NIOSH HEALTH HAZARD EVALUATION REPORT

HETA 2004-0145-2941
CH_2M Hill Hanford Group, Inc. and United States Department of Energy, Office of River Protection Richland, Washington

July 2004

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

PREFACE

The Hazard Evaluation and Technical Assistance Branch (HETAB) of the National Institute for Occupational Safety and Health (NIOSH) conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health (OSHA) Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employers or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

HETAB also provides, upon request, technical and consultative assistance to federal, state, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease. Mention of company names or products does not constitute endorsement by NIOSH.

ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Dr. Yvonne Boudreau, Dr. John Cardarelli and Mr. Gregory Burr of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Desktop publishing, review and preparation for printing were performed by Lisa Maestas and Ellen Blythe.

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For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Highlights of the NIOSH Health Hazard Evaluation

Evaluation of Hazardous Waste Vapor Exposures at Hanford Tank Farm Site

NIOSH personnel evaluated personal protection equipment (PPE) issues and the potential for occupational exposures to vapors at the Hanford Tank Farm site.

What NIOSH Did

- We spoke privately with 54 employees and managers of CH_2M Hill Hanford Group (CHG).
- We looked at vapor sampling reports, health risk assessments, medical records, and medical surveillance and respiratory protection programs.
- We took air samples for ammonia and volatile organic compounds (VOCs).
- We watched work activities of employees.

What NIOSH Found

- There are adequate data and scientific technology to characterize the constituents within the tanks.
- Over time, the vapors within the tank head space will change in chemical makeup and concentration.
- Employees are exposed to vapors during work activities.
- Interviewed workers reported acute and chronic health effects after vapor exposures.
- Workers have not been routinely provided with PPE for exposures to tank vapors and there are difficulties in the process to get a respirator.
- Information about components of vapor exposures has not been collected for all employee exposures.
- Exposure monitoring has often not been done at the time of the exposure.
- Employees' personal sampling data are not readily accessible to CHG employees or managers, limiting the ability to make informed decisions about PPE choices.
- Medical monitoring after vapor exposures is not consistent.
- The analysis of air samples collected from the tank head space can take weeks or months to complete, potentially resulting in errors due to sample decay and a delay in selecting the appropriate level of PPE.

What CHG Managers Can Do

- At a minimum, provide air purifying respirators to workers entering a tank farm to protect them from vapor exposures.
- Analyze real-time air samples collected in the head space of storage tanks prior to the start of any work on the tank.
- Analyze real-time personal breathing zone sample information within 24 hours after collection.
- Share all monitoring and sampling information with employees and work together to develop ongoing sampling and respirator needs.
- Improve respirator deployment and maintenance procedures.
- Provide consistent medical evaluations for all vapor exposed persons.
- Develop centralized, easily accessible collection of standardized medical, environmental and personal monitoring data.
- Implement recommendations specified in the NIOSH report, "Evaluation of data for DOE site remediation workers."

What CHG Employees Can Do

- Wear the recommended PPE.
- Attend safety and personal protection training programs.
- Ask all questions about correct use of personal protection and about results of sampling and medical monitoring.
- Report all vapor exposures to a supervisor or other designated management representative.
- Report all vapor-related symptoms to a health care provider and obtain a copy of your medical records for all vapor exposure events.

CDC Workplace Safety and Health

What To Do For More Information:
We encourage you to read the full report. If you would like a copy, either ask your health and safety representative to make you a copy or call 1-513-841-4252 and ask for HETA Report 2004-0145-2941

NIOSH

Health Hazard Evaluation Report 2004-0145-2941
CH_2M Hill Hanford Group, Inc. and
U.S. Department of Energy, Office of River Protection
Richland, Washington
July 2004

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SUMMARY

The National Institute for Occupational Safety and Health (NIOSH) received a confidential request from employees of CH_2M Hill Hanford Group, Inc., and a subsequent request from the United States Department of Energy, Office of River Protection, to evaluate the potential for exposures and health effects of vapors emitted from hazardous waste storage tanks at the Hanford Site in Richland, Washington. In response to these requests, NIOSH representatives conducted an evaluation at the Hanford Tank Farms in March 2004.

The tanks contain a mixture of chemical and radiological waste which is being transferred to another location for processing into glass. Although there is no occupational exposure limit (OEL) for the mixture of chemicals and compounds that may be present in vapor that escapes from the tanks, OELs do exist for some of the individual vapor constituents. NIOSH investigators determined that employees at the Hanford Site may be exposed to vapor mixtures emanating from the "head space" (air space above the tanks' liquid contents) area of the tanks and that these exposures, on occasion, may be in sufficiently high concentrations to pose a health risk to exposed workers.

The tank farm workforce was not routinely provided personal protective equipment (PPE) to protect them from tank vapors. Exposure data for individual workers were limited in quantity and quality, not easily accessible and, in some situations, had not been obtained until hours after an accidental exposure had occurred. Due to these data limitations, the true exposure potential was difficult to ascertain.

Of the 54 interviewed workers, 35 reported a variety of acute and chronic health concerns they believed were related to vapor exposures. Those interviewed were also concerned about the available PPE and the adequacy and accuracy of the environmental monitoring which has been performed. To ensure their safety, NIOSH investigators recommend that, at a minimum, a NIOSH approved air purifying respirator be provided to any worker entering a tank farm to protect against exposure to nuisance vapors. For workers entering known vapor release area, higher levels of respiratory protection may be required, such as powered air-purifying respirators equipped with high-efficiency particulate air filters and organic vapor/ammonia cartridges, airline respirators, or self-contained breathing apparatus. NIOSH also recommends that the employer routinely sample the head space of the tanks and conduct personal sampling while the employees are working. Results from this sampling should then be discussed with

employees to develop mutually agreeable strategies for further sampling and appropriate personal protection.

NIOSH investigators determined a potential for significant occupational exposures and health effects from vapors released from the hazardous waste storage tanks. Although the concentrations of the compounds in the vapor will change over time and during waste movement activities, vapor constituents may be present at sufficiently high concentrations to pose a health risk to workers. Recommendations are given in this report to help protect workers, including providing, at a minimum, air purifying respirators to workers and routinely sampling the head space of the tanks and the personal breathing zones of the workers.

Keywords: SIC 4953 (Hazardous waste material disposal sites), uranium, plutonium, nuclear weapons, hazardous waste, tank waste, vapors, radioactive waste, respirators, personal protective equipment, remediation, mixed waste, Department of Energy site.

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INTRODUCTION

On August 5, 2002, the National Institute for Occupational Safety and Health (NIOSH) received a confidential request from employees of CH_2M Hill Hanford Group, Inc. (CHG) for a Health Hazard Evaluation (HHE) of the Hanford Tank Farms Site in southeast Washington State. NIOSH was asked to evaluate personal protection and health risks for employees exposed to vapors from the tank waste. NIOSH investigators reviewed data provided by the requesters and CHG, and conducted several conference calls with requesters and CHG management representatives to discuss the HHE request. After performing these activities, NIOSH investigators determined that an onsite visit was necessary to complete the HHE. Details regarding the proposed nature of the site visit were provided to the requesters and CHG representatives. In response to the site visit request, NIOSH received a second request for an HHE at this site from management of the United States (US) Department of Energy (DOE), Office of River Protection (ORP). The reasons given for the second request were similar to those in the initial request. In response to the two requests, NIOSH representatives conducted a site visit in March 2004.

