INDUSTRIAL HYGIENE ASPECTS OF THE PRODUCTION AND DISPOSAL OF LOW LEVEL RADWASTE

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ABSTRACT

Much attention has been focussed on the protection of workers in the nuclear industry from the long and short term effects of radiation. In addition to radiation, personnel at nuclear facilities may be exposed to many toxic and other hazards of a non nuclear origin. These hazards originate from the gases, volatile materials, particulates and liquids employed during construction, production, or disposal operations at nuclear facilities. Toxic exposure routes are respiratory, dermal, or ingestion. Sources of nonradioactive exposure are chemicals and procedures employed in routine operations, decontamination operations, radwaste disposal and characterization of waste sites. Additional hazards are related to noise, heat explosions, pryophoricity and pathogenicity.

The industrial hygienist has traditionally been involved in recognizing and evaluating worker exposures in the industrial environment. In this respect, the industrial hygienist can set guidelines, anticipate hazards and audit facilities and operations with regard to occupational safety and health conditions. Regulations such as the Occupational Safety and Health Act and 10CFR61, "Licensing Requirements for Land Disposal of Low Level Waste," mandate the elimination of hazards to workers. Fortunately many, but not all, of the requirements for personnel protection in radiation operations, such as gloves, disposable clothing, respirators, etc., may also protect the workers against nonradioactive hazards. Nuclear facilities operate air sampling systems for the primary purpose of detecting gaseous and particulate radioactive emissions. In focussing on the generation and disposal of low level waste, it is apparent there are requirements for sampling systems and personnel protection which go beyond that required by good radiation practice. In particular, in decontamination operations, formulations have been employed comprising acids, bases, oxidants, reductants, inhibitors and complexing agents which must be treated chemically, or physically prior to disposal to meet 10CFR61, paragraph 56 requirements. This could lead to exposure to hazardous materials from the reagents, during the addition and during subsequent volume reduction and compaction steps. Many of the chemicals employed exhibit some degree of biological toxicity. Several of these chemicals are corrosive, explosive, combustible, or are a fire hazard. Industrial, medical and laboratory sources produce an even greater variety of low level waste, each with its own identifiable nonradioactive hazard.

Compliance with 10CFR61 and previous good practice has reduced the chance of inadvertent exposure to hazardous materials at commercial low level waste sites, however, two categories of low level waste sites require utmost precaution. These are CERCLA sites which contain mixed wastes of unknown origin and mixed wastes contained in burial sites, pits, tanks and seepage ponds, at U.S. DOE prime installations. At production facilities, it is possible to remove, or eliminate hazards. Conversely, this is not possible during the characterization phase at low level waste sites. These sites require health and safety precautions during characterization and sampling identical with that employed at nonradioactive facilities. Health and safety experience at nuclear facilities and waste sites will be presented.

ROLE OF INDUSTRIAL HYGIENIST

The industrial hygienist's responsibility in the nuclear cycle is to recognize health related hazards involved in the operations. The industrial hygienist usually works in conjunction with site health physics, or safety personnel, as a consultant, or staff functionary. In the consultant role, the industrial hygienist must rely upon the HP or safety personnel to make the recognition of possible health hazards. The staff IH must make periodic audits of the operation to identify the hazards. Arrangements can also be made by the HP for routine IH audits[1].

After the process hazards have been identified, a series of hazard evaluations and possible sampling must be conducted.

The increasing quantities of hazardous waste materials that are being generated are an increasing concern for many disciplines, including industrial hygienists. The generators of hazardous waste are responsible for the safe disposal of these materials. Included in this responsibility are the long term threats to public and worker health and to air and water quality that are posed by the disposal of many types of treated and untreated hazardous waste and by the inappropriate handling, storage, use and disposal of hazardous waste.

In order to minimize these exposures, it is necessary for all individuals responsible for safety and health during the handling of hazardous materials to have a basic understanding of industrial hygiene and its principles.

GUIDES, CODES, REGULATIONS AND STANDARDS FOR CHEMICAL AND PHYSICAL AGENTS

The Occupational Safety and Health Act of 1970 has been the most significant piece of legislation impacting upon worker health in the United States. This act brought into importance the concept of safeguarding the health of workers and the development of the science of industrial hygiene. The act is comprehensive in covering all situations involving exposures and employer employee relationship. The OSHA Act is a uniform program of occupational health regulations which apply to all businesses engaged in commerce, regardless of their location within the United States. Threshold limit values which are regulations which limit exposure to toxic chemicals were incorporated into the regulation and now have the effect of law are the most important industrial hygiene aspect of the law.

