal and compounds	Varies	BLP[3,9,12] BLP(EOS)[15] BLS[13,16] BT[9] CXr[2,7] PFT[2] PPS[2,13] U[3,5,9,12,13,16,17] U(EOS)[15]
Nicotine	00054-11-5	BLP[3] BUN[7] U[3]
Nitric acid	07697-37-2	CXr[2,7] PFT[2,7]
Nitric oxide	10102-43-9	CXr[2,7] Ecg40[2] ExA[4] PFT[2,7]
Nitroaniline, p-	00100-01-6	BL[7] BL(MHgb)[2,7,8,11,16] CBC[2,7] LFT[2,7] U[16] U(Cyt Hmt)[16]
Nitrobenzene	00098-95-3	BL[7] BL(COHb)[4,11] BL(EOS)[15] BL(MHgb)[2,3,5,7,8,11,16] CBC[2,7] U[2,3,5,7] U(EOS)[15,18] U(ESW)[11] U(EWW)[12,18]
Nitrobiphenyl, 4-	00092-93-3	**RIC**[1] U[2]
Nitrochlorobenzene, p-	00100-00-5	BL(MHgb)[2,7,8,11,16] CBC[2,7] U[16] U(Cyt Hmt)[16]
Nitrogen dioxide	10102-44-0	CXr[2,7] Ecg40[2] ExA[4] PFT[2,7]
Nitrogen trifluoride	07783-54-2	BL[7] BL(MHgb)[2,7,8,11] CBC[2,7]
Nitropropane, 2-	00079-46-9	CXr[2] LFT[7] PFT[2] WBC[7]
Nitrosodimethylamine, N-	00062-75-9	**RIC**[1] LFT[7] PFT[2]
Nitrotoluene (all isomers)	Varies	BL[7] BL(MHgb)[2,7,8,11,16] CBC[2,7] U[7,16] U(Cyt Hmt)[16]
Octachloronaphthalene	02234-13-1	LFT[2,7]
Oxalic acid	00144-62-7	BUN[7] U[3]
Oxygen difluoride	07783-41-7	CXr[2,7] PFT[2,7]
Ozone	10028-15-6	BL(PMN)[16] CXr[2,7] PFT[2,7,16]
Paraquat	04685-14-7	CXr[2,7] LFT[2] PFT[2,7] U[3] Ua[2]
Parathion	00056-38-2	BLS[9] CH[3,7,10,15] CH(BLP)[16] CH(BLP RBC)[16] CH(BLS RBC)[2] CH(RBC)[7,11] U[3-5,10] U(EOS)[11,15,18] U(EWW)[18]
Pentachloronaphthalene	01321-64-8	LFT[2,7]

Specific Medical Tests Published in the Literature for OSHA-Regulated Substances (Continued)