BACKGROUND

The Hanford Site includes approximately 586 square miles of semi-arid shrub-steppe vegetation located in southeastern Washington State, just north of the confluence of the Snake, Yakima, and Columbia Rivers. The federal government acquired the Hanford Site in 1943 for the national defense production of plutonium. About 6% (approximately 35 square miles) of the land area is or has been actively used for the production of nuclear materials, nuclear waste storage, and nuclear waste disposal.[1]

The Hanford Tank Farms consist of 177 large underground storage tanks located on the Hanford Site.[2,3] These waste storage tanks were built in groups called tank "farms." The tanks contain approximately 53 million gallons of high-level radioactive waste (60% of the country's nuclear waste burden) generated from plutonium and uranium processing carried out in nine nuclear reactors from 1943-1989 as part of the US nuclear weapons program. The tanks are connected through underground pipes to allow pumping of waste from tank to tank, and between farms. In 1989, all production activities were discontinued and in May of that year, the U.S. Department of Energy (DOE), U.S. Environmental Protection Agency (EPA), and the Washington State Department of Ecology signed the Hanford Federal Facility Agreement and Consent Order, also known as the Tri-Party Agreement, which outlines the legally enforceable milestones for cleanup/remediation of the Hanford Site.[4]

One hundred forty-nine of the one hundred seventy-seven underground tanks are of single-shell construction (single-shell tanks [SSTs]) and the remaining twenty-eight are double-shell tanks (DSTs). A typical SST is 75 feet in diameter and 30 feet tall, constructed from reinforced concrete and lined with steel where the waste meets the inner wall surfaces.[1,5] Of the 64 SSTs built during World War II, half were filled to 100% capacity and the other half were 40% filled by late 1946. During 1947-1949, 42 additional SSTs were built, and 18 more were constructed during 1950-52.[6]

In 1952, recovery of waste uranium became a priority. This involved the sluice-mining of old wastes from the tanks and a subsequent solvent extraction process that used tri-butyl phosphate and saturated kerosene. These processes created large volumes of chemically complicated waste. To conserve tank space, the new wastes were scavenged with ferrocyanide salts and nickel. This process precipitated cesium-137 to the bottom of the tanks. The supernate was then discharged to the ground and ferrocyanide was left in the tanks. Reduction/oxidation operations performed on the waste caused some of the tank contents to generate heat and to self-boil. During 1953-1955, 21 new tanks were built with special engineering devices to accommodate self-boiling wastes. Space limitations resulted in decisions to allow ground disposal of some wastes originally designated for storage in SSTs. The last four SSTs were built during 1963-1964. Since that time, 28 DSTs have been constructed. The age and integrity of the SSTs is a concern due to potential leakage. At least 66 of the SSTs are assumed to have leaked. A 55,000-gallon leak was confirmed in 1956, and 115,000 gallons of waste escaped in 1973.[2,3] In 1980, DOE removed the aging SSTs from active use and, since then, efforts have been underway to transfer the liquid waste from the SSTs to the DSTs.[7]

The tanks at Hanford contain a mixture of liquid and solid (sludge and saltcake) wastes with both radioactive and chemically toxic hazardous constituents.[7] In addition to the radioactive waste, the tanks contain chemicals including sodium hydroxide; sodium salts of nitrate, nitrite, carbonate, aluminate and phosphate; and hydrous oxides of aluminum, iron, and manganese. Mixed tank waste may also contain heavy metals such as lead, chromium, zirconium, potassium, and cadmium. Waste in some of the tanks includes detectable amounts of organic compounds (some volatile) that resulted from spent nuclear fuel and plutonium separation processes.

CHG has been the contractor for the DOE ORP since December 1999 and is responsible for storing the tank waste and retrieving it for treatment.[8] CHG plans to remove liquid waste from the tanks, separate the radioactive elements from non-radioactive chemicals, and create solid waste for disposal. These plans involve the transfer of waste from older SSTs to upgraded DSTs for temporary storage with bonuses to CHG from DOE of up to $2 million for each tank emptied before 2006. Eventually, the tank waste will be pumped to a treatment facility that is under construction at the Hanford site. Treatment of the waste will consist of vitrification into glass logs, which will be stored by CHG until permanent disposal sites are identified. Hanford cleanup operations are expected to be complete by 2035.[4,8]

Vapor Exposures

Since 1946, the wastes from various processes have been transferred among tanks, so the chemical and physical characteristics of the wastes vary. The tank contents are subject to a variety of influences (e.g., changes in barometric pressure and chemical reactions) that cause pressure to build up within the tanks, which must be released through venting. The majority of the tanks are passively vented and so the vapor releases are unpredictable. Workers can potentially be exposed to these vapors when performing certain tasks at the tank farms.

Several situations have been identified that pose a higher than normal potential for personnel exposures. Examples include breaching an enclosed system, waste intrusion (such as pump installation and core sampling), saltwell pumping, transfer of waste, and a variety of maintenance activities.[9] Vapor releases are more likely when layers of waste are stratified and the work task requires breaking through the layers, or when the environmental conditions are such that atmospheric stagnation occurs (e.g., calm winds, temperature inversion). Based on sampling performed by CHG and other contractors, a variety of compounds has been identified in the vapors, including ammonia, nitrous oxide, benzene, butanol, acetone, hexane, and xylene.[8,10,11]

Respiratory Protection

The policy for respiratory protection at the Hanford site has changed over the years since the cleanup process began. Supplied air respirators were initially required for tank workers. In 1995 and 1996, evaluations of the tank contents were conducted by the Westinghouse Hanford Company (WHC) under contracts from DOE.[12,13] Based on the results of these evaluations, WHC considered the tank constituents to be characterized and the tank vapor exposures to be controlled, so the requirement for supplied air respirators was discontinued. Subsequently, CHG required respiratory protection only for certain types of work activities and locations on the tank farms.

Any work conducted within an air monitoring zone (AMZ) would require the presence of an industrial hygiene (IH) technician to perform real-time air monitoring, and respiratory protection with a minimum of a full-face piece air-purifying respirator (APR).[1] Where respiratory protection was not required, APRs and powered air-purifying respirators (PAPRs)[2] could be requested by workers.

Personnel Data

In the mid 1990s, the Hanford Site changed from a Management and Operating contract system, in which the prime contractor directly employed the majority of the workforce, to an Integrated Management Contract, in which the prime contractor oversees a large tiered system of contractors, who are the actual employers of the remediation workforce.[10] In this increasingly layered work environment, responsibilities for medical and exposure monitoring, data collection, and data maintenance became complex, diffuse, and non-uniform.[14]

The enforcement relationships among DOE, its contractors, and subcontractors were also found to impact the collection and maintenance of critical worker data. The DOE promulgates worker safety and health standards through two mechanisms – rules and orders. Under the Price-Anderson Act Amendments of 1988, DOE can fine and take legal action against contractors for rules violations.[15] In contrast, contractors violating orders can only be penalized through payment reductions.[16] The result is that worker monitoring and records are generally comprehensive and standardized where covered by rules, and less so where only orders exist.

