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BIOLOGICAL AND ENVIRONMENTAL MONITORING AS AN AID TO PROTECTING WORKERS IN THE MINING AND SMELTING INDUSTRY

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An objective of industrial hygiene is to protect the worker against the health effects of ingestion and inhalation of substances that in some forms and above certain quantities or concentrations might be toxic. One of the tools used in providing protection against the effects of such substances as lead, arsenic, and cadmium is biological monitoring. Another and companion tool is air monitoring.

Biological monitoring is a general term that includes routine analysis of body fluids, primarily blood and urine, to determine concentrations of the contaminants. An effective biological monitoring program will show, in advance of possible illness, when such concentrations are rising and approaching levels associated with health effects and when, therefore, preventive measures must be taken. Biological monitoring yields a measure of the potential effect of total exposure of the individual and in that sense is superior to air monitoring as a means of determining the extent to which protection may be needed. Even when air monitoring shows that airborne concentrations in the workplace are at levels indicating a desired degree of protection, work habits and practices, personal hygiene, or even spare-time activities might result in a worker's ingestion as well as inhalation of different amounts of contaminants than those indicated by air monitoring. More importantly, the potentially harmful absorption and accumulation of certain substances can be detected best by analysis of samples of blood or urine.

Biological monitoring is quite consistent with the sound and prudent practice of industrial hygiene. The American Industrial Hygiene Association defines industrial hygiene as a science "devoted to the recognition, evaluation, and control of those environmental factors . . . which may cause sickness. . . ." As the most effective and the most accurate means of recognizing and evaluating occupational exposure to various substances and therefore of triggering control measures, biological monitoring constitutes sound and prudent industrial hygiene practice.

The criticism has been made that a program of biological monitoring uses the workers involved as "human guinea pigs." This charge is not valid, because the objective of any health maintenance program that includes biological monitoring is protection based upon scientific data obtained from experimentation that has already been done.

Although biological monitoring has significant advantages over other procedures in many situations as part of the detection, prevention, and compliance mechanisms, this procedure is not applicable in dealing with some substances that might be found in the workplace. This is because those substances are not readily excreted in urine or because they cannot be measured in urine or blood. Such substances include asbestos and silica, for which environmental monitoring, coupled with comprehensive medical examinations, must be used for the assessment of industrial hygiene problems related to operations involving those particular substances.

Environmental monitoring, particularly the sampling and analysis of air in the workplace, is an important procedure and every employer should have an air sampling program in effect. Two purposes can be served thereby:

1. Areas in a plant can be identified in which airborne concentrations violate adopted and promulgated standards of exposure. These measurements can be used to indicate where engineering controls and modification of work practices need to be instituted or improved, if to do so is feasible.

Control of concentrations of dust and fume by exhaust ventilation is the usual method of preventing employees from inhaling excessive quantities of substances that could, in time, accumulate in the body and cause illness. The required degree of control by this or other means is not always feasible or immediately available, however, and existing controls can be supplemented by approved respirators which, when properly fitted and worn, will effectively prevent inhalation of contaminants. Ordinarily, on most jobs, respirators need be worn only part of the time.

2. The effectiveness of engineering controls can be evaluated by air monitoring.

Air sampling, however, has a number of serious deficiencies and may not accurately measure the worker's exposure actually effective in causing absorption of airborne substances. Air samples can be unreliable indicators of employee risk, particularly for such materials as lead, cadmium, and arsenic which can also be ingested. As ordinarily done, air sampling and analysis do not correct for large particles which cannot be inhaled and for the varying solubilities of airborne compounds. An environmental "exposure limit," based simply on airborne concentrations, should not, therefore, function as the sole compliance mechanism or be the only measure used for the worker's protection. Similarly, biological samples alone should not be relied upon, but should be supplemented with air sampling data to verify exposure sources or indicate poor personal hygiene, work habits and practices, etc.

The air sampling pumps used for environmental monitoring are sometimes referred to as "sophisticated instruments." They are not sophisticated at all. They merely consist of a sample holder and filter, a piece of plastic tubing and a vacuum pump. This equipment typically measured only the total mass of airborne particles. The equipment also produces measurements which are subject to considerable variation and so are unreliable as indicators of either employee health or the condition of the working environment.