Name of Substance	CAS Number	Specific Medical Tests (References in Superscript)
Pentachlorophenol	00087-86-5	BL[9,17] BLP[3,5] BLP(EOS)[11,18] BLS[9] U[2-5,7,9] U(EWW)[17,18] U(PTS)[18] U(PWW)[11]
Perchloroethylene (tetrachloroethylene)	00127-18-4	BL[3,12,16] BL(16H)[5] BL(EWW)[15,18] BL(PNS)[15] BL(PTS)[18] BL(PWW)[11] ExA[3,4,10,12,16] ExA(16H)[5] ExA(DE)[5] ExA(EOS)[6,15] ExA(EWW)[15,18] ExA(PNS)[15] ExA(PTS)[18] ExA(PWW)[11] LFT[2,7] U[2,16] U(16H)[5,11] U(EOS)[15,18] U(EWW)[5,11,18] Ua[2]
Perchloromethyl mercaptan	00594-42-3	CXr[2,7] LFT[2] PFT[2,7] Ua[2]
Perchloryl fluoride	07616-94-6	BL[7] BL(MHgb)[2,7,8,11,16] CBC[2,7] CXr[2,7] PFT[2,7] U[16] U(Cyt Hmt)[16]
Phenol	00108-95-2	LFT[2,7] U[2,5,7,9,12] U(L2H)[3,15] U(EOS)[11,15,18] U(PPS)[17] Ua[2,7]
Phenyl glycidyl ether (PGE)	00122-60-1	PFT[2]
Phenylhydrazine	00100-63-0	BL[7] BLP(Hgb)[7] CBC[7] LFT[7] PFT[2] U[7] Ua[7]
Phosdrin (Mevinphos®)	07786-34-7	BLS[9] CH[7] CH(BLS RBC)[2] CH(RBC)[11]
Phosgene (carbonyl chloride)	00075-44-5	BGa[16] CXr[2,7] Ecg[16] ExA[4] PFT[2,7] SpC[16] WBC[16]
Phosphine	07803-51-2	CXr[7] PFT[7]
Phosphorus (Yellow)	07723-14-0	CBC(Anm)[2] DXr[2,6,7] KFT[6] LFT[2,7]
Phosphorus pentachloride	10026-13-8	CXr[2,7] PFT[2,7]
Phosphorus pentasulfide	01314-80-3	CXr[2,7] PFT[2,7]
Phosphorus trichloride	07719-12-2	CXr[2,7] PFT[2,7]
Phthalic anhydride	00085-44-9	CXr[7] PFT[7] U[5]
Picric acid	00088-89-1	BUN[7] LFT[2,7] Ua[2]
Pindone (2-pivalyl-1,3-indandione)	00083-26-1	BL[7] BLP(PTT)[2,7] CBC[7] Ua(RBC)[7]
Platinum, metal, and compounds	Varies	BL[9,17] BT[9] U[9,17]
Polychlorobiphenyl (42% chlorine) (PCB)	53469-21-9	AdT[3] BL[3,15] BLP[3] BLS[9,17] LFT[2,7]
Polychlorodiphenyl (54% chlorine) (PCB)	11097-69-1	AdT[3] BL[3,15] BLP[3] BLS[9,17] LFT[2,7]
Portland cement	65997-15-1	CXr[2,7] PFT[2,7]
Propiolactone, beta-	00057-57-8	**RIC**[1] PFT[2]
Propyl nitrate, n-	00627-13-4	BL[7] BL(MHgb)[2,8,11,16] CBC[2,7] Ua[7] Ua(Cyt Hmt)[16]

Propyleneimine	00075-55-8	BL[7] CBC[7] CBC(GL)[2]
Pyridine	00110-86-1	ExA[4] LFT[2] Ua[2]
Quinone	00106-51-4	Oph[2,7]
Selenium compounds, except SeF_6	Varies	BH[3] BL[7,9,13] BLP[15] LFT[2] U[3,7,9,15] U(24H)[13] WBC[7]
Selenium hexafluoride (SeF_6)	07783-79-1	CXr[2,7] PFT[2,7]
Silica, amorphous, diatomaceous earth	61790-53-2	CXr[2,7] PFT[2,7] Rdg[7] SpC[7] TBS[7]
Silica, crystalline cristobalite	14464-46-1	CXr[2,7] PFT[2,7] Rdg[7] SpC[7] TBS[7]
Silicates—soapstone	—	CXr[2,7] PFT[2,7]
Silicates—talc (without asbestos)	14807-96-6	CXr[2,7] PFT[2,7] Rdg[7] SpC[7] TBS[7]
Silver, metal and compounds	Varies	BL[9,17] BT[9] Pgm[2] U[9,17]
Sodium fluoroacetate	00062-74-8	Ecg[2,7] Ua[2,7]
Sodium hydroxide	01310-73-2	CXr[2] PFT[2]
Stibine	07803-52-3	BL[7] BLP(Hgb)[7] CBC[7] LFT[2,7] RBC(Hem)[2] U[7] Ua[2,7] WBC[7]
Stoddard solvent	08052-41-3	CBC[2] ExA[4] LFT[2] Ua[2]
Strychnine	00057-24-9	BUN[7] Cnv[2,7,16]
Styrene	00100-42-5	BL(16H)[5] BL(EOS)[11,15,18] BL(EWW)[18] BL(PNS)[11,15] BL(PTS)[18] ExA[4,5,9,12] ExA(DE)[15] ExA(PNS)[15] Neur[7] U[3,5,7,9,10,12] U(EOS)[10,11,15,18] U(EWW)[18] U(PNS)[11] U(PTS)[18]
Sulfur dioxide	07446-09-5	CXr[2,7] ExA[4] PFT[2,7]
Sulfur monochloride	10025-67-9	CXr[2] PFT[2]
Sulfur pentafluoride	05714-22-7	CXr[2,7] PFT[2,7]
Sulfuric acid	07664-93-9	CXr[2,7] PFT[2,7]
Sulfotep (TEDP)	03689-24-5	BLS[9] CH[7] CH(BLS RBC)[2] CH(RBC)[11]
Tellurium hexafluoride	07783-80-4	CXr[7] PFT[7] U[6]
Tetraethyl pyrophosphate (TEPP)	00107-49-3	BLS[9] CH[7] CH(BLP RBC)[16] CH(BLS RBC)[2] CH(RBC)[7,11]
Tetrachloroethane, 1,1,2,2-	00079-34-5	BUN[7] LFT[2,7] Ua[2,7]
Tetrachloronaphthalene	01335-88-2	LFT[2,7]
Tetraethyl lead	00078-00-2	BL[3] BMU[2,7] U[3,7,16] U(EOS)[4] Ua[2,7]
Tetramethyl lead	00075-74-1	BMU[2,7] U[7] U(EOS)[4] Ua[2,7]
Tetranitromethane	00509-14-8	BL[7] BL(MHgb)[2,7,8,11] CBC[2,7] CXr[2,7] PFT[2,7]
Tetryl	00479-45-8	CBC[7] CBC(Anm)[2] LFT[7]
Thallium and compounds	Varies	BH[7] BL[3,9,17] BT[9] NCS[15] U[3,4,7,15,16] Ua[2,7]