The DOE has issued orders for many monitoring requirements using criteria such as the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs). However, because these requirements are specified in orders, rather than rules, they have limited enforceability at DOE sites. As a consequence, at many DOE sites, IH monitoring data are generally less complete than radiation data. For example, the National Academy of Public Administration reported that inadequate IH monitoring and data collection rules have led to a general lack of information about chemical exposures.[16]

Deficits in IH data collection and reporting were found to be particularly acute if responsibilities for safety and health were not clearly distributed between DOE, contractors, and sub-contractors.[14,17] This included the Hanford site, where organizational changes combined with a lack of codified data collection rules to create gaps in IH data for remediation workers. At one time, the Hanford Environmental Health Foundation (HEHF) held primary responsibility for IH monitoring, assessment, and recordkeeping. In 1996, coordination of IH programs at the Hanford site became the shared responsibility of the Occupational Medical Services Contractor at HEHF and three prime contractors on site. These prime contractors provided their own IH monitoring and recordkeeping and were not required to submit IH exposure monitoring reports to DOE. In turn, subcontractors had their own IH programs and data systems, and were not always required to report data to their prime contractor.

At Hanford, the decentralization of IH services impeded integration of occupational medicine and exposure data.[18] Employee Job Task Analyses (EJTA) provided individualized hazard and exposure information for both routine and special work activities and links to the individual level Hanford Industrial Hygiene Exposure database. A Job Hazard Analysis (JHA) was used to determine the personal exposure monitoring needed for specific aspects of a project. This information was entered into a Risk Management Medical Surveillance database to determine medical qualifications and medical monitoring requirements.[10] However, the IH and radiation exposure data of the contractor,

[1] Air-purifying respirator: A respirator with an air-purifying filter, cartridge, or canister that removes specific air contaminants by passing ambient air through the air-purifying element without the use of a blower.
[2] Powered air-purifying respirator: An air-purifying respirator that uses a blower to force the ambient air through air-purifying elements to the facepiece.

Bechtel Hanford Inc., were not included in the system. In addition, JHAs had not been fully integrated as of 1998, nor had they been required of subcontractors.[10]

In 1997, DOE developed an exposure assessment guide outlining exposure monitoring procedures for DOE sites.[19] It describes the need to link hazards, exposures, and medical monitoring across departments and to individual workers, and establishes the need for complete, task-based documentation of monitoring. This document focuses on hazard recognition and anticipation and is compliance-oriented, recommending the use of baseline random monitoring to determine the probability that a particular activity will exceed an occupational exposure limit. The Guide specifies that rapidly changing remediation activities will necessitate more frequent sampling, and encourages the use of American Industrial Hygiene Association monitoring guidelines for exposures expected to frequently exceed certain exposure limits. The Guide details recommendations supporting an order, rather than a rule, possibly limiting its impact on exposure monitoring.

During the late 1990s, NIOSH conducted a feasibility study to determine the types of information that were available to identify and characterize potential occupational exposures and health outcomes in DOE site remediation workers.[20] This study was not specific to the Hanford site, but applies to Hanford as well as other DOE sites. The study found that:

- Data collection and maintenance were fragmented and inconsistent due to decentralized management and increased subcontracting at DOE sites.
- IH monitoring and data collection requirements were not codified or standardized, so exposure data tended to be incomplete.
- Remediation workers employed by subcontractors were excluded from some data and records systems.
- Site information systems were segregated by department, and sometimes by contractor, complicating linkage of workers to their data.
- Some historical data were no longer available.
- Recommendations in the DOE Exposure Assessment Implementation Guide for Order 440.1-1 do not include routine monitoring of individual workers, which could lead to incomplete data for surveillance and epidemiologic purposes.[19]
- In the absence of DOE rules governing non-radiological monitoring and data collection and reporting, IH data for subcontractors will continue to have large gaps.
- If monitoring is limited only to areas or personnel where exposures are expected to be high, this would hinder the ability to evaluate dose-response relationships.

NIOSH concluded that administrative and organizational factors at DOE sites hinder efforts to identify remediation workers and lead to deficiencies in their work history, exposure, and medical data. It was recommended that centralized collection of a standardized core of data on remediation workers begin as soon as possible. The results and recommendations of the study were provided to the DOE Assistant Secretary for Environment, Safety, and Health in December, 2000, but the recommendations were not implemented.

METHODS

NIOSH representatives visited the Hanford Tank Farms March 9-11, 2004. An opening conference was held on March 9, which was attended by 32 employee and management representatives from CHG, DOE ORP, and the Hanford Atomic Metal Trades Council, an organization representing the various unions present at the Hanford site. Following the opening conference, NIOSH representatives were provided a drive-by tour of the tank farms.

During the remainder of the site visit, the NIOSH medical officer reviewed the medical surveillance program, met with the medical services contractor for the Hanford site, reviewed vapor exposure reports, and interviewed employee and management personnel. Prior to the NIOSH site visit, CHG employees were informed by management and union personnel of the dates that NIOSH would be on-site and of our availability for private interviews; CHG personnel who volunteered to participate were interviewed.

The NIOSH industrial hygienist and health physicist met with CHG industrial hygienists and IH technicians to review their existing and recently drafted environmental sampling strategies; observed a Vapor Solutions Team meeting; observed work activities in various tank farms; and reviewed the CHG IH exposure assessment strategy, the available environmental sampling data, the respiratory protection program (including respirator selection, distribution and cleaning), and personal protective equipment (PPE) policies and practices.

Direct-reading samples for ammonia and volatile organic compounds (VOCs) were collected using either a handheld photoionization detector or colorimetric detector tubes. In the C and SY tank farms, ammonia concentrations were monitored with a Biosystems Toxilog Ultra (651 South Main Street, Middletown, Connecticut 06457) real-time monitor. In the C tank farm, Draeger tubes (101 Technology Drive, Pittsburgh, Pennsylvania 15275) were used to measure VOC concentrations in the ambient air and head-space.

Other data and documents were provided to NIOSH by employees and management before and after the site visit, and these were also reviewed. They included vapor sampling reports, health risk assessments from independent consultants, medical records, the CHG written respiratory protection program, the OSHA Log and Summary of Occupational Injuries and Illnesses (form 300) for the years 2001-2003, a summary of work-stoppages between 2002 and 2003, and medical surveillance reports.[21,22,23,24,25]

A closing conference was held on March 11 at the conclusion of the NIOSH site visit during which NIOSH personnel presented preliminary findings and recommendations. The closing conference was attended by 28 employee and management representatives from the same groups present at the opening conference.

EVALUATION CRITERIA

General

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and this potentially increases the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent becomes available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs),[26] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[27] and (3) the U.S. Department of Labor, OSHA PELs.[28] Employers are encouraged to follow the OSHA

PELs, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criteria.

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970, Public Law 91–596, sec. 5(a)(1)].[29] Thus, employers should understand that not all hazardous chemicals have specific OSHA exposure limits, such as PELs and short-term exposure limits (STELs). An employer is still required by OSHA to protect their employees from hazards, even in the absence of a specific OSHA PEL.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended STEL or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

Hazardous Waste Site Chemical Exposures

Preventing exposure to toxic chemicals is a primary concern at hazardous waste sites. Most sites contain a variety of chemical substances in gaseous, liquid, or solid form. These substances can enter the body via inhalation, skin absorption, ingestion, or through a puncture wound (injection). A contaminant can cause damage at the point of contact or can act systemically, causing a toxic effect at a part of the body distant from the point of initial contact.[30]

Chemical exposures are generally divided into two categories, acute and chronic. Symptoms resulting from acute exposures usually occur during or shortly after exposure to a sufficiently high concentration of a contaminant. The concentration required to produce such effects varies widely from chemical to chemical. The term "chronic exposure" generally refers to exposures to relatively low concentrations of a contaminant over a long period of time. The concentrations required to produce symptoms of chronic exposure depend upon the chemical, the duration of each exposure, and the number of exposures. For a given contaminant, the symptoms of an acute exposure may be completely different from those resulting from chronic exposure.