Air sampling and biological monitoring can be combined to assess the effectiveness of respirators, particularly when dealing with such compounds as lead, cadmium, or arsenic. For example, Table 1 shows the results of testing respirator efficiencies used in the production of arsenic. The figures were obtained by collecting air samples, both insdie and outside of a respirator, under actual field conditions.

Biological samples also can be used as an indication of the effectiveness of respirators. Table 2 shows the results of biological monitoring for employees handling arsenic compounds. In April the type of respirator being used was changed. By December, there was a 50 per cent reduction in average urinary excretion of arsenic, indicating the effectiveness of the new respirator employed in April and the value of employee training programs.

A truly effective industrial hygiene program gives adequate emphasis to both air sampling and biological monitoring. When used together, the sources of employee absorption of some potentially toxic materials can be established, i.e., personal hygiene,

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workplace exposure, etc. The prevention of occupational disease can be achieved by the diligent application of a health maintenance program involving both types of monitoring.

TABLE 1

Respirator Testing

Run	*Respirator Type*	*Per Cent Efficiency Arsenic*
1	Welsh 7500-8	98.76
2	Welsh 7500-8	99.10
3	MSA Type H	⩾99.43 and ⩾99.18
4	MSA Type H	⩾97.47 and ⩾96.61
5	Willson R-12	⩾99.22 and ⩾98.95
6	Willson R-12	99.63
7	AO R-57	99.83
8	AO R-57	97.12

TABLE 2

Month	*Per Cent Reduction in Average Urinary Excretion*
Changed to Different Respirators	
April	—
Sept.	12.1
Oct.	15.6
Emphasized Proper Use of Respirators	
Dec.	50.3

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INDUSTRIAL HYGIENE CONSIDERATIONS IN REFINERY OPERATIONS

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A refinery is a masterpiece of engineering skill—in this maze of vessels and pipelines a marvelous transformation of crude oil is taking place; a great variety of petroleum and petrochemical products which have a great effect on the economy of this country and on the world are being produced.

To the casual observer or to a person not trained in occupational health, the only possible hazard they associate with the refinery is a fire or an explosion. To the novice industrial hygienist, the presence of occupational health hazards, with the exception of the noise, is also obscure. The only evidence that some "toxic" agent is lurking in the background is the "refinery odor" that can be detected at all areas. To the refinery worker, to the owner of the refinery, and to the community members that depend on the jobs provided by the refinery, the "odor" is affectionately referred to as "the smell of money."

During normal operating conditions in a refinery, the potential for exposure to occupational health hazards in an operating unit is at a minimum. The reason for this is that very few personnel are in the unit and the products are all in a closed system. The greatest potential for exposure occurs during turn around of a unit or units. At this time vessels are opened, catalyst is replaced, surfaces on tanks, pressure vessels, pipes, etc., are cleaned and welded, and insulation is stripped and replaced. A high potential for exposure continues until all units are back on stream.

The workmen experiencing the greatest exposure potential are the maintenance personnel who are assigned to perform their labors in the refinery complex. The personnel least exposed are probably the unit operators. Automation and centralization of control instrumentation have contributed greatly to the reduction of operating personnel exposures. Of course, during turn around most refinery personnel become involved and the exposure risk increases. At this time, contract personnel are brought in to perform all types of work and they are also exposed to the potentially harmful agents.

The major occupational health hazards that can be identified in refinery operation include noise, dusts, chemicals, and sanitation.

Noise

Noise is the most obvious and pervasive harmful agent. It is generated by electric motors, steam turbines, cooling fans, forced draft fans, primary and secondary air intakes for burners, steam leaks, high pressure air and steam letdowns, pressure control values, power generators, compressors, sand blasting, fluid transmission pipes, flares, and mechanical equipment needing maintenance or replacement. Sources like the high pressure steam and air letdown can generate 125 dBA at a distance of 50 feet from the outlet. In a typical refinery, at least 75 per cent of the area bounded by the battery lines of the whole refinery complex may exceed 85 dBA.