Originally, the establishment of threshold limit values was done on the basis of professional opinion and judgement of professional organizations involved in industrial hygiene. The two oldest and most significant of these organizations are the American Conference of Governmental Industrial Hygienists (ACGIH). In fact, the threshold limit values which are established every year by the ACGIH as law. Since 1970, approximately 17 changes have been made in some 500 threshold limit values which were originally incorporated into the OSHA Act[2].

Under the Occupational Safety and Health Act, authority was established with the Secretary of Labor to enforce these threshold limit values as well as to establish new standards. Under the act, the National Institute for Occupational Safety and Health (NIOSH) was established within the Department of Health, Education and Welfare (now the Dept. of Health and Human Services), to conduct research and training, develop criteria, publish a list of toxic substances and make investigations relative to these responsibilities. The OSHA Act also provides for the participation of State Official Agencies in carrying out the provisions of the act. Several State agencies have taken over the responsibilities for establishing and enforcing standards for protecting the health of workers coming within their jurisdictions. These so-called State compliance programs are monitored by the Department of Labor.

For the hazardous waste materials manager, all conditions involving worker exposures are regulated by the OSHA Act when there is an employer/employee relationship. There have been no new standards or guidelines established as regulation for the hazardous waste industries. Therefore, the hazardous waste manager must rely upon a knowledge of the OSHA Act in satisfying compliance with employee exposures.

The hazardous materials manager should have a working knowledge of exposure limit values. These limits are usually referred to as threshold limit values (TLV's) or permissible exposure limits (PEL's). These exposure limit values are the crux of most occupational health codes, regulations and standards. The manager should have a current updating of the OSHA Act, as well as the annually published list of threshold limit values of airborne contaminants and physical agents provided by the American Conference of Governmental Industrial Hygienists. This list is reviewed annually and values are updated as relative data becomes available. Therefore, the ACGIH listing is the most current data on TLV's. Intended changes are published as part of the annual list and comments supportive with data are requested.

The National Institute for Occupational Safety and Health has responsibility for developing and publishing criteria dealing with toxic materials and harmful agents under the OSHA Act. However, recent legal decisions and the lack of funding by the present administration has allowed few new changes in the OSHA standards.

The American Industrial Hygiene Association publishes a hygienic guide series covering an extensive list of chemicals. A hygienic guide for a governed material contains the following information: physical properties restricted to 8-hour permitted exposure limits, short term exposure limits, toxic properties and required industrial hygiene and medical practices.

PRINCIPLES OF TOXICOLOGY

Toxicologists study the nature and action of toxic materials upon the human. This is a complex and ongoing area of study. Many industrial hazards have been known to be toxic for centuries. There are many chemical agents that have been around for a long time and only recently have become known to be potentially toxic. Additionally, there are many new materials being introduced all the time that we are not fully aware of their toxic potential[3].

A basic principle of toxicology relative to industrial hygiene is the dose-response relationship. The theory is that the potential toxicity, or harmful action inherent in a substance, is manifested only when that substance comes in contact with a living biological system in an adequate concentration and over a certain amount of time. The toxic potential of a chemical is ultimately defined by the relationship between the dose (the amount) of a chemical and the response that is produced in the biological system over time.

Basic laboratory assessment of the dose-response is the LD-50 or LC-50 test. The LD-50 refers to the lethal dose at which 50% of the test agents will expire at a given concentration[4].

In the work environment, toxic chemicals can enter the body by various routes. The most important route of exposure in industry is inhalation. Next in importance is contact with the skin and eyes. An additional route which does not happen regularly in industry is ingestion. The response to a given dose of toxic agents may be varied markedly depending on the route of entry.

Inhalation exposures are of prime importance to the industrial hygienist. With exposures involving aerosols or particulate, the most important factor involving the exposure is particle size. Particles that are too large to pass through the nasal passages and reach the lungs are of less concern than smaller particles that can reach the deep areas of the lungs.

Exposures involving gases and vapors are of most concern with the solubility of the agent. Water soluble agents will tend to react with the upper areas of the nasal passages while insoluble gases and vapors will pass deeper into the lungs where conceivably more damage may occur.