For either chronic or acute exposure, the toxic effect may be temporary and reversible, or may be permanent (disability or death). Some chemicals may cause obvious symptoms such as burning, coughing, nausea, tearing eyes, or skin rashes. Other chemicals may cause health damage without any such warning signs. This is a particular concern for chronic exposures to low concentrations where health effects, such as cancer or respiratory disease, may take several years or decades after exposure to manifest. In addition, some toxic chemicals may be colorless and/or odorless, may dull the sense of smell, or may not produce any immediate or obvious physiological sensations. Thus, a worker's senses cannot be relied upon in all cases to warn of potential toxic exposure.

The effects of exposure not only depend on the chemical, its concentration, route of entry, and duration of exposure, but may also be influenced by personal factors, such as the individual's smoking habits, alcohol consumption, medication use, nutrition, age, and gender.

An important exposure route of concern at a hazardous waste site is inhalation. The lungs are extremely vulnerable to chemical agents. Even substances that do not directly affect the lungs may pass through lung tissue into the bloodstream, where they are transported to other vulnerable areas of the body. Some toxic chemicals present in the atmosphere may not be detected by human senses, i.e., they may be colorless, odorless, and their toxic effects may not produce any immediate symptoms. Respiratory protection is therefore extremely important if there is a possibility that the work-site atmosphere may contain such hazardous substances.

Direct contact of the skin and eyes by hazardous substances is another important route of exposure. Some chemicals directly injure the skin. Some pass through the skin into the bloodstream, where they are transported to vulnerable organs. Skin absorption is enhanced by abrasions, cuts, heat, and moisture. The eye is particularly vulnerable because airborne chemicals can dissolve in its moist surface and be carried to the rest of the body through the bloodstream. Wearing protective equipment, not using contact lenses in contaminated atmospheres (since they may trap chemicals against the eye surface), keeping hands away from the face, and minimizing contact with liquid and solid chemicals can help protect against skin and eye contact.

Ammonia

Ammonia is a severe irritant of the eyes, respiratory tract, and skin. It may cause coughing; burning and tearing of the eyes; runny nose; chest pain; cessation of respiration; and death. Symptoms may be delayed in onset. Exposure of the eyes to high gas concentrations may produce temporary blindness and severe eye damage. Exposure of the skin to high concentrations of the gas may cause burning and blistering. Repeated exposure to ammonia gas may cause chronic irritation of the eyes and upper respiratory tract.[31,32] The NIOSH REL for ammonia is 25 ppm for up to a 10-hour TWA. The NIOSH STEL for ammonia is 35 ppm. The OSHA PEL for ammonia is 50 ppm for an 8-hour TWA, while the ACGIH has set limits of 25 ppm for an 8-hour TWA and a STEL of 35 ppm.

Volatile Organic Compounds and Mixtures

VOCs describe a large class of chemicals which are organic (i.e., contain carbon) and have a sufficiently high vapor pressure to allow some of the compound to exist in the gaseous state at room temperature. Research suggests that the irritant potency of VOC mixtures can vary. While in some instances it may be useful to identify some of the individual chemicals which may be present, the concept of *total volatile organic compounds (TVOC)* has been used in an attempt to predict certain types of health effects.[1] The use of this TVOC indicator, however, has never been standardized. It should be emphasized that the highly variable nature of these complex VOC mixtures can greatly affect their irritancy potential. Considering the difficulty in interpreting TVOC measurements, caution should be used in attempting to associate health effects (beyond nonspecific sensory irritation) with specific TVOC levels.

Synergistic action and potentiation are two phenomena whereby some chemical combinations result in adverse health effects in excess of what might be caused by any individual chemical exposure. Synergistic action describes a situation in which the toxic effects of two or more chemicals in combination significantly exceed the individual toxic effects of those chemicals. Potentiation occurs when one chemical makes another much more toxic; alone, the potentiating chemical may produce little or no toxicologic effect. Applying exposure criteria without considering the possible effects of synergism or potentiation may underestimate the true potential for impairment to a worker's health as a result of exposure to chemical mixtures.

In the absence of information to the contrary, concurrent exposure to two or more hazardous substances acting on the same target organ system should be considered as an additive exposure (and not as synergistic action or potentiation). To measure the effect of an additive exposure on a particular organ system, each substance in the mixture is computed as a fraction of its own occupational health evaluation criterion. If the sum of these fractions exceeds 1, employee exposure to that particular mixture of substances is considered excessive. This concept has been described by the following formula:

$$C1/T1 + C2/T2 + ... + Cn/Tn$$

Where Cn refers to the observed atmospheric concentration of an air contaminant and Tn to its corresponding occupational health exposure criterion. The relevant occupational health exposure criteria used to derive this formula were established, not to safeguard against health effects unique to a substance, but to prevent the "additive effect" of exposure to multiple substances with similar health effects. Therefore, when evaluating worker exposure to substances with similar physiological effects, the combined effect of all substances, rather than that of any one individually, should be given primary consideration.

Medical Monitoring

A medical program is essential to assess and monitor workers' health and fitness both prior to employment and during the course of work; to provide emergency and other treatment as needed; and to keep accurate records for future reference.[30] In addition, OSHA requires a medical evaluation for employees required to wear a respirator,[33] and certain OSHA standards include specific medical requirements.[34] Information from a site medical program may also be used to conduct future epidemiologic studies; to adjudicate claims; to provide evidence in litigation; and to report workers' medical conditions to federal, state, and local agencies, as required by law.

When developing an individual program, site conditions must be considered and the monitoring needs of each worker should be determined based on the worker's medical and occupational history, as well as current and potential exposures on site. The routine job tasks of each worker should also be considered. While it is often impossible to identify every toxic substance that exists at each hazardous waste site, certain types of hazardous substances or chemicals are more likely to be present than others. Some of these include aromatic hydrocarbons, dioxin, halogenated aliphatic hydrocarbons, heavy metals, herbicides, insecticides, polychlorinated biphenyls (PCBs), and asbestos. Table 1 lists these groups, representative compounds, target organs, health effects, and available medical monitoring procedures.

RESULTS

Medical Evaluation

Employee Interviews

CHG reportedly employs approximately 500 tank farm workers. Of these, 54 (11%) volunteered and participated in private interviews during the NIOSH site visit. Interviewed employees included chemical operators, tank farm specialists, training coordinators, pipe-fitters, general maintenance workers, administrators, electricians, safety representatives, project planners, health physics technicians, industrial hygienists, project managers, engineers, project facilitators, carpenters, and quality control inspectors.