Past and present activity in noise control by industry and the enforcement of the OSHA noise standard has resulted in the development and installation of various noise control devices in refinery operations. For example: flares have been equipped with silencers; cooling fans have been designed with more blades and operate at slower speeds;

forced draft fans on boilers or stacks have been equipped with silencers; pipelines have been lagged with acoustical materials; electric motors of the totally enclosed fan cooled (TEFC) variety have been equipped with mufflers; primary intake air openings on burners have been equipped with mutes; acoustic plenums have been constructed around the secondary air intakes for burners; turbines, pumps, and motors have been enclosed in acoustic booths; high pressure steam and air let-down outlets have been equipped with silencers; greater attention has been given to the repair of steam leaks, to the replacement or repair of bad bearings and to dampening of vibrating equipment; control valves are being replaced with "trim or drag" valves that drastically reduce the noise at the valve body and eliminate transmission of the noise along the pipeline.

Adoption of one or more of the noise control techniques has resulted in significant reduction of noise levels at the source and significant changes in the quality of the ambient noise at the unit and refinery as a whole.

Dusts

The dusts to which a refinery worker can be exposed, especially the maintenance and crafts personnel (company or contractor), include asbestos, silica, catalyst, coke, and residue or scale accumulated inside vessels or pipes.

Exposure to asbestos occurs when the old insulation is stripped from the vessels and pipes, when the new insulation is trimmed to fit the vessel or pipes, and during clean up of the waste insulation and debris. Preventing exposures requires that the material to be stripped be wetted down before stripping begins, that the scrap be disposed of in closed and labeled containers, that dust-producing operations such as trimming and grinding be done with the use of exhaust ventilation, and that personnel wear respiratory protective devices when conditions warrant it.

Exposure to silica occurs when the vessels and pipelines are sandblasted. Not only is the person doing the sandblasting exposed, but so are the refinery workers who may be working in an area downwind from the sandblasting operation. Recent studies by contractors for NIOSH have shown that sandblasters are definitely exposed even though they are wearing the common sandblasting hood and supply air.

To ameliorate exposure to silica, many employers have changed from river sand to fine fused slag known as "Black Beauty" and "Stan-Blast." Better respiratory protective hoods are also being used.

When a unit is shut down for turn around, catalyst beds are changed. Exposure occurs when the workmen enter the confined spaces to remove the catalyst or when the vessel is being charged. Toxic substances that may be found in the catalyst include: silica, nickel, vanadium, iron, cobalt, and other substances. Use of appropriate protective clothing will reduce the exposure to catalyst dust. General and/or local exhaust ventilation must be used in confined spaces.

Chemicals

The chemicals to which refinery personnel can be exposed, either in the gaseous or liquid state, are legion. These chemicals can be raw products, intermediate products, or final saleable products. The following are examples of some of the common potential exposure to be anticipated:

1. Operating personnel who sample the product streams, check the product storage tanks, and open drain pipes on various vessels or water knock-out tanks are exposed to varying concentrations of hydrocarbon vapors.

2. Personnel at the product loading locations, tankers and barges may, depending upon the prevailing atmospheric conditions, experience significant exposures to hydrocarbon vapors. A recent study conducted by Shell Oil of

the potential exposure of personnel attending to the loading operations experienced their highest exposure when loading tankers with top loading and no vapor recovery systems.

3. Laboratory personnel who analyze the many samples are exposed to the hydrocarbon vapors; most laboratories are ill-equipped as far as local exhaust capabilities are concerned.

4. Personnel who work with antiknock additives for gasoline must constantly be on the alert to prevent exposure to those extra-hazardous agents. Proper protective clothing must be worn by personnel, adequate local exhaust ventilation must be provided when working with these agents in confined spaces, and an adequate supply of kerosene must be available in the event that decontamination of the skin or clothing is necessary.

5. Personnel working in the alkylation unit, especially if hydrogen fluoride is used as the catalyst, must observe very strict precautions if contact with this very corrosive agent is to be avoided. Impervious clothing must be worn; the extent of protection needed is dictated by the work to be performed and the location in the unit.