In addition to this toxic classification, chemicals can be classified by their physiological effects. Irritants are those agents that are capable of causing inflammation of mucous membrances with which they come in contact. Asphyxiants are agents that effect the bodies ability to utilize an adequate oxygen supply. Anesthetics are gases or vapors that depress the central nervous system. Hepatoxic agents are chemicals that effect the action of the liver and kidneys. Neurotoxic agents are materials which, in one way or another, produce their main toxic effect on the nervous system. Pneumoccniosis producing dusts are agents which affect or damage the lungs. This includes asbestos and silicas.

PRINCIPLES AND PRACTICES OF INDUSTRIAL HYGIENE ASSESSMENTS

The general principles in evaluating the occupational environment concern recognition of potential hazards, the evaluation of the exposures, the interpretation of the survey data and the implementation of controls. The recognition of potential hazards includes being familiar with the processes and maintaining an inventory of physical and chemical agents encountered. The procedures and the preparation of a field study include the selection of proper instruments, calibration of equipment and the development of required analytical methods. Once the survey has been conducted, the industrial hygienist must interpret the results. At this point, the health standards and previous data are required for comparison. Knowledge of proper corrective measures is a matter of education and experience in dealing with industrial hygiene responsibilities[5].

The industrial hygienist must become familiar with all processes involved in the particular area of concern. He must discern what chemicals and substances are used and how the usage of this material may interreact with the worker. This condition becomes quite difficult for a hazardous waste manager in that the materials being used may not have been properly characterized qualitatively or quantitatively before being handled. In this type of situation, it is necessary for the industrial hygienist to take a conservative approach in assuring that all workers are going to be adequately protected in the "worst-case" situation.

After the listing of chemicals has been developed it is necessary to learn which of the chemicals are significantly toxic by referring to the OSHA standards, the ACGIH TLV's or NIOSH criteria documents. In checking these references, it is necessary to ascertain whether or not the chemical is a health hazard from inhalation, direct absorption through the skin, ingestion or from all three potential situations.

A survey should be conducted at the facility to evaluate the potential exposures of the workers. Reviews should be made of the workers routine job requirements and such conditions noted. Included in this evaluation should be a notation of the control measures in use.

To aid in the evaluation, it may be necessary to collect air samples representative of the concentrations of air being breathed by the workers. The types of sampling instruments used include: (1) direct reading; (2) those which remove the contaminant from a measured quantity of air; (3) those which collect a known volume of air for subsequent laboratory analysis. The choice of a particular sampling instrument depends upon a number of factors. Among these are: (1) portability and ease of use; (2) efficiency of equipment or device; (3) reliability under various conditions for type of analysis or information required by availability and (4) personal choice and experience[6].

No single universal sampling instrument is available and it is doubtful that such an instrument will ever be available. Therefore, the hazardous waste manager should become aware of the various types of instruments available and the various conditions in which this instrumentation might be needed for use.

In addition to being knowledgeable about the collection of the sample, the industrial hygienist must have a working knowledge of the analytical chemistry involved in measuring samples that have been submitted to the laboratory for analysis. There are many factors involved in the sampling of the air that can subsequently affect the analytical analysis of these samples. In order to be knowledgeable about analytical techniques the industrial hygienist should be familiar with the ACGIH Manual of Analytical Methods, the AIHA Hygienic Guides and the NIOSH Manual of Air Sampling and Analysis.

Nuclear utilities have a variety of processing options prior to disposal. The processing may be accomplished by mobile contractor equipment, or fixed utility owned equipment. A review of solidification processes indicates possible respiratory and dermal injury from chemicals. The most common method of solidification employs cement. Cement is a respiratory hazard due to its free silica content and a dermal hazard due to its high pH. Other caustic compounds, such as $CaCl_2$, $CaOH_2$ sodium metasilicate, are added as accelerators.

Several specialized solidification processes have been developed and must be explored for other toxic compounds. Other solidification agents have included asphalt, urea formaldehyde, and other proprietary compounds. The major constituent added to the radwaste process is usually boric acid.

Nuclear activities eventually wind up with the production of low level radioactive waste. Many of the waste matrices pose no personnel hazard and require no special precautions. The principal components in low level radioactive non fuel cycle wastes have been listed by B.S. Bowerman (Ref. 7), et al. These substances are combustible, volatile, corrosive and pathogenic. Non fuel cycle wastes are derived from industrial, medical and laboratory sources. Table I lists the principal substances from this source.