Of those interviewed, 35 (65%) reported having had at least one exposure to vapors from the tanks that resulted in at least one immediate or chronic symptom. The immediate symptoms reported included headache (13 employees), bloody nose (7), throat irritation (6), coughing (5), skin rash (5), metallic taste (5), eye irritation (3), dizziness (3), shortness of breath (3), nausea (2), nose irritation (2), chest tightness (1), and skin itching (1). Symptoms and health effects that were reported to be ongoing after the exposure included frequent headaches (10), decrease in pulmonary function test values (8), new-onset asthma (6), chronic cough (5), frequent nose bleeds (5), sinus infections (4), hoarseness (3), memory loss (3), shortness of breath (3), bronchitis (2), pneumonia (2), ringing in ears (1), blood in stools (1) and scarring of lungs (1).

Two employees provided medical records. There was one diagnosis of contact dermatitis after a skin exposure to vapors and one note from a physician that a history of nose bleeds could be related to exposures to irritants from the vapors.

Other issues that were reported by the interviewed employees included the following:

Management issues:

- perception that the primary interest of CHG management is completing work quickly to obtain tank cleanup bonuses, without regard for the safety of employees;
- inconsistent and sometimes punitive response to Stop-Work requests and Problem Evaluation Requests (PERs);[3]
- work "restrictions" being misused to fire employees;
- distrust of IH technicians by field workers;
- designation of symptoms and injuries as non-work-related by HEHF personnel to keep numbers down for public reports;
- need for the HEHF medical facility to remain open and available during night shifts so night-shift personnel can be evaluated there for exposures;
- inconsistencies between information that is provided in training classes and what actually occurs in the field;
- construction workers not provided with proper safety training so CHG can avoid the time and cost this would entail; and
- concerns regarding compensation for long-term effects of vapor exposures, even after retirement.

Exposure and monitoring issues:

- inconsistencies in medical evaluations for vapor exposures;
- disincentives to report vapor exposures, including lost work time and too much paperwork;
- too little detail provided to field workers regarding the specific compounds for which the IH technicians are monitoring;
- too little personal air monitoring;
- difficulty procuring specific data regarding the constituents in the tanks;
- uncertainty as to why "old" data are used to characterize tank contents when ongoing processes, such as mixing of the contents of different tanks, could change the concentrations of the constituents;
- perception that air monitoring zones (AMZs) are not determined based on science, but rather are arbitrarily selected and constructed;
- information not readily provided on results of Summa canister[b] tests;
- potential radon exposures;
- concerns about asbestos exposure during remodeling of buildings; and
- past and/or current exposure to beryllium and the receipt of appropriate medical evaluations.

Respirator issues:

- difficulty in procuring respirators when someone wants to wear one voluntarily; and
- PAPRs with non-working batteries.

Interviewed workers also made suggestions for improvements including providing small vehicles (such as tractors) to transport equipment and personnel between tank farms; providing improved lighting of the tank farms at night using the large light fixtures that are already in place on the tank farms; utilizing science (such as barometric pressure and real-time monitoring) to establish AMZs and PPE criteria; conducting sampling before, during, and after waste transfers; and providing more personal exposure monitoring.

Vapor Exposures

There were 9 reported tank vapor exposures in 2001, 21 during 2002, 30 during 2003, and 10 from January 1 to March 19, 2004.[7] Interviewed employees reported that not all perceived exposures are reported. Reasons that were given for this included discouragement of reporting by some supervisors due to lost work time and too

[3] A Problem Evaluation Request is a mechanism for CHG employees to report perceived problems.

[b] An airtight, stainless-steel container with an inner surface that has been electropolished and chemically deactivated (called the "Summa" process). Although they vary in size, a 6-liter Summa canister is commonly used to collect air samples. A laboratory evacuates a Summa canister to a high vacuum and ships the canister to the sampling locale. The advantage is that the air being sampled is "drawn" into the canister by the high vacuum, eliminating the need for sampling pumps.

much paperwork, and perception by the employees that some exposures were not of enough concern to warrant reporting.

Review of the OSHA 300 injury and illness logs for 2001-2004 showed six entries for "respiratory irritation" in 2001, two entries listing "tank vapors/emissions" in 2002, three entries listing "tank vapors/emissions" in 2003 and one entry for "unknown vapor" exposure for January 1 through March 29, 2004. CHG reported that only five of the vapor exposures since January 2001 resulted in recordable or lost time injuries; two in 2002, and three in 2003.[7]

A summary of work stoppages from 2002 to 2003 was provided by management. These reports indicate that out of approximately 5,000 job evolutions[4] per year, only 25 and 41 (66 total) work stop orders were requested by employees for 2002 and 2003, respectively. Reasons for the work stoppages were radiation contamination concerns (21), personal safety concerns (14), equipment concerns (14), procedural concerns (13), beryllium concerns (3), and only one vapor-emission concern. All work stop orders were requested by CHG employees and none by the construction trade union.

Medical Monitoring

Employees who report symptoms after a vapor exposure are medically evaluated at the time of the exposure. Procedures include a urinalysis, complete blood count (CBC), and blood chemistry analysis to assess liver and kidney function and overall health (for details of the CHG blood chemistry analysis, see Appendix A). For "unknown toxicant" exposures, 100 milliliters (ml) of urine and 30 ml of blood are collected and preserved for 30 days in order to allow time to perform an onsite investigation to identify the potential exposures and evaluate the biological samples as indicated.

Routine annual medical evaluations for the CHG tank farm employees include urinalysis, CBC, blood chemistry analysis, pulmonary function testing, and a physical examination. CHG reported that they are working to develop a "panel of experts" to determine whether the current medical testing and evaluation program is sufficient for workers exposed to vapors.

In April 2002, the HEHF began a review of laboratory and physical findings of tank farm workers.[35,36,37] The review has included all Hanford Site workers who presented to HEHF, either for routine monitoring or for post-exposure evaluations, between April 2002 and September 2003, and is continuing. The review has compared laboratory values for tank farm workers with those values for all other Hanford Site workers. The values being compared include liver function tests, urinalysis results, and CBC results. Thus far, there have reportedly not been significant differences found in these values between the two work groups.

Environmental Evaluation

Reported CHG Interventions

CHG reported that in November 2003, they adopted a standard for vapor exposure to be "as low as reasonably achievable" (ALARA), a practice that is mandated by the Nuclear Regulatory Commission (NRC) for radiation exposures. The ALARA approach used by the NRC assumes that **any** exposure carries some risk. The risk is assumed to be linear, so as exposure level increases, so does the risk of adverse health effects. Instead of operating at or just below OELs, one must stay as far below the exposure limits as possible. This affords a wider margin of error should a control fail or malfunction.

A Vapor Solutions Team, a diverse group of management and labor participants, has been assembled to improve CHG hazard identification, controls, training, and communication for tank farm chemical odors and vapors.[38] NIOSH investigators observed a meeting of this group in which various issues

[4] A job evolution consists of about 6 to 10 workers performing a specific task in a tank farm. During 2002 and 2003, there were about 400 to 500 evolutions per month, or about 5,000 per year.

were discussed. For example, a presentation on recently installed engineering controls summarized the various control methods that included sealing fugitive emission pathways in the tank farms, raising the height of exhaust stacks (tank C-103), installing new powered exhausters with extended height 27-foot stacks (AN and AW farms), and installing exhaust fans (with external switches) in control cabinets to reduce the opportunity for vapor accumulation.[7] The meeting environment encouraged debate of opposing views and appeared to be an effective means to address vapors concerns.