6. When sour crude is processed, exposure to hydrogen sulfide can occur at the crude storage tanks or anywhere on the closed system prior to its removal at the sweetening unit; from this point, exposures can occur in the closed system leading to and at the sulfur plant.

7. Exposures to toxic substances used in ancillary operations include: elemental lead used to seal the connecting joints in vessels, or lead fumes generated while welding or burning on painted surfaces; lead oxide used as a primer paint on the outside surfaces of vessels and piping; elemental mercury used in pressure sensing devices; water treatment chemicals that include chromates, acids, and caustic materials; radioactive sources used as level gauges and density sensors; *fumes from welding or brazing* operations, especially when working in confined spaces or on contaminated surfaces.

Sanitation

Refineries are show places when it comes to housekeeping and outward appearance in the units. Unfortunately, this zeal for cleanliness is lost when it comes to lunch rooms, restrooms, water fountains, change rooms, and places where food is prepared and served in the unit.

If occupational health hazards in petroleum refining operations are to be identified, quantified and controlled and if prevention of exposures are the objectives of the management, a comprehensive industrial hygiene program must be instituted to accomplish the following:

1. Examine the work environment and environs: (a) study work operations, processes, and materials to assess the nature of the potential for exposure to harmful conditions. This will require an assessment of work habits, equipment use, materials used as raw and intermediate materials or products and byproducts, number of persons exposed, duration of exposure, and mode of exposure; (b) make appropriate measurements to establish the concentration of contaminant or magnitude of exposure.

2. Interpret results of field studies, examinations, and measurements to determine the ability of the stresses to cause illness and the degree of hazard potential created by these stresses.

3. Make specific recommendations as to the need for and type of control measures necessary to minimize or eliminate exposure. These measures may include one or more of the following: isolation of the process or work operation to reduce the number of exposed personnel; substitution of a hazardous material with one of no known hazard or at least one of lesser hazard; alteration of the process or work cycle to minimize human exposure; appropriate application of ventilation practices and equipment to provide an atmosphere safe for

human occupancy; provide shielding or enclosures and limit the time of exposure and distance between the stress agent and the worker; good housekeeping practices, including cleanliness of the work place, proper waste disposal, adequate washing, toilet, and restroom facilities, healthful domestic water supply and lunch room facilities, and control of insects and rodents; appropriate personal protective devices such as respirators, hearing protectors, and other special clothing consistent with the nature of the hazard.

4. Review plans for new or modified expansion of facilities or processes; review engineering designs of facilities and health hazard control methods; and review and approve materials purchased for use in process or operation. This practice will assure that occupational health hazards are recognized and eliminated while in the planning or design stages rather than retrofitting after the fact.

5. Prepare realistic rules, regulations, standards, or operating procedures to conduct work in a health-safe manner.

6. Prepare appropriate methods of alerting the worker to the hazards associated with the materials or process. This should include material safety data sheets, warning labels for bulk and small containers, placards at the site of potential exposure, and hazard control bulletins.

7. Develop and conduct programs for the education of managers and plant employees in the prevention of occupational diseases.

8. Conduct epidemiologic studies among workers and similar industries to discover the possibilities of the presence of occupational diseases. Correlation of plant studies, worker exposures, and incidence of disease will help in guiding the development of realistic standards by governmental agencies.

9. Coordinate with various company organizations such as manufacturing, production, safety, fire protection, medical, employee relations, engineering, etc., on matters relating to the use of hazardous substances and control of personnel exposures.

Conclusion

To the casual observer who tours an oil refinery while it is in full operation, the presence of occupational health hazards and the potential for personnel exposures are not obvious. However, to the professional industrial hygienist, the subtle exposures that occur while the refinery is operating smoothly and while the refinery units are on turn-around are real and present cause for action. Maintenance personnel have the highest risk potential and turnaround operations pose the greatest opportunities for exposure. Noise and chemical dusts, mists, and vapors are the hazardous agents of greatest concern.

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