TABLE I

Materials Present in Non Fuel Cycle Waste

SUBSTANCE	CAS		OSHA	
Toluene	1088-88-3	A840CFR261	2	T
Xylene M	108-38-3	A840CFR261		T
Xylene O	95-47-6			
Xylene P	106-42-3			
Sodium Hydroxide	1310-73-2		2,1	
Ethanol	6T-56-1	A840CFR261.31	1	
Benzene	71-43-2		2	
Ethyl Acetate	141-78-6		1	
Biological Waste				

The sources and mode of protection of these wastes are too varied to discuss the individual hazards associated with their use and disposal. It is important to point out that these substances can pose a hazard in transport and to workers at the burial site. A discussion of the hazards connected with all stages of the waste produced in the fuel cycles would be too lengthy for this paper, however, a look at the hazards connected with low level waste disposal at nuclear utilities is illustrative of the potential occupational hazards at these plants. These wastes are produced in normal operations, or during decontamination procedures[2,3]. Ultimately the waste is prepared for disposal by solidification, or in high integrity containers.

PERSONAL PROTECTIVE EQUIPMENT

It has always been one of the fundamentals of industrial hygiene that personal protective equipment is a last resort type of control to be used only when engineering controls are not feasible or practical. In fact, this philosophy is stated in the Occupational Safety and Health Act. However, there are many situations in industry involving short term exposures for which there are no feasible engineering controls can

TABLE II

Nuclear Utility Health Hazards

CHEMICALS	HAZARD
Cement	Inhalation
$CaCl_2$	Dermal and Inhalation
Lime	Dermal and Inhalation
Sodium metasilicate	Combustible, Inhalation
Asphalt	Volatiles, Burns
Dow Media (Styrene Monomer)	Carcinogen, Combustible
Urea Formaldehyde	Carcinogen
Envirostone	Dusts
Boric Acid	Inhalation

be employed. In these situations personal protective devices are extremely important as a means of protecting the worker against inadvertent or unexpected conditions. When hazardous materials are involved, it is often the only way of handling the situation is to protect the worker with a respirator, face shield and coveralls before opening a container of toxic material. Even if the worker does not expect to need the equipment, it is better to be prepared and protected if toxic material escapes its confinement. Personal protective equipment appears to be very simple to provide, yet indeed, it requires a certain amount of important thought by the professional before issuing the equipment to the workers.

When respirators are used for protection against inhalation hazards, it is necessary to specify respirators that are designed to protect against the specific types of substances involved and the concentration ranges that are to be expected. All respirators used should be approved by the National Institute for Occupational Safety and Health, or in rare cases involving the U.S. Bureau of Mines. Professionals should be aware that certain respirators are designed only for particle removal, or for gases and vapors. It is possible to find units that are designed to protect against both types of agents. However, this requires a study of the specifications for the instrumentation by the professional.

Once a proper respirator has been chosen, it will be necessary to fit-test that instrument to the worker. There are several types of tests available including a test using non-toxic easily smelled agents such a banana oil to test the quality of the fit. There are more sophisticated types of testing in which the air inside of the respirator is monitored after the employee has been shown how to use the device.

In emergency situations, including many of those involved in handling hazardous waste, it may be necessary to provide self-contained breathing apparatus. These are units in which a worker carries his oxygen supply on his back and is protected from up to 60 minutes with a supply of oxygen which will allow him to work or escape to a safe environment, if necessary.

In handling toxic materials, it is not only necessary to protect the employee from the inhalation of chemicals but, also to protect various parts of the whole body either completely or partially. The term protective clothing is used to cover an entire class of devices used to protect the whole body. There are a wide variety of materials available to meet the requirements of the many types of conditions which might occur. Fabrics range from cotton which is not that protective to glass fibers, orlon, nylon and even teflon. These man made materials can be made impervious by coating them with plastics, rubber and neoprene. While some protective clothing is supplied and laundered by the employer or the employee, it is more common today to provide the worker with disposable coveralls.

The hazardous waste industry has been in the forefront in developing clothing that is impervious to liquids, gases and vapors. These outfits are often referred to as "moon suits," "frog suits" and "bunny suits." The worker may be required to shower with the suit on and then shower to clean himself after carefully removing the suit using standardized procedures. Respiratory protective equipment is almost always required in conjunction with this type of clothing. The wearing of impervious clothing can impose serious limitations on the amount of time the worker can wear the clothing and perform strenuous activities. This work time is limited even further by the use of respirators which may include self-containing breathing devices.

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