Specific Medical Tests Published in the Literature for OSHA-Regulated Substances (Continued)

Name of Substance	CAS Number	Specific Medical Tests (References in Superscript)
Tin, inorganic compounds (exc oxide)	Varies	BL[13] CXr[15] U[3,9,17]
Tin, organic compounds	Varies	Ecg40[2,15] Glau[2] KFT[15] LFT[2,7,15] RBC(Hem)[2] U[2,3,15]
Toluene	00108-88-3	BL[3,5,9,10,15,17] BL(EOS)[11,15,18] BL(EWW)[18] ExA[3-5,9,11] ExA(DE)[9,15] U[2-5,7,9] U(EOS)[10,11,15,18] U(EOS 2D)[17] U(L2H)[15] Ua[2,7]
Toluene-2,4-diisocyanate (TDI)	00584-84-9	CXr[2,7] PFT[7] PFT(PPS)[2]
Toluidine, o-	00095-53-4	BL[7] BL(MHgb)[2,8,11,15] CBC[2] Ua[2]
Trichloroethane, 1,1,2-	00079-00-5	ExA[4]
Trichloroethylene	00079-01-6	BL[3,12] BL(EOS)[15,18] BL(ESW)[11] BL(EWW)[15,18] BLP[5] ExA[3-5,7,11,12] ExA(EWW)[15] ExA(PNS)[15] PFT[2] U[3-5,12] U(EOS)[15,18] U(ESW)[11] U(EWW)[11,15,18]
Trichloronaphthalene	01321-65-9	LFT[2,7]
Trinitrotoluene, 2,4,6- (TNT)	00118-96-7	BL[7] BL(MHgb)[15] CBC[7] CBC(ApA)[2] LFT[2,7] Ua[2]
Trichlorophenoxyacetic acid (2,4,5-T)	00093-76-5	BLP[3] U[3,4] U(24H)[12]
Trichloropropane, 1,2,3-	00096-18-4	ExA[4]
Uranium and compounds	07440-61-1	BL[7] CBC[2,7] CXr[2,7] U[2-4,7,9] Ua[2,7]
Vanadium fume (pentoxide)	01314-62-1	BL[17] CXr[2,7] PFT[2,7] U[5,7,13,15] U(EOS)[18] U(EWW)[18]
Vinyl chloride	00075-01-4	**APh**[1] **Br**[1] **GGT**[1] **SGOT**[1] **SGPT**[1] APh[9] Br[7] CXr[7] ExA[3,4] GGT[7] LDH[7] LFT[15] PFT[2,7] SGOT[7] SGPT[7] U[3,15] Ua[7] Usg[9]
Warfarin	00081-81-2	BL[7] BLP[3] BLP(Hyt)[2] BLP(PTT)[2,7,12] CBC[7] Ua(RBC)[2,7]
Xylene, all isomers	Varies	BL[3,7,12] BL(DE)[5] BL(EOS)[15] CBC[7] CBC(HeD)[2] ExA[3,4,10] LFT[2,7] U[3,5,9,10,12] U(EOS)[11,15,18] U(EOS 2D)[17] U(EWW)[18] U(L2H)[15] Ua[2,7]
Xylidine	01300-73-8	BL[7] BL(MHgb)[2,7,8,11] CBC[2,7]
Zinc chloride fume	07646-85-7	BL[9,17] BT[9] CXr[2,7] PFT[2,7] U[2,3,7,9,15]
Zinc oxide fume	01314-13-2	BL[9,17] BT[9] CXr[2] PFT[2] U[2,3,7,9,15] WBC[7]
Zirconium and compounds, except ZrCl4	Varies	BL[9,17] BT[9] (GraS)[2]