In a Vapor Solutions Progress report sent to NIOSH in May 2004, the following interventions were noted:[39]

- Fugitive emission sources were located and sealed in all 149 SSTs; inspections continue to locate any additional source points and ensure adequacy of the sealing.
- Leaks were sealed in Continuous Air Monitoring (CAM) cabinets in AN, AP, and AW Farms, and externally operated vent fan switches were installed.
- The C-103 SST breather filter stack was extended to a height of 15 feet; a risk ranking was completed to identify additional SSTs for which stack extensions would be beneficial.
- Design and fabrication were started for eight additional SST stack extensions; installation is scheduled to begin August 2, 2004, with completion scheduled for November 12, 2004.
- Design has started to extend the DST AP Exhauster stack to approximately 25 feet; installation is planned to begin November 19, 2004, and be complete on December 13, 2004.
- In-farm cooling stations have been designed and are being fabricated to reduce employee fatigue associated with working while wearing supplied air respirators; the first station will be operational June 4, 2004, with the last of three being operational by June 30, 2004.
- Work in process includes conceptual design of scrubber systems for actively exhausted tank farms; evaluation of cameras and remote reading instrumentation to reduce personnel rounds in the tank farms; design of instruments to detect and alert personnel to potential tank vapor emissions from barometric pressure changes; and correlation of ambient weather conditions to the potential for vapor exposure.

CHG Respiratory Protection Policy Modifications

At the time of the initial employee request for a NIOSH evaluation, CHG required respiratory protection only for certain types of work activities and locations on the tank farms. Any work conducted within an AMZ would require the presence of an IH technician to perform real-time air monitoring and respiratory protection with a minimum of a full-face piece APR. Where respiratory protection was not required, APRs and PAPRs were reportedly available to workers upon request. However, it was reported by workers that respirator-procurement procedures often made it difficult to obtain these respirators. This frequently resulted in work delays and decisions by workers to just not use a respirator.

Respirator procurement problems were evident during the site visit when a NIOSH investigator attempted to obtain a respirator. The respirator pickup station was initially unmanned. When the attendant arrived, he did follow CHG procedures for distributing respirators, including requesting proof of medical clearance and fit-testing. Respirator maintenance (cleaning and repair) activities were not observed; these were reportedly conducted by an off-site contractor. The attendant reported concerns regarding the ease of and timeliness for respirator issuance and the inability to accurately track the location of respirator components.

Approximately one week after the NIOSH site visit, several tank farm workers reported exposures to tank vapors. In response to this, CHG management instituted the requirement that all tank farm work be conducted with respirators until extensive reviews and assessments could be completed.[40] The resulting respirator requirements were reported as:

- Employees working in an AMZ will be accompanied by an IH technician and will be required to wear a PAPR with hood or a full-face APR with high efficiency particulate air (HEPA) and combination chemical cartridges for ammonia and organics.

- Employees working anywhere else will be required to wear either a hooded PAPR or a full-face APR without HEPA, but with the combination chemical cartridges.

Approximately one month after the NIOSH site visit, employees reported concerns about exposure to nitrous oxide. As a result, supplied air respirators were required for all workers in the SST farms and for workers in DST farms where the ventilation was not functional.[40] The supplied air is reportedly provided using self contained breathing apparatus (SCBA), bottle racks, or air compressors at certain sites. Since there were not enough supplied air respirators for the entire work force, work has reportedly been cut back significantly so that only those with the required respiratory protection are allowed to work.

CHG Exposure Monitoring

Evaluation of vapor levels in the tank farms often does not occur until hours after an exposure has been reported. In addition, data for personal air monitoring is not easily accessible and cannot be readily compared with medical data for an individual employee. Some characterization data, based on Summa canister sampling, indicated that these samples may not have been analyzed for weeks or months after being obtained. This delay in processing could result in substantial underestimation of the head-space concentration due to sample decay.

NIOSH Environmental Evaluation

Spot checks for ammonia were made during the NIOSH entry of the C and SY Tank Farms using a Biosystems Toxilog Ultra real-time monitor. All measurements made in the vicinity of workers' breathing zones were below the NIOSH PEL of 35 ppm for a STEL. While higher ammonia concentrations were measured when the sensor was placed within six inches of the exhaust stacks of some of the tanks (typically within an AMZ), these concentrations do not represent a personal exposure but rather identify potential point sources. Similar results were obtained from spot checks for VOCs using either colorimetric detector tubes or a handheld photoionization detector. The results from these limited spot checks were in agreement with measurements made simultaneously by CHG IH personnel.

DISCUSSION

Workers had a variety of acute and chronic health concerns, some of which could be related to exposures they have received while working in or near the tank farms. Many of the interviewed workers who reported that they had vapor exposures also said that they had not formally reported these to their supervisor or other CHG representative because they felt this was discouraged due to lost work time, or a perception by the employee that the exposure was not significant. As a result, it is likely that vapor exposures are underreported. It is important that all vapor exposures be reported and evaluated in order to develop a thorough data base that can be used to monitor exposures and their health outcomes.

The tank farm environment at Hanford is relatively unique in terms of potential exposures due to the mixture of compounds in the tanks and the resultant mixture of constituents in the vapors. Because of this, the health risks from exposure to the tank vapors have not been well documented. More data are needed to better identify and understand the potential health effects from these exposures. An important step in this process is CHG's pursuit of an expert panel to help develop the most appropriate medical monitoring for the Hanford tank farm workers. In addition, some health effects could be latent, i.e., might not manifest until some time (even years) after exposure has occurred. Therefore, long-term medical monitoring, even after retirement, would be prudent.

It should be noted that while many of the individual chemical constituents in the tank head space vapors have an OEL, none exists for the complex mixture of these chemicals. Under this scenario, the employer is authorized to use other published studies and information as a guide for determining appropriate PPE.[41] Prior to the NIOSH evaluation, the employer determined, based on DOE-contracted studies, that due to characterization and control of the vapors, minimal PPE was needed while working in the tank farms. Since the NIOSH site visit, several changes have been implemented to better protect tank farm workers, including increased use of PPE.

The studies and data reviewed by NIOSH suggest that a potential for significant occupational exposures to tank vapors exists due to accidental or fugitive releases. The probability of such exposures, however, and the accidental release rates are difficult to predict.[1,13] At the time of this survey, the CHG workforce was not routinely monitored for potential chemical hazards, should they be exposed from an accidental release of tank vapors. Since the NIOSH site visit, there have been substantial changes in the Health and Safety program including additional exposure monitoring.

Other issues which arose during the NIOSH evaluation included an interest by some employees in wearing PAPRs instead of APRs. From an assigned protection factor standpoint, NIOSH recognizes no difference between half- and full-face PAPRs and full-face APRs; the NIOSH assigned protection factor for both is 50. The assigned protection factor for loose-fitting PAPRs is 25, one half that of tight-fitting PAPRs. CHG managers reported that a decision not to use PAPRs had been based on the potential for ammonia cartridge breakthrough. This issue is discussed further in number 3 of the Conclusions section.

After the NIOSH site visit, CHG reportedly increased monitoring for ammonia and organic compounds.[40] Approximately 33 new sampling devices were purchased. CHG reported that most workers were now wearing a personal sampling device including active sampling pumps for ammonia and organics, passive samplers for organics, and color-changing personal monitors for ammonia.

In addition, CHG reported procurement of new direct-reading devices to conduct environmental and personal monitoring for nitrous oxide. It was reported that field testing with these new instruments began in May 2004.[38,39]

Other reported interventions included:

- identifying the need for mercury and formaldehyde sampling and monitoring;
- sampling of Tanks C-203 and C-204 head space for nitrous oxide, hydrogen gas, methane, carbon dioxide, ammonia, and organic vapors, with other C Farm tanks to follow;
- using the Pacific Northwest National Laboratory vacuum testing chamber to conduct confirmatory tests on all equipment used in the field for IH sampling and monitoring and on new equipment being procured and put into service;
- exchanging technical information with the Savannah River Site regarding mercury vapor and dimethyl mercury chemistry and IH controls;
- hiring of a new Safety Director, 11 additional IH technicians, and a new Health Director, who is a specialist in Industrial Hygiene;
- developing an 8-hour Chemical Hazard Awareness Training course and annual refresher training;
- implementing an integrated IH database to manage monitoring data from direct reading instruments and personal monitoring data in an effort toward consolidation of Industrial Hygiene database information;
- providing data from nitrous oxide source sampling, dispersion point sampling (3-5 feet from the source), and personal monitoring devices to employees on a weekly basis through weekly tailgate sessions and internal newsletter distribution; and
- assembling data from vapor reports since 1996 into a database for evaluation of locations and conditions where vapors are prevalent.

The selection of appropriate PPE is complex. Key factors that must be addressed are the identification of the hazards, routes of exposure (inhalation, skin absorption, ingestion, and eye or skin contact), performance of the PPE, matching the work requirements and task-specific conditions, impaired vision, mobility, communication, heat stress, and physical and psychological stress or other medically-related conditions. Additionally, the amount, duration, and durability of protection provided by PPE depend on the hazard. The dynamic conditions at the Hanford Tank Farm make PPE selection a formidable task. The more that is known about the hazards at the site, the easier this task becomes. Current environmental and personal exposure data are necessary to determine the best possible PPE.

As outlined in 10 CFR 1910.120,[41] the proper selection and use of PPE should be based on the protection it provides to workers from the specific hazards which they are likely to encounter. The Hanford Tank Farm working environment is complex in that both radiation and chemical hazards are present and the respective hazard levels are subject to change during waste disturbing activities. Since this work-site hazard profile is dynamic and complex, the appropriate selection of PPE should adapt accordingly. For example, the selection criteria should consider the exposure potential and work tasks while inside the tank farm fence line. At a minimum, an air-purifying respirator (such as an N95 charcoal-impregnated filtering face piece respirator) may be appropriate for general entries in which a worker will not participate in waste-disturbing activities. This is consistent with the current ALARA philosophy adopted by the CHG management, in that some level of protection is always required in case of a fugitive emission. Further, the level of respiratory protection should increase (hooded PAPRs, APRs, supplied air, etc.) commensurate with the exposure potentials to various emissions. Due to the large size of some of the tank farms, it is also reasonable to apply differing respiratory selection criteria for different workers inside the fence line depending on their exposure potentials (tasks, distance from sources, meteorological conditions). Although the constituents in the tank head space vapors may be characterized based on sampling results, the exposure potentials may vary according to meteorological conditions or waste disturbing activities. This dynamic situation requires flexibility in PPE selection.

PPE should be used in conjunction with other protective methods, such as engineering and administrative controls, and its effectiveness evaluated periodically. Two basic objectives of any PPE program should be to protect the wearer from safety and health hazards and to prevent injury to the wearer from incorrect use and/or malfunction of the PPE. In general, the written respiratory protection program of CHG addresses these objectives.[42]

CONCLUSIONS

1. There are adequate data and scientific technology to characterize the compounds within the tanks, but the concentrations in the head space vapors are subject to change.[12,13]

2. Exposure data for individual workers are limited in quantity and quality and are not kept in an easily-accessible data base. Exposure monitoring often is initiated hours after an accidental release has been identified. This limits the utility of these data to determine the true exposure potential and may not adequately characterize employee exposures.

3. Some ammonia data suggest that cartridge breakthrough times range between 69 and 1,266 minutes based on test conditions that may or may not be representative of the environmental conditions at the Hanford site (e.g., ammonia concentrations up to 300 ppm, humidity up to 75%, and flow rates up to 64 liters per minute; PAPR flow rates are about 170 liters per minute).[43] OSHA regulations state that employers must develop cartridge/canister change schedules based on available data or information.[33] Such information includes the exposure assessment and information based on

breakthrough test data, mathematically based estimates, and/or reliable use recommendations from the employer's respirator and/or chemical suppliers. The CHG written respiratory protection program attempts to address this issue by listing several agents (e.g., acrylonitrile, benzene, butadiene, formaldehyde, vinyl chloride, and methylene chloride) that have OSHA change-out schedules, but the program neglects to specifically address ammonia, one agent of concern.[43] If ammonia concentrations are below the level that is immediately dangerous to life or health (IDLH) (300 ppm), then a PAPR could be a legitimate alternative to an APR.

4. Interviewed employees who reported vapor exposures reported both immediate and chronic symptoms that could be related to their exposures to vapors.

5. The Hanford Site activities and exposures are uncommon because few facilities of this type exist. In a previous NIOSH study, recommendations were made to improve DOE data collection and analysis to better understand the potential health effects in Hanford and other DOE site workers, but these recommendations have not been implemented.[20] Until more is known about the workers' exposures and potential health effects, medical surveillance will need to be comprehensive.

RECOMMENDATIONS

1. The employer should develop and implement technologies and equipment (e.g., thermal imaging) to identify potential leak points and improved protection of employees working in the tank farms.[41]

2. Due to the dynamic nature of the chemical concentrations in the tank head space, workers should be provided air purifying respirators (N95 charcoal impregnated filtering face-piece or better) upon general entry into the tank farm areas to offer protection during an accidental release of tank vapors. Appropriate training should be provided. Higher levels of respiratory protection (e.g., PAPRs, supplied air) should be considered for more intrusive work activities that may occur in AMZs.

3. The employer should conduct routine personal and real-time monitoring on workers with potential exposure to vapors. These workers may be identified by the type of work to be conducted, the head space concentrations, the chemical hazard potentially encountered, and/or other factors that are unique to the work activity. This information will provide exposure characterization data on workers involved in accidental releases of head space vapors and on the escaping vapor concentration levels, which will lead to more informed decisions regarding PPE selection.

4. The CHG written respiratory protection program should be revised to specifically address the cartridge breakthrough issue for the 15 most abundant in-tank vapor-phase chemicals (carbon dioxide; nitrogen oxide; total non-methane hydrocarbon; dodecane; tridecane; ammonia; tetradecane; undecane; 1-Butanol; 3-Hexanone; acetic acid ethyl ester; C7-Cyclopentane as propyl; Dodecane, 2,6,11-trimethyl-Dodecane; and hydrogen). The OSHA decision logic tree provides a diagram for the development of a respirator cartridge change schedule that could serve as an effective communication tool for the workers.[44]

5. The employer should share sampling results with employees (with personal identifiers removed) and, using this information, work with employee representatives to determine sampling and personal protection needs. This information should be collected and stored in a data base easily accessible to employees and management.

6. Workers should be encouraged to report all vapor exposures and potentially work-related health problems to their supervisors or other designated individual. Vapor exposures should be reported even if there are no apparent symptoms because symptoms might occur well after an exposure. Because the work-relatedness of certain health concerns may be difficult to assess, each person concerned about possible work-related health problems should be fully

evaluated by a physician, preferably one familiar with occupational conditions. A complete evaluation would include a full review of symptoms and occupational history, a medical exam, a review of exposures, targeted diagnostic tests, and follow-up examination(s) to note the progress of the affected worker. Individuals with definite or possible occupational health problems should be protected from exposures that are presumed to cause or worsen the disease. In some cases, workers may have to be reassigned to areas where exposure is minimized or nonexistent.

7. CHG and DOE should develop centralized collection of a standardized core of medical, environmental and personal monitoring data on workers, as was recommended to DOE by NIOSH in 2000.[20]

8. CHG and DOE should continue with plans to develop an expert panel to determine the most appropriate medical monitoring protocols for exposures to the mixture of chemicals present at the Hanford site.

9. Employees should report all vapor exposures to their supervisor or other designated management representative in order to provide the most helpful information for planning personal, environmental and medical monitoring.

10. Employees should report all vapor-related symptoms to a health care provider and should obtain copies of their medical records related to these exposures.

11. To better study potential respiratory effects of vapor exposures, pulmonary function test results should be compared for tank farm workers vs. other workers at the Hanford Site, as is currently being done by HEHF for blood and urine tests.

12. Employees concerned about past or current exposures to beryllium should contact the Hanford Building Trades Medical Screening Program at 800-866-9663.

13. If an employee submits a PER, CHG should provide feedback to the employee on resulting outcomes and CHG should provide a mechanism for rebuttal, if appropriate.

14. Summa canister contents should be analyzed as soon as possible after collection, and prior to the commencement of waste disturbing activities, so the information can be used to select the appropriate personal exposure monitoring.

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Table 1. Common Chemical Toxicants Found at Hazardous Waste Sites: Health Effects and Medical Monitoring[30]

Hazardous Substance or Chemical Group	Compounds	Target Organs	Potential Health Effects	Medical Monitoring
Aromatic Hydrocarbons	Benzene Ethyl benzene Toluene Xylene	Blood Bone marrow CNS* Eyes Respiratory Skin Liver Kidney	All cause: Defatting dermatitis CNS* depression: decreased alertness, headaches, sleepiness, loss of consciousness Benzene: suppresses bone-marrow function causing blood changes. Chronic exposure can cause leukemia.	Occupational/general medical history emphasizing prior exposure to these or other toxic agents. Medical exam with focus on liver, kidney, nervous system and skin. Laboratory tests: CBC**, platelet count, liver and kidney function
Halogenated Aliphatic Hydrocarbons	Carbon tetrachloride Chloroform Ethyl bromide Ethyl chloride Ethylene dibromide Ethylene dichloride Methyl chloride Methyl chloroform Methylene chloride Tetrachloroethane Tetrachloroethylene (perchloroethylene) Trichloroethylene Vinyl chloride	CNS* Kidney Liver Skin	All cause : CNS* depression: decreased alertness, headaches, sleepiness, loss of consciousness. Kidney changes: decreased urine flow, swelling (especially around eyes), anemia. Liver changes: fatigue, malaise, dark urine, liver enlargement, jaundice. Vinyl chloride is a known carcinogen.	Occupational/general medical history emphasizing prior exposure to these or other toxic agents. Medical exam with focus on liver, kidney, nervous system and skin. Laboratory tests: liver and kidney function, carboxyhemoglobin where relevant.
Heavy Metals	Arsenic Beryllium Cadmium Chromium Lead Mercury	Multiple organ systems including: Blood Cardiopulmonary Gastrointestinal Kidney Liver Lung CNS* Skin	All are toxic to the kidneys. Each heavy metal has its own characteristic symptom c-luster, both short and long-term effects.	History and physical exam should look for symptom clusters associated with the specific metal exposure. Laboratory: metal content in blood, urine and tissues (e.g., blood lead level; urine screen for arsenic, mercury, chromium and cadmium), CBC**, kidney function and liver function where relevant, chest x-ray or pulmonary function testing where relevant.
Polychlorinated Biphenyls (PCBs)		Liver Possible CNS* Possible Respiratory system Skin	Various skin ailments including chloracne; may cause liver toxicity; carcinogenic to animals	Physical exam should focus on skin and liver. Laboratory: serum PCB levels, triglycerides and cholesterol, liver function tests.

*   CNS = Central Nervous System
** CBC = Complete Blood Count

APPENDIX A

Constituents of CHG Blood Chemistry Analysis

Glucose – a measure of the sugar level in the blood; high levels are associated with eating before the test and diabetes

Waste products:
BUN (Blood Urea Nitrogen) – waste product produced in the liver and excreted by the kidneys; elevated with kidney malfunction
Creatinine – waste product from muscle breakdown; elevated levels occur with kidney malfunction
BUN/Creatinine ratio – mathematical relationship of BUN and creatinine; if abnormal, can help identify the cause of the abnormality
Uric Acid – elevated levels can be caused by kidney malfunction

Electrolytes:
Sodium - regulated by the kidneys and adrenal glands; level can be an indicator of kidney disease
Potassium – controlled by the kidneys; important for proper function of nerves, muscles and heart; elevated levels can indicate kidney disease
Chloride – major negative ion in the blood; changes often accompany sodium losses and excesses; abnormal values may indicate kidney disease
Carbon Dioxide (CO_2) – reflects acid status of the blood; abnormalities may indicate kidney or respiratory malfunction

Enzymes:
AST (asparate aminotransferase) or SGOT (Serum Glutamic-Oxalocetic Transaminase) – these are the same compound; elevated with tissue damage, especially heart and liver
ALT (alanine aminotransferase) or SGPT (Serum Glutamic Pyruvic Transaminase) – these are the same compound; found primarily in the liver but also to a lesser degree, the heart and other tissues; useful in diagnosing liver function more so than SGOT levels
GGT (Gamma-Glutamyl Transpeptidase) – elevated in liver disease; very sensitive to alcohol use
Alkaline Phosphatase – found primarily in bone and liver; elevated in liver or bone damage
LDH (Lactic Dehydrogenase) – present in all body cells; can be elevated from anything that damages cells, including blood drawing; if elevated by itself, probably processing error
Bilirubin – breakdown product of hemoglobin in red blood cells; elevated in liver disease

Protein:
Albumin – general index of overall health and nutrition
Globulin – general index of overall health and nutrition; “antibody” protein important for fighting disease
Albumin/Globulin ratio – mathematical relationship between albumin and globulin

Blood Fats:
Total Cholesterol – elevations are associated with heart disease
High-density Lipoproteins (HDL) – “good” cholesterol; helps remove excess cholesterol from the arteries
Low-density Lipoproteins (LDL) – “bad” cholesterol; facilitates deposit of cholesterol in the arteries
Total Cholesterol/HDL ratio – mathematical relationship between total cholesterol and HDL cholesterol that indicates risk for heart disease
Triglycerides – fat in the blood; elevations associated with heart disease

Minerals:
Calcium – controlled by parathyroid glands and kidneys; elevated levels may indicate kidney malfunction
Phosphorous – regulated by the kidneys; elevated levels may be due to kidney disease

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