[a] This is an updated version of TABLE 2 of L. I. Murthy & W. E. Halperin, 1995, Medical Screening and Biological Monitoring: A Guide to the Literature for Physicians, J. Occup. Environ. Med. 37(2): 170-184.

Abbreviations Used in Appendix 2

1M = After 1 month's exposure
2D = After 2 days' exposure
6M = Every 6 months
16H = 16 hours after end of exposure
24H = 24-hour collection
AdT = Adipose tissue
Anm = Anemia
ApA = Aplastic anemia
Aph = Alkaline phosphatase
BF = Body fluid (chemical/metabolite)
BGa = Blood gas analysis
BH/N = Body hair/nail
BL = Whole blood (chemical/metabolite)
BLC = Blood cyanide
BLL = Blood lead
BLM = Metabolite in blood
BLP = Blood plasma
BLS = Blood serum
BLW = Blood analyzed weekly
BMU = Biologic monitoring of urine every 3 months
Br = Bilirubin
BT = Biologic tissue/biopsy
BUN = Blood urea nitrogen
CBC = Complete blood count
CH = Blood cholinesterase
CXr = Chest X-ray
Cnv = Convulsions
COHb = Carboxyhemoglobin
Cyt = Cytology
DE = During exposure
DXr = Dental X-ray
Ecg = Electrocardiogram
Ecg40 = Electrocardiogram on workers over 40 years
EOS = End of shift
Emg = Electromyogram
ESW = End of shift at end of worksheet
EWW = End of workweek
ExA = Expired air
FOB = Fecal occult blood screening
Frg = Fragility
FSH = Follicle stimulating hormone
GGT = Gamma glutamyl transpeptidase
GL = Granulocytic leukemia
Glau = Glaucoma
GraS = Granuloma of the skin
GUT = Genito-urinary tract
Hem = RBC hemolysis
HeD = Hematopoietic depression
Hmt = Hematuria
Hyt = Hypoprothrombinemia
Hgb = Hemoglobin
KFT = Kidney function tests
L2H = Last 2 hours of 8-hour exposure
L4H = Last 4 hours of 8-hour exposure
LDH = Lactic dehydrogenase
LFT = Liver function tests

Abbreviations Used in Appendix 2 (Continued)

LH = Luteinizing hormone
LTT = Lymphocyte transformation test
MHgb = Methemoglobin
NCS = Nerve conduction studies
Neur = Neurologic examination
Oph = Ophthalmic examination
PFT = Pulmonary function tests
Pgm = Pigmentation evidence
PMN = Polymorphonuclear leukocytes
PNS = Prior to next shift
PPS = Pre- and postshift
PpT = Photopatch testing
PTS = Prior to shift
PTT = Prothrombin time
PWW = Prior to last shift of workweek
PXr = Pelvic X-ray
RBC = Red blood cells
Rdg = Radiography
ReC = Reticulocyte count
Ria = Radioimmunoassay
RIC = Reduced immunologic competence
SCr = Serum creatinine
SCt = Sperm count
SGOT = Serum glutamic oxalacetic transaminase
SGPT = Serum glutamic pyruvic transminase
SpC = Sputum cytology
TBS = Tuberculin skin test
TE = Total estrogen (females)
TFT = Thyroid function test
U = Urine (chemical/metabolite)
Ua = Urinalysis (routine)
Usg = Ultrasonography of the liver
WBC = White blood cell count/differential
ZPP = Zinc protoporphyrin

References in Appendix 